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Module on

# Fatty Acids

By

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**Text:**

## 1) INTRODUCTION TO FATTY ACIDS:

Fatty acids are defined as compounds synthesized in nature by condensation of malonyl coenzyme A units under the influence of a fatty acid synthase complex. Fatty acid molecule is amphipathic and has two distinct regions or ends i.e a long hydrocarbon chain, which is hydrophobic (water insoluble) and not very reactive chemically, and a carboxyl acid group which is ionized in solution (COO-), extremely hydrophilic (water soluble) and readily forms esters and amides.In neutral solutions, salts of fatty acids form small spherical droplets or micelles in which the dissociated carboxyl groups occur at the surface and the hydrophobic chains project towards the centre. In cells, fatty acids only sparingly occur freely, instead they are esterified to other components and form the saponifiable lipids. Fatty acids locatedwithin the adipose tissue in ruminants occur almostentirely as triglycerides with a predominance of C16and C18 fatty acids.

## CLASSIFICATION OF FATTY ACIDS:

Fatty acids are classified into following groups based upon the degree of saturation in the carbon chain:

### A) Saturated fatty acids (SFA)

Fatty acids that do not contain carbon-carbon double bonds (-C=C-) are called saturated fatty acids, as they cannot undergo further hydrogenation. Under normal conditions, these compounds are most often white solids. Saturated fatty acids having a chain of more than 10 aliphatic carbon atoms are non-volatile and insoluble in water. Shorter chain fatty acids (C8–10) occur in nature only in the form of triglycerides.The SFA have the general formula R-COOH.

**Table1: Some common saturated fatty acids**

| Trivial name | Systematic name | Abbreviation | Typical sources |
|---|---|---|---|
| butyric | Butanoic | C4:0 | dairy fat |
| caproic | Hexanoic | C6:0 | dairy fat |
| caprylic | Octanoic | C8:0 | dairy fat, coconut and palm kernel oils |
| capric | Decanoic | C10:0 | dairy fat, coconut and palm kernel oils |
| lauric | dodecanoic | C12:0 | coconut oil, palm kernel oil |
| myristic | Tetradecanoic | C14:0 | dairy fat, coconut oil, palm kernel oil |
| palmitic | Hexadecanoic | C16:0 | most fats and oils |

Saturated fatty acids are further classified into four subclasses according to their chain length i.e short, medium, long and very long.

- **Short-chain fatty acids**: Fatty acids that contain three to seven carbon atoms.
- **Medium-chain fatty acids**: Fatty acids that contain eight to thirteen carbon atoms.
- **Long-chain fatty acids**: Fatty acids with from fourteen to twenty carbon atoms.
- **Very-long-chain fatty acids**: Fatty acids that contain twenty one or more carbon atoms.

### B) **Unsaturated fatty acids**

Fatty acids that contain double bonds are known as unsaturated fatty acids, these may be further hydrogenated by the addition of hydrogen. They are usually colourless liquids. For most of them, all double bonds are in the cis position.The position of the double bond is most commonly denoted by using the symbols like Δ, k, l, **m,**etc where

**k, l** and **m** represent the carbon atom on which there is the double bond, counting from carboxyl group. For example, linoleic acid can be denoted as $\Delta^{9\ 12}$, which means that the double bonds are located at the 9th and 12th carbon atoms.

Currently, there are two main classes of unsaturated fatty acids, namely **Monounsaturated fatty acids**, which include omega-9 fatty acids (ω-9 or n-and **Polyunsaturated fatty acids**, which include omega- 6 (ω-6, n-6) and omega- 3 (ω-3, n-3).

### a) Monounsaturated fatty acids

More than one hundred *cis*-MUFA occur in nature, but most are very rare compounds. Oleic acid (OA) is the most common MUFA and it is present in considerable quantities in both animal and plant sources.It contains Omega-9 fatty acids which are commonly found in vegetable and animal fats. This monounsaturated fat is described as omega-9 because the double bond is on the ninth position from the omega end. These fatty acids are also known as oleic acidsor monounsaturated fats and can often be found in canola, sunflower, olive, and nut oils. Unlike omega-3 and omega-6 fatty acids, omega-9 fatty acids are produced by the body, but are also beneficial when obtained with food.

**Table 2: Some monounsaturated fatty acids**

| Common name | Systematic name | Delta abbreviation | Typical sources |
|---|---|---|---|
| palmitoleic | *cis*-9-hexadecenoic | 16:1Δ9c (9c-16:1) | marine oils, macadamia oil, most animal |

| | | | |
|---|---|---|---|
| oleic | *cis*-9-octadecenoic | 18:1Δ9c (9c-18:1) (OA) | all fats and oils, especially olive oil, canola oil and high-oleic sunflower and safflower oil |
| gadoleic | *cis*-9-eicosenoic | 20:1Δ9c (9c-20:1) | marine oils |
| nervonic | *cis*-15-tetracosenoic | 24:1Δ15c (15c-24:1) | marine oils |
| *cis*-vaccenic | *cis*-11-octadecenoic | 18:1Δ11c (11c-18:1) | most vegetable oils |

b) **Polyunsaturated fattyacids** have at least two double bonds, and at least 18 carbon atoms in the alkyl chain of their structure. Biological activity of the molecule depends on the configuration and the specified position of the cis double bonds. The position of double bonds when counted from methyl end (-CH3) of the fatty acids is represented by omega (ω) system. The two double bonds are not conjugated but separated by amethylene interrupted carbon. For example, linoleic acid is also called 9, 12-octadecadienoic acid. The essential fatty acids (EFAs) include linoleic acid (LA) and α- linolenic acid (ALA), they are not synthesized in the human body because of the lack of appropriate enzymes. Other polyunsaturated fatty acids can be synthesized only if EFA will be delivered with food and when no enzyme defect would occur in the metabolic pathway. Linoleic acid is considered the most important of all omega-6 fatty acids, because it can be obtained with other acids of this group such as ALA or ϓ-linolenic acid (GLA).

Omega-6 fatty acid and Omega-3 fatty acid arepolyunsaturated fats, essential for human health because they cannot be synthesized in the body. For this reason, people must obtain omega-6 fatty acids andOmega-3 fatty acid by consuming foods such as meat, poultry, and eggs, nut and plant-based oils like canola and sunflower oils.

**Table 3: Some nutritionally important n-3 PUFA and n-6 PUFA**

| Common name | Systematic | Abbreviation | Typical sources |
|---|---|---|---|
| linoleic acid | *cis*-9,*cis*-12-octadecadienoic | 18:2n-6 (LA) | most vegetable oils |
| docosatetraenoic acid | *cis*-7,*cis*-10,*cis*-13,*cis*-16- | 22:4n-6 | 22:4n-6 very minor component in animal tissues |
| stearidonic acid | *cis*-6,*cis*-9,*cis*-12,*cis*-15- | 18:4n-3 (SDA) | fish oils, genetically enhanced soybean oil, blackcurrant seed oil, hemp oil |
|  | *cis*-7,*cis*-10,*cis*-13,*cis*-16, *cis*-19- | 22:5n-3 (n-3 DPA) | fish, especially oily fish (salmon, herring, anchovy, smelt and mackerel) |

These two types of essential fatty acids are n-3 and n-6. Linoleic acid is the important n-6 fatty acid in the diet, while alpha-linoleic acid is the important n-3 fatty acid. Plants and plant oils contain both of these, although most of the alpha-linoleic acid is in plant oils, notably from soybean, canola, flaxseed and walnut oils. However, linoleic and alpha-linoleic acid do not perform the same physiological functions in the cell. Indeed, the two fatty acids can serve competing roles. On the other hand, alpha-linoleic acid can be converted to small amounts ofsomewhat longer n-3 fatty acids i.e Eicosapentaenoic acid (EPA)and Docosapentaenoic acid (DHA), which play important physiological roles. Both EPA and DHA are found in far higher concentrations in fish and marine mammals that eat fish. Thus, fish, especially oily fish (anchovies, sardines, mackerel, salmon, and herring) are the main dietary source of these n-3 fatty acids.

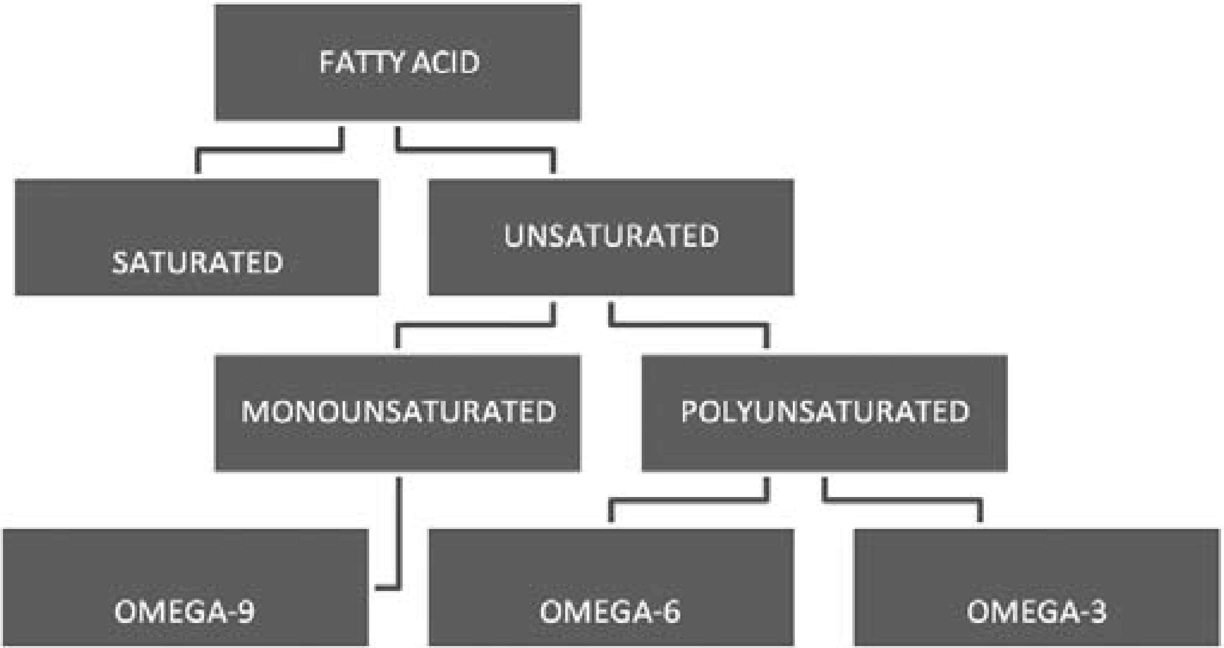
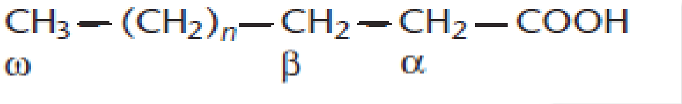


Fig. 1: Classification of fatty acids

## 2) BRIEF STRUCTURE OF FATTY ACIDS

Fatty acids are carbon chains with a methyl group at one end of the molecule (designated as omega‘ω’) and a carboxyl group at the other end.

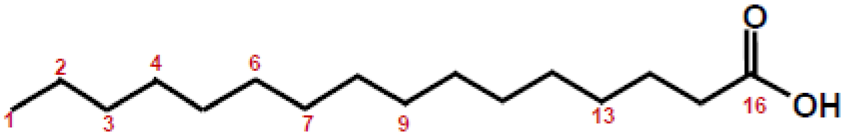


$$\underset{\omega}{CH_3} - (CH_2)_n - \underset{\beta}{CH_2} - \underset{\alpha}{CH_2} - COOH$$

The carbon atom next to the carboxyl group is called theα carbon, and the subsequent one is calledβcarbon. The letter *n* is also often used instead of the Greek ‘ω’ to indicate the position of the double bond closest to the methyl end. The systematic nomenclature for fatty acids may also indicate the location of double bonds with reference to the carboxyl group (Δ).

### a) Structure of saturated fatty acids

Saturated fatty acids are ‘filled’ (saturated) with hydrogen. Most saturated fatty acids are straight hydrocarbon chains with even number of carbon atoms. The most common fatty acids contain 12–22 carbon atoms. Eg:-

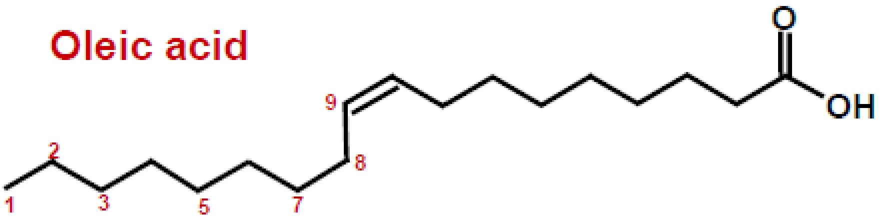


Palmitic acid 16:0

### b) Structure of unsaturated fatty acids

Monounsaturated fatty acids have one carbon–carbon double bond in the entire structure, which can occur at different positions. These are also called as **monoenes.** The most common monoenes have a chain length of 16–22 and a double bond with the cis configuration. This means that the hydrogen atoms on either side of the double bond are oriented in the same direction. Trans-isomers may be produced during industrial processing (hydrogenation) of unsaturated oils and in the gastrointestinal tract of ruminants. The presence of a double bond causes restriction in the mobility of the acyl chain at that point. The cis configuration gives a kink in the molecular shape and cis fatty acids are thermodynamically less stable than the trans forms. The cis fatty acids have lower melting points than the trans fatty acids or their saturated counterparts.

In polyunsaturated fatty acids (PUFAs) the first double bond may be found between the third and the fourth carbon atom from the α carbon; these are called ω-3 fatty acids. If the first double bond is between the sixth and seventh carbon atom, then they are called ω-6 fatty acids. The double bonds in PUFAs are separated from each other by a methylene interrupted carbon. PUFAs, which are produced only by plants and phytoplankton, are essential to all higher organisms, including mammals and fish. ω-٣ and ω-6 fatty acids cannot be interconverted, and both are essential nutrients. PUFAs are further metabolized in the body by the addition of carbon atoms and by desaturation (extraction of hydrogen). Mammals have enzymes called desaturases that are capable of removing hydrogens only from carbon atoms between an existing double bond and the carboxyl group. β-oxidation of fatty acids may take place in either mitochondria or peroxisomes.



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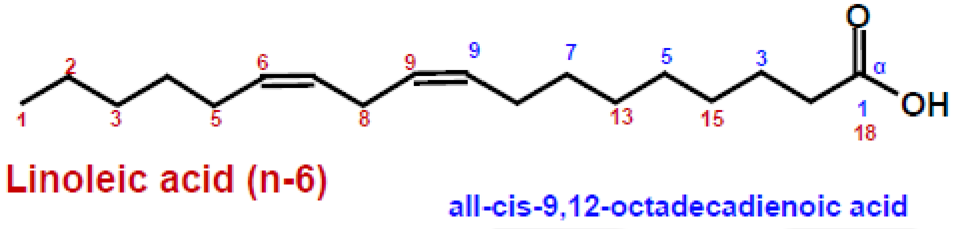
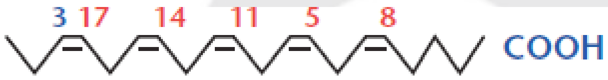


(POLYUNSATURTED)

**Table 4: Structure of different unbranched fatty acids with a methyl end and a carboxyl (acidic) end.**

| | Methyl end carboxyl end | Saturation | Δ-characteristics |
|---|---|---|---|
| **Stearic 18:0** |  | **Saturate**<br>**Monoene** | **18:0** |
| **Linoleic 18:2, ω-6** |  | **Polyene** | **18:2 Δ9,12** |
| **α-Linolenic 18:3, ω-3** |  | **Polyene** | **18:3 Δ9,12,15** |
| **EPA 20:5, ω-3** |  | **Polyene** | **20:5 Δ5,8,11,14,17** |
| **DHA 22:6, ω-3** |  | **Saturate** | **20:6 Δ4,7,10,13,16,19** |

## 3) METABOLISM OF FATTY ACIDS

An adult consumes approximately 85 g of fat daily, most of which is in form of triacylglycerols. During digestion, free fatty acids (FFA) and monoacylglycerols are released and absorbed in the small intestine. In the intestinal mucosa cells, FFA are re-esterified to triacylglycerols, which are transported via lymphatic vessels to the circulation as part of chylomicrons. In the circulation, fatty acids are transported bound to albumin or as part of lipoproteins. FFA are taken up into cells mainly by protein transporters in the plasma membrane and are transported intracellularly via fatty acid-binding proteins (FABP). FFA are then activated (acyl-CoA) before they are shuttled via acyl-CoA-binding protein (ACBP) to mitochondria or peroxisomes for α-oxidation (and formation of energy asATPand heat) or to endoplasmic reticulum for esterification to different classes of lipid. Acyl-CoA or certain FFA may bind to transcription factors that regulate gene expression or may be converted to signal molecules (eicosanoids). Glucose may be transformed to fatty acids (lipogenesis) if there is a surplus of glucose/energy in the cells .

## De novo synthesis of fatty acids

The synthetic process involves the breakdown of excess dietary carbohydrates to acetate units and condensation of acetate, as acetyl coenzyme A (CoA), with bicarbonate to form malonyl CoA. Acetyl CoA then combines with a series of malonyl CoA molecules to form saturated fatty acids of different carbon lengths, of which the end product is palmitic acid (16:0). The fatty acid synthetic reactions up to this stage take place within the fatty acid synthetic complex. Once palmitic acid is released from the synthetic complex, it can be elongated to stearic acid and even higher saturated fatty acids by further additions of acetyl groups, through the action of fatty acid elongation systems.

In animal tissue, the desaturation of *de novo* synthesized saturated fatty acids stops with the formation of the n-9 series MUFA. This conversion is performed by Δ9 desaturase, which is a very active desaturase enzyme in mammalian tissues, and introduces double bonds at the 9-10 position of the fatty acid chain. Oleic acid (18:1Δ9 or 18:1n-9) is its main product. The products of *de novo* synthesis are esterified with glycerol to form TG. In liver, these TG are incorporated into very low density lipoproteins (VLDL) and transported out into circulation. In adipose tissue they are stored as lipid droplets. If a low-fat, high carbohydrate diet is eaten consistently, the adipose tissue consists mostly of 16:0, 18:0 and 18:1n-9, which are the main products of *de novo* synthesis. Individuals eating large amounts of LA will deposit this fatty acid in adipose tissue .In the absence of dietary LA and other PUFA, 18:1n-9 is further desaturase and this step is followed immediately by elongation to form the n-9 family of PUFA. Reactions and properties and uses of fatty acids.

## 4) RANCIDITY OF FATTY ACIDS

Fats and oils play an important role in the flavor, aroma, texture and nutritional quality of foods, pet foods, and feeds. Fats and oils may be added during manufacturing or they may be inherent to the product or ingredient. The product may be pure oil or it may be part of a complex mixture with proteins, carbohydrates, minerals, and vitamins. The product may contain almost no fat or it may contain a considerable amount of it. Regardless of the source of fat, the amount of fat, or the product composition, predicting and monitoring fat and oil quality is an important component of developing and manufacturing high quality products. As soon as a food, feed, or ingredient is manufactured, it begins to undergo a variety of chemical and physical changes.

Oxidation of lipids is one common and frequently undesirable chemical change that may impact flavor, aroma, nutritional quality, and, in some cases, even the texture of a product. The chemicals produced from oxidation of lipids are responsible for rancid flavors and aromas. Vitamins and other nutrients may be partially or entirely destroyed by highly reactive intermediates in the lipid oxidation process. Oxidized fats can interact with proteins and carbohydrates causing changes in texture. Of course, not all lipid oxidation is undesirable. Enzymes, for example, promote oxidation of lipid membranes during ripening of fruit. For most products, though, predicting and understanding oxidation of lipids is necessary to minimize objectionable flavors and aromas arising from fat rancidity.

## Types of Rancidity

The term “rancidity” is used to describe two entirely different processes:

- ✓ **Oxidative rancidity** is a condition caused by fat oxidation
- ✓ **Hydrolytic rancidity** is a condition caused by fat hydrolysis

**a) Oxidative rancidity** of fats such as shortenings and salad and cooking oils refers to the undesirable odors and flavors which develop when such products are exposed to the oxygen in the air. Products containing these fats, including but not limited to food products such as fish, poultry, meat, frozen vegetables and dry milk can become rancid as the fats in the products react to air. The poly-unsaturated fatty acid portions of these foods react with oxygen to form peroxides. The peroxides decompose to yield a complex of mixtures, including aldehydes, ketones, and other volatile products. These products are responsible for “rancid” odors and flavors. It is important to note that fish contain highly unsaturated (poly-unsaturated and mono-unsaturated) fatty acids which make some fish products particularly susceptible to oxidative deterioration. Highly saturated products, such as butter, are not so much prone to oxidative rancidity due to the absence of poly-unsaturated fatty acid compounds. These products also tend to be more solid at room temperature.

**b) Hydrolytic rancidity** refers to the odor that develops when triglycerides are hydrolyzed and free fatty acids are released. This reaction of lipid with water sometimes requires a catalyst, but results in the formation free fatty acids and salts from free fatty acids (soaps). In particular, the short chain fatty acids such as common butter fats, are odorous.

Rancidity in foods may be very slight, indicated by a loss of freshness to very severe, indicated by objectionable odors and/or flavors. Slight degrees of rancidity are much more common in foods, and are of much more practical concern than severe rancidity. A slight degree of rancidity may not be objectionable to consumers, but products, which do not seem fresh will not attract repeat purchases. If customers do not return to a product, the long-term effects of a slight degree of rancidity can be very serious.

Even though meat is held under refrigeration or in a frozen state, the poly-unsaturated fat will continue to oxidize and slowly become rancid. The fat oxidation process, potentially resulting in rancidity, begins immediately after the animal is slaughtered and the muscle, intra-muscular, inter-muscular and surface fat becomes exposed to oxygen of the air. This chemical process continues during frozen storage, though more slowly at lower temperature. Air tight packaging will, however, retard the development of rancidity.

## 5) REACTIONS,PROPERTIES AND USES OF FATTY ACIDS

- **REACTIONS:**

Reactions converting acids to esters or vice versa and the exchange of ester groups are among the most widely used in fatty acid and lipid chemistry . They find applications from micro scale preparation of methyl esters for GC (gas chromatographic) analysis to the industrial production of oleo chemicals and biodiesel. The exchange of groups attached to the fatty acid carboxyl is usually an equilibrium process driven to one product by an excess of one reactant or the removal of one product, which is usually carried out with the aid of a catalyst. The catalyst may be an acid, a base, or a lipolytic enzyme. These reactions produce the fatty acids and methyl esters that are the starting point for most oleo chemical production. As the primary feed stocks are oils and fats, glycerol is produced as a valuable byproduct. Reaction routes and conditions with efficient glycerol recovery are required to maximize the economics of large-scale production. There is increasing interest in the use of lipase enzymes for large-scale reactions. Enzymes can exert regio- or stereospecific control over reactions and may also offer a degree of selectivity for particular fatty acids, not observed with acid or base catalysts. Although the reactions of the carboxyl group are normally independent of those of the double bonds in the fatty acid molecule, the presence of a double bond at the 4, 5, or 6 position often results in slower reaction when a reaction is catalyzed by a lipase.

### a) Hydrolysis

The reaction can be catalyzed by acid, base or lipase, but it also occurs as an un-catalyzed reaction between fats and water dissolved in the fat phase at suitable temperatures and pressures. Historically, soaps were produced by alkaline hydrolysis of oils and fats, and this process is still referred to as saponification. Soaps are now produced by neutralization of fatty acids produced by fat splitting, but alkaline hydrolysis may still be preferred for heat-sensitive fatty acids.

### b) Esterification

Fatty acids are converted to esters by reaction with an excess of alcohol using an acid catalyst or a lipase. For the preparation of methyl esters for GC analysis, boron trifluoride, sulfuric acid, or anhydrous hydrogen chloride in methanol are commonly used. Reaction is complete in 30 minutes at reflux. Propyl and butyl esters are prepared in a similar way with the corresponding alcohols. It is not always possible to use an excess of alcohol, for example, in the synthesis of triacylglycerols using a protected glycerol. A more reactive fatty acid derivative such as the acid chloride or anhydride is used, or the fatty acid is reacted directly with the alcohol, using di cyclo hexyl carbodiimide (DCC) plus 4-dimethylaminopyridine (DMAP) as a coupling agent, for example, in the synthesis of acylglycerols.

### c) Ester Exchange Reactions

The fatty acid or alcohol groups present in an ester can be exchanged in a number of ways like reaction with an excess of other fatty acids (acidolysis), alcohols (alcoholysis), or other esters (inter esterification). Generally, the starting point will be a triacylglycerol, and these reactions provide routes by which the composition and properties of oils and fats can be modified.

- **Acidolysis**: This reaction can be acid or enzyme catalyzed and may be used to modify triacylglycerol composition. Acidolysis of an oil containing only C16 and C18 fatty acids with fatty acids rich in lauric acid (e.g., from palm-kernel oil) resultsin a triacylglycerol enriched in medium-chain fatty acids.
- **Alcoholysis**: Methanolysis of triacylglycerols is used to prepare methyl esters for fatty acid analysis, a process frequently referred to as transesterification. This can be acid-or base-catalyzed, the method being chosen to avoid modifying acid-or base-sensitive fatty acids and to minimize reaction times.

Biodiesel is produced on the industrial scale by methanolysis of vegetable oils (usually rape or soybean) or waste fat, particularly using frying oils. Methanolysis proceeds with modest amounts of base catalyst, provided the levels of free fatty acid and water in the oil are low. The fatty acid content may be reduced by physical or chemical treatment before methanolysis but for waste fats, alternative processes that do not use base catalysis may be preferred. Lipase catalyzed methanolysis is less sensitive to fatty acid and water in the oil and has been tested in batch and fixed-bed reactor conversion of waste oil and grease to biodiesel.

### d) OXIDATION

The fatty acid alkyl chain is susceptible to oxidation both at double bonds and adjacent allylic carbons. Free-radical and photo oxidation at allylic carbons are responsible for deterioration of unsaturated oils and fats, resulting in rancid flavors and reduced nutritional quality, but they are also used deliberately to polymerize drying oils. Oxidation of double bonds is used in oleo chemical production either to cleave the alkyl chain or to introduce additional functionality along the chain.

- **Autoxidation and Photo-oxidation**

Both autoxidation and photo-oxidation produce allylic hydro-peroxides from unsaturated centers.During this process, the position and geometry of the double bond may change. The hydro peroxide mixtures produced by autoxidation and photo oxidation are notthe same, indicating that different mechanisms are involved. Free radical oxidationcan be promoted or inhibited. Deliberate promotion speeds the polymerization ofdrying oils, and strenuous efforts are made to inhibit the onset of rancidity in edibleoils. Light, in the presence of oxygen, promotes oxidation of unsaturated fatty acids. Ultraviolet radiation decomposes existing hydroperoxides, peroxides and carbonyl and other oxygen-containing compounds, producing radicals that initiate autoxidation. Photo-oxidation by longer wavelength near ultraviolet or visible light requires a sensitizer. Naturally present pigments such aschlorophyll, hematoporphyrins and riboflavin act as sensitizers as dyes, including erythrosine and methylene blue. Light excites these sensitizers to the triplet state that promotes oxidation by type I and type II mechanisms. Unlike autoxidation, there is no induction period.

- **Epoxidation**

Epoxides are produced by reaction of double bonds with peracids. This proceeds by a concerted mechanism, giving cis stereospecific addition. Thus, a cis olefin leads to formation of a cis epoxide and a trans olefin to a trans epoxide. The order of reactivity of someperacids is m-chloroperbenzoic>performic>perbenzoic>peracetic; electron withdrawing groups promote the reaction. The carboxylic acid produced is a stronger acid than the strongly hydrogen bonded peracid and may lead to subsequent ring opening reactions especially in the case of formic acid. Small scale reactions are carried out with m-chloroperbenzoic acid in a halocarbon or aromatic solvent, in the presence of bicarbonate to neutralize the carboxylic acid as it is formed. Oils, mainly soybean but also linseed, are epoxidized on an industrial scale (100,000 tons per year) as stabilizers and plasticizers for PVC. The reactive epoxide groups scavenge HCl produced by degradation of the polymer. Epoxidation is carried out with performic or peracetic acid produced in situ from the formic or acetic acid and high strength hydrogen peroxide (70% w/w).

### ➢ Bulk Properties of Fatty Acids

Fatty acids are poorly soluble in water in their un-dissociated (acidic) form, whereas they are relatively hydrophilic in the form of potassium or sodium salts. Thus, the actual water solubility, particularly of longer-chain acids, is often very difficult to determine since it is markedly influenced by pH, and also because fatty acids have a tendency to associate, leading to the formation of monolayers or micelles. The formation of micelles in aqueous solutions of lipids is associated with very rapid changes in physical properties over a limited range of concentration. The point of change is known as the critical micellar concentration (CMC), and exemplifies the tendency of lipids to associate rather than remain as single molecules. The CMC is not a fixed value but represents a small concentration range that is markedly affected by the presence of other ions and by temperature. Fatty acids are easily extracted with nonpolar solvents from solutions or suspensions by lowering the pH to form the uncharged carboxyl group. In contrast, raising the pH increases water solubility through the formation of alkali metal salts, which are familiar as soaps. Soaps have important properties as association colloids and are surface-active agents.

The influence of a fatty acid's structure on its melting point is such that branched chains and cis double bonds will lower the melting point compared with that of equivalent saturated chains. In addition, the melting point of a fatty acid depends on whether the chain is even- or odd numbered; the latter have higher melting points. Saturated fatty acids are very stable, whereas unsaturated acids are susceptible to oxidation with greater susceptibility in molecules having more double bonds. Thus, unsaturated fatty acids should be handled under an atmosphere of inert gas and kept away from oxidants and compounds giving rise to formation of free radicals.

- **Uses of fatty acids**

1) **Role of Fatty acids in vegetable oils:** Unsaturated fatty acids present in vegetable oils are characterized by high absorbability and antiallergic properties. In cosmetic industry, vegetable oils are used mainly as the vehicle for other active ingredients, dissolved or dispersed in oil-water type emulsions. The most often used essential unsaturated fatty acids are those from the omega-3, omega-6 and omega-9 series.

**2) Roles of n-6 and n-3 Fatty Acids in Cellular Regulation:** The n-6 or n-3 polyunsaturated fatty acids often affect the regulatory physiology following their incorporation into phospholipids in plasma membranes. Following an appropriate stimulus, the fatty acid is freed and then converted into a certain paracrine, which is the category of regulatory molecule that acts locally on nearby cells. However, n-6 and n-3 polyunsaturated fatty acids in membranes can also directly affect opening and closing of ion channels and thus the electrical excitability of membranes. In this way they potentially can influence cardiac arrhythmias, which are disturbances in rhythm of beating of heart.

### 3) Role of Fatty Acids in the Pharmaceutical/Personal Hygiene

Fatty acids are widely used as inactive ingredients (excipients) in drug preparations, and the use of lipid formulations as the carriers for active substances is growing rapidly. The largest amount of lipids used in pharmaceuticals is in the production of fat emulsions, mainly for clinical nutrition but also as drug vehicles. Another lipid formulation is the liposome, which is a lipid carrier particle for other active ingredients. In addition, there has been an increase in the use of lipids as formulation ingredients owing to their functional effects (fatty acids have several biological effects) and their biocompatible nature. Moreover, fatty acids themselves or as part of complex lipids, are frequently used in cosmetics, soaps, fat emulsions and liposomes.

**4) Role of fatty acids in Skin**: Linoleic acid occurs most abundantly in sunflower oil, soybean oil, safflower, corn oil, sesame oil, peanut oil, grape seed oil and wheat sprout oil. This compound plays a significant role in maintaining the beauty of skin. In dry skin it strengthens the lipid barrier of epidermis, protects against trans epidermal loss of water and normalizes the skin metabolism. Linoleic acid is a natural component of sebum. In persons with acne skin, a decrease in LA content in sebum is observed, which leads to blocked pores and formation of comedos and eczemas. The use of linoleic acid for oily skin and problematic skin care leads to improvement of the work of sebaceous glands, unblocking of pores and decrease in the number of comedos. Moreover, this acid is built in the structure of cell membrane and is also used for production of intercellular cement of the skin.