

**Novel Technologies for Food Processing and Shelf Life Extension**  
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**Lecture - 29**  
**Food Lipids (Nature & Occurrence)**

This part of the lecture on food lipids will mainly focus on the nature and occurrence of lipids in various biological materials.

**Lipids**

- Lipids are heterogeneous group of naturally occurring substances which are insoluble in water but soluble in organic solvents such as chloroform, ether, benzene, hexane, etc.
- Lipids contain hydrocarbon groups as primary parts of the molecule and are present in or derived from living organisms.
- Compound classes covered in this definition include


Fatty acids (FA)  
Acylglycerols  
FA esters (e.g. Waxes)  
Isoprenoid hydrocarbons

The slide features a yellow background with a blue and orange header. A pyramid diagram on the right side lists four classes of lipids: Fatty acids (FA), Acylglycerols, FA esters (e.g. Waxes), and Isoprenoid hydrocarbons. The bottom of the slide includes the IIT Kharagpur logo, the Swayam logo, and a navigation bar.

Lipids are heterogeneous group of naturally occurring substances which are insoluble in water, but soluble in organic solvents such as chloroform, ether, benzene, hexane, etc. They contain hydrocarbon groups as primary parts of the molecule and are present in or derived from living organisms, may be either from plant source or from animal source. The compound classes of lipids which are covered in this definition include fatty acids, acylglycerols, fatty acid esters and isoprenoid hydrocarbons.

## Functions of lipids


- Stored in adipose tissue (triglycerides) and are one of the major energy source
- Some lipids are essential nutrients like fat soluble vitamins
- Biological membranes (phospholipids, cholesterol and glycolipids together with proteins)
- Act as receptors, antigens and membrane anchors for proteins
- Facilitate the digestive process
- Electrical insulator of axon of neurons
- Improve texture, flavour and palatability of food

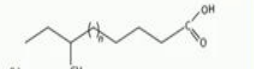


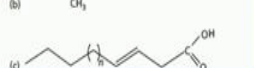
Functions of lipids: These lipids are stored in adipose tissues in the form of triglycerides. They are one of the major sources of energy to the cell. Some lipids are essential nutrients like fat soluble vitamins. They also are the constituents of biological membrane and are very important to their structure and function. They act as receptors, antigens and membrane anchors for proteins. They facilitate the digestive process, they act as electrical insulator of action of neurons and, more importantly they improve texture, flavour and palatability of foods.


## Fatty acids (FA)


- Fatty acids are characterized by a long chain of carbon atoms (generally 12–22) ending in a carboxyl functionality.
- Substitutions or variations in chain structure may occur, yielding a diversity of FA types.
- These include
  - ✓ Saturated FA
  - ✓ Unsaturated FA
  - ✓ Branched chain FA
  - ✓ Oxygenated FA

(a) 

(b) 

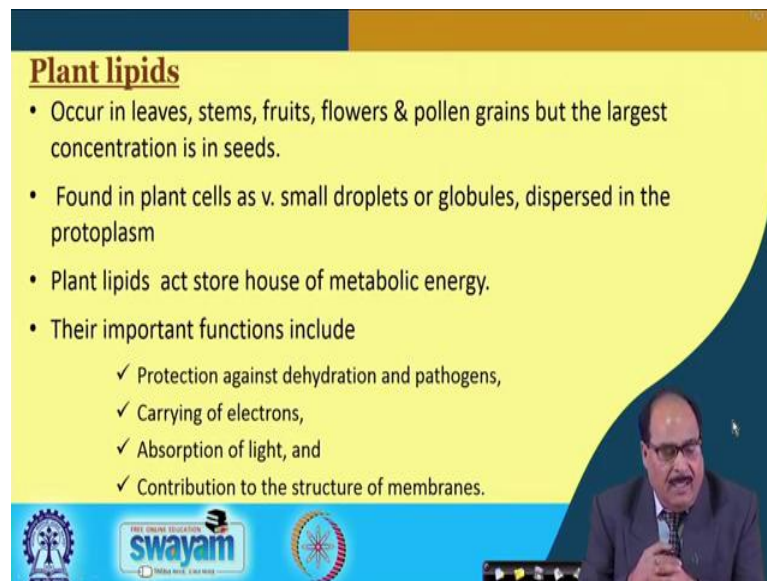
(c) 





The lipids constitute of fatty acids. So, the fatty acids are characterized by a long chain of carbon atoms generally 12 to 22 carbons, ending in a carboxyl functionality. There might be different substitutions or variations in the chain structure and which may result

into different types of fatty acids, including saturated, unsaturated, branched chain, or oxygenated fatty acids.



**Plant lipids**

- Occur in leaves, stems, fruits, flowers & pollen grains but the largest concentration is in seeds.
- Found in plant cells as v. small droplets or globules, dispersed in the protoplasm
- Plant lipids act store house of metabolic energy.
- Their important functions include
  - ✓ Protection against dehydration and pathogens,
  - ✓ Carrying of electrons,
  - ✓ Absorption of light, and
  - ✓ Contribution to the structure of membranes.

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Plant lipids occur in leaves, stems, flowers, fruits, pollen grains and but the largest concentration of the lipid in plants is found in seeds. They are found in plant cells as very small droplet or globules dispersed in the protoplasm. Plant lipids act as store house of metabolic energy. Their important functions in the plant include protection against dehydration and pathogens, carrying of electrons, absorption of light and contribution to the structure of membrane.



**Common lipids in plants**

- Most common lipids found in plants include
  - ✓ Saturated fatty acid (SFA) - Palmitic acid
  - ✓ Mono unsaturated fatty acid (MUFA) - Oleic acid
  - ✓ Polyunsaturated fatty acids (PUFA) - Linoleic acid and linolenic acid
- Plants contain less SFA such as lauric and myristic acids.
- Plant oils are a mixture of mixed triglycerides.

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The commonly found lipids in plant systems include saturated fatty acids (SFA) like palmitic acids, monounsaturated fatty acids (MUFA) like oleic acid and polyunsaturated


fatty acid (PUFA) such as linoleic and linolenic acids. Plants contain comparatively less saturated fatty acids like lauric and myristic acids. Plant oils are mixture of mixed triglycerides.

**Difference between plant & animal lipids**

Animal fats	Plant fats
Example : Butter fat, lard, etc.	Example : Coconut / olive /sunflower etc. oil
Relatively rich in SFA	Comparatively rich in USFA
Solid at room temperature	Liquid at room temperature
Less iodine number	High iodine number
Higher Reichert-meissl number	Relatively Lower reichert-meissl number
More prone to hydrolytic rancidity	More prone to oxidative rancidity
Stored in liver, beneath the skin	Stored in fruits and seeds
Stored in cells called adipocytes	Stored as granules (oil droplets)

**Fats and oils**

- Fats are triglycerides that are solids at room temperature
  - Usually derived from animals
  - Mostly SFA
- Oils are triglycerides that are liquids at room temperature
  - Usually derived from plants
  - Mostly USFA

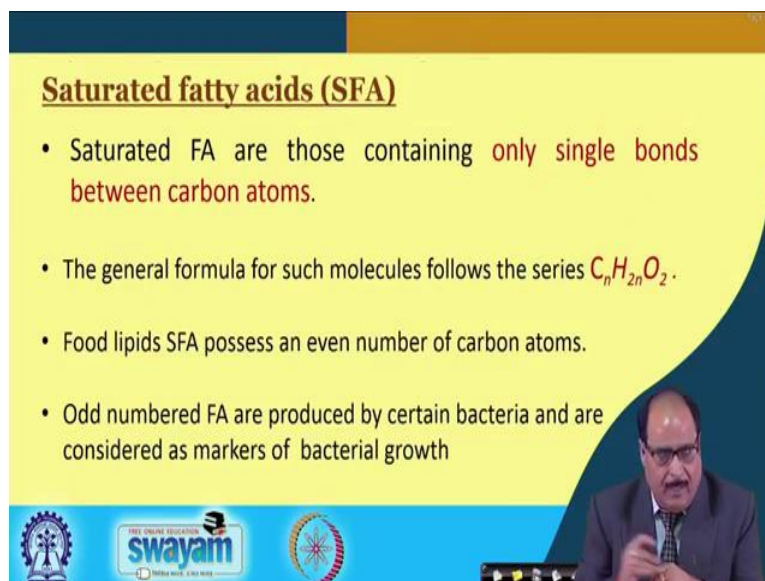


Difference between the plant lipids and animal lipids:

Animal fats	Plant fats
Example : Butter fat, lard, etc.	Example : Coconut / olive /sunflower etc. oil
Relatively rich in SFA	Comparatively rich in USFA
Solid at room temperature	Liquid at room temperature
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More prone to hydrolytic rancidity	More prone to oxidative rancidity
Stored in liver, beneath the skin	Stored in fruits and seeds
Stored in cells called adipocytes	Stored as granules (oil droplets)

In fact, fats and oils basically are in form of lipids. They are triglycerides that are solid or may be liquid at room temperature.

So, the triglycerides which are solid at room temperature are generally termed as fat. They are usually derived from animals and they contain mostly saturated fatty acids. Whereas, the oils are the triglycerides that are mostly liquid at room temperature, they are usually derived from plants and they have more amount of unsaturated fatty acids. So, chemically both of them are triglycerides. And, it is the basic difference of the fatty acids which are present in them like nature of the fatty acid, chain of the fatty acid lengths or degree of saturation of the fatty acids, which makes them solid or liquid.



**Saturated fatty acids (SFA)**

- Saturated FA are those containing **only single bonds between carbon atoms**.
- The general formula for such molecules follows the series  $C_nH_{2n}O_2$ .
- Food lipids SFA possess an even number of carbon atoms.
- Odd numbered FA are produced by certain bacteria and are considered as markers of bacterial growth

Logos: Swayam (Free Online Education), and other educational institutions.

Video inset: A man in a suit and glasses speaking.


Saturated fatty acids are those that contain only single bond between carbon atoms. They fit to the general formula  $C_nH_{2n}O_2$ . Food lipids saturated fatty acids possess in general an even number of carbon atoms; odd numbered fatty acids are produced by certain bacteria and are considered as markers of the bacterial growth.



### Monoene or monounsaturated fatty acids (MUFA)

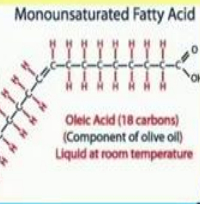
- Contain one double bond between adjacent carbon atoms; general formula is  $C_nH_{(2n-2)}O_2$ .
- Double bond is at a number of locations along the carbon chain, resulting monoene isomers e.g. 16:1 (n-9) and 16:1 (n-11).
- All double bonds in FA are generally of *cis geometry*; converted into *trans geometry* when lipids are exposed to heating (cooking, frying, etc.).

Saturated Fatty Acid




Stearic Acid (18 carbons)  
(Component of animal fat)  
Solid at room temperature

Monounsaturated Fatty Acid



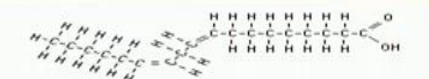
Oleic Acid (18 carbons)  
(Component of olive oil)  
Liquid at room temperature




Unsaturation means all the carbon balances are not saturated; there is some double bond. So, the monounsaturated means 1 double bond; this is a fatty acids that contain 1 double bond between adjacent carbon atoms and they fit to the general formula of  $C_nH_{2n}O_2$ . The double bonds in monounsaturated fatty acids is generally at a number of locations along the carbon chain, resulting monoene isomers for example, 16:1 (n-9) and 16:1 (n-11). All double bonds in fatty acids are generally of *cis geometry*. However, when these fats are exposed to heat treatment like cooking, frying etc., then *cis* is converted into *trans geometry*. In *cis geometry*, in a double bond OH groups are on the same side of the chain whereas, in the *trans geometry* they are located on the opposite side of the chain. So, the composition of *cis* and *trans* fats is of nutritional significance and importance in food science.

### Polyene or Polyunsaturated fatty acids (PUFA)

- PUFA contain more than one double bond in the carbon chain.
- PUFA from all natural sources contain *cis geometry*.
- Majority of natural PUFAs contain double bonds in a methylene interrupted pattern.
- Maximum number of double bonds possible in a PUFA is limited by
  - ✓ Chain length
  - ✓ Position of the first double bond from the carboxyl carbon
- Maximum number of double bonds in naturally PUFAs is 4 for C18, 5 for C20 and 6 for C22.



Linoleic acid, a polyunsaturated fatty acid.  
Both double bonds are *cis*.



Polyunsaturated fatty acids contain more than 1 double bond; poly i.e. 2, 3, 4, 5 or more double bond in the carbon chain. Polyunsaturated fatty acids are commonly called as PUFA. They contain double bonding in cis geometry; majority of natural PUFA contain double bond in a methylene interrupted pattern. The maximum number of double bond possible in a PUFA is limited by the chain length and position of the first double bond from the carboxyl atom. Maximum number of double bonds in naturally occurring polyunsaturated fatty acids are 4 for C18 carbon, 5 for C20 carbon and 6 for C22 carbon containing fatty acids. So, most of the food fats or oils contain double bonds ranging from 1 to 6. So, polyunsaturated fatty acids are those that contain higher number of double bonds like 4, 5, 6 in their structure.

**Branched chain fatty acids (BCFA)**

- Do not commonly occur in food products.
- BCFA can fall within two categories

BCFA

Methyl group replaces H atoms of the C-chain

Single methyl branch on the second-last or third-last carbon of the chain, which is usually odd numbered, i.e., C13, C15, or C17

Isoprenoid acids

Derived from isoprene units. e.g. 2,6,10,14-Tetramethylpentadecanoic acid (Pristanic acid) and 3,7,11,15-Tetramethylhexadecanoic acid (Phytanic acid).

HOOC CCCC(C)CCCC(C)CCCC(C)CCCC(C)C  
3,7,11,15-tetramethylhexadecanoic (phytanic) acid

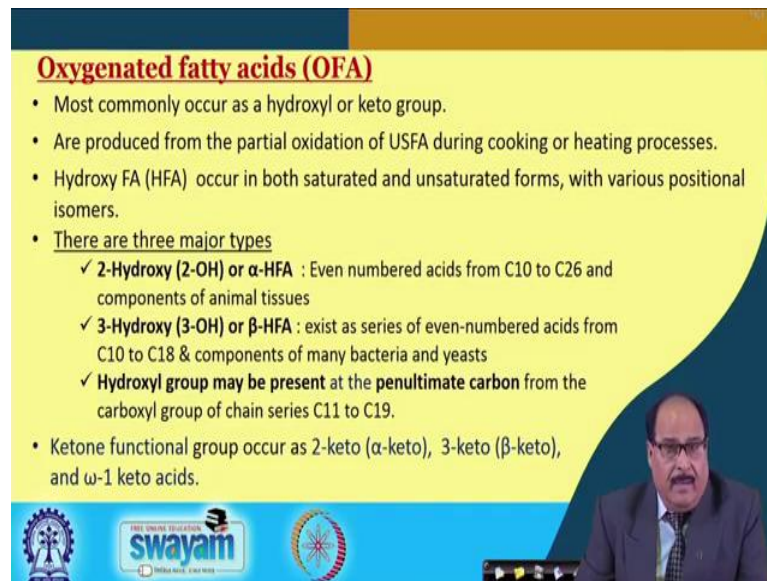
HOOC CCCC(C)CCCC(C)CCCC(C)CCCC(C)C  
2,6,10,14-tetramethylpentadecanoic (pristanic) acid

HOOC CCCC(C)CCCC(C)CCCC(C)CCCC(C)C  
4,8,12-trimethyltridecanoic acid

Another important fatty acids is the branched chain fatty acid (BCFA); however, they are normally not found in food materials. They are of 2 types; methyl group replaces hydrogen atom of the carbon chain in one group of the branched chain fatty acids. In another group, it is the isoprenoid acids (normally derived from isoprene units).

**Oxygenated fatty acids (OFA)**

- Most commonly occur as a hydroxyl or keto group.
- Are produced from the partial oxidation of USFA during cooking or heating processes.
- Hydroxy FA (HFA) occur in both saturated and unsaturated forms, with various positional isomers.
- There are three major types
  - ✓ **2-Hydroxy (2-OH) or  $\alpha$ -HFA** : Even numbered acids from C10 to C26 and components of animal tissues
  - ✓ **3-Hydroxy (3-OH) or  $\beta$ -HFA** : exist as series of even-numbered acids from C10 to C18 & components of many bacteria and yeasts
  - ✓ **Hydroxyl group may be present at the penultimate carbon** from the carboxyl group of chain series C11 to C19.
- Ketone functional group occur as 2-keto ( $\alpha$ -keto), 3-keto ( $\beta$ -keto), and  $\omega$ -1 keto acids.



Oxygenated fatty acids (OFA):

They most commonly occur as a hydroxyl or keto group. They are produced from the partial oxidation of unsaturated fatty acids, during cooking or heating processes. And therefore, they become of nutritional significance that is of concern in food science and processing. Hydroxy fatty acids (HFA) occur in both saturated and unsaturated forms with various positional isomers. There are 3 major types of OFA or HFA:

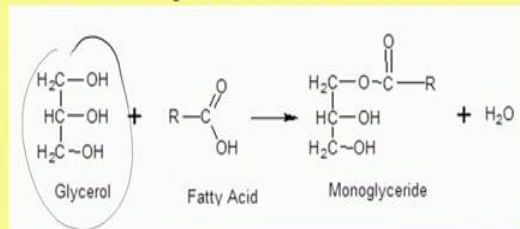
- ✓ 2-Hydroxy (2-OH) or  $\alpha$ -HFA : Even numbered acids from C10 to C26 and components of animal tissues
- ✓ 3-Hydroxy (3-OH) or  $\beta$ -HFA : exist as series of even-numbered acids from C10 to C18 & components of many bacteria and yeasts
- ✓ Hydroxyl group may be present at the penultimate carbon from the carboxyl group of chain series C11 to C19.

Ketone functional group occur as 2-keto, 3-keto or omega 1-keto acids.



## Acylglycerols (Glycerides)

- Consist of one, two, or three FA (acyl) residues esterified to hydroxyl residue(s) of a glycerol molecule.
- Are formed by substitution of the glycerol backbone by acyl residues in which the substitutions are along FA carbon chain.



Acylglycerols or glycerides consist of 1, 2 or 3 fatty acid residues esterified to hydroxyl residue of a glycerol molecule. A glycerol molecule having 3 hydroxyl groups reacts with fatty acids (RCOOH). So, ester linkage is formed between the hydroxyl group, as well as carboxyl group of the glycerol and fatty acids. The resulting compounds like glyceride, monoglyceride, diglycerides, or triglycerides are formed. In this case, it is one fatty acid esterified with alcohol linkage of the glycerol molecule. So, monoglycerides are formed by substitution of glycerol backbone by acyl residues in which substitutions are along with the fatty acids carbon chain.

So, if it is 1 substitution, it is monoglyceride; 2 substitutions diglycerides and if all the 3 hydroxyl groups are substituted by fatty acids or esterified with fatty acids, then it becomes triglycerides.

### Monoacylglycerol or monoglyceride (MG)

- Single substitution of one hydroxyl group of the glycerol molecule with an acyl residue via an ester linkage.
- Three positional isomers
  - ✓ Top C position *Sn-1*, central C position *Sn-2*, or terminal C position *Sn-3*.
- MG are most important group of emulsifiers.
- The *Sn-2* isomer retains its molecular symmetry and is, therefore, non-chiral.

Stereoisomers of monoacyl-*sn*-glycerols

Monoglycerol or monoglyceride (MG): The fatty acids may join at the Sn-1 position, at Sn-2 position, or at Sn-3 positions. And, depending upon their position there may be 3 isomers, or 3 positional isomers like, like Sn-1 isomer Sn-2 isomer or Sn-3 isomers; Sn-2 isomer retains its molecular symmetry and is therefore, non-chiral. These are very important group of lipids, which are generally used as emulsifier in food processing in preparation of different types of product.

### Diacylglycerols or diglycerides (DG)

- Substitution of two hydroxyl groups of the glycerol molecule with an acyl residue via an ester linkage.
- DG contain 2 FA, three isomers are possible.
- DG also acts as an emulsifier.

Glycerol + 2 Fatty Acid → Diglyceride + 2 H<sub>2</sub>O

Diacylglycerols or diglycerides (DG): There are 2 hydroxyl group of the glycerol molecule esterified with 2 fatty acids. Again 3 isomers might be possible i.e. Sn-1 Sn-2, Sn-3, etc. Diglycerides also act as emulsifiers.

### Triacylglycerols or triglyceride (TG)

- Full substitution of all 3 hydroxyl groups of glycerol molecule with ester linked acyl residues.
- Commonly been referred as oils or fats depending on their melting point and FA composition.
- Represent the depot lipids of plants and animals (in adipose tissues.)
- A large variety of positional isomers may be possible depending on diversity of component FA & their positional distribution.

✓ TG from plants like palm and coconut contain high proportion of SFA and are solid at room temperature.

✓ TG from corn, peanuts, soybeans, sunflowers, and olives oil contain high proportion of unsaturated fatty acids and are liquid.

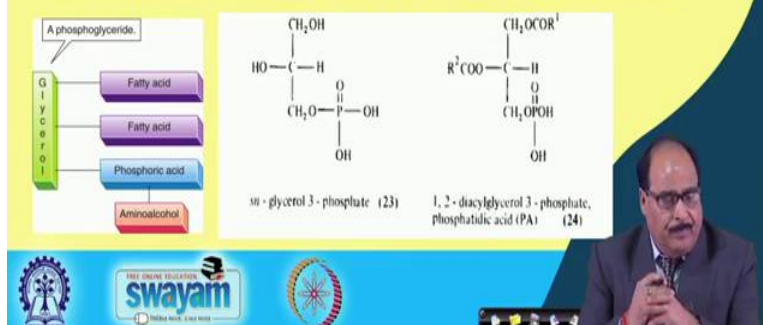


In case of triglycerides or triacylglycerols (TG), there is full substitution i.e. all the 3 hydroxyl groups of the glycerol molecule are esterified. It may so happen that all the 3 hydroxyl groups are esterified with the same fatty acid i.e. 3 molecules of same fatty acid like stearic acid. Stearic acid is attached in all the 3 positions Sn-1, Sn-2, Sn-3, or 2 fatty acids Sn-1, Sn-2, may be stearic acid and Sn-3 may be formic acid or in all the 3 positions, Sn-1, Sn-2, Sn-3; there may be 3 different fatty acids. So, if at all the 3 positions there are same fatty acids attached, it is called simple triglyceride and if the 3 fatty acids are different, the resulting triglyceride is known as mixed triglyceride and most of the food fats and oils are mixtures of mixed triglycerides.

Triglycerides from the plants like palm, coconut, etc., contain comparatively high proportion of saturated fatty acids and are solid at room temperature. And, on the other hand, the triglycerides from plant materials like corn, peanuts, soyabean, sunflower oil etc. or even olive oil contain high proportion of unsaturated fatty acids, or polyunsaturated fatty acids, and they are liquid at room temperature.

## Phospholipids (PL)

- Derivatives of glycerophosphoric acid or more strictly Sn-glycerol 3-phosphate
- PL molecules are unique amongst most lipids in being amphipathic structures.
- Contain both hydrophilic or polar region (the phosphate and head group) together with a hydrophobic or nonpolar region (the acyl residues and glycerol backbone).



Phospholipids are another important category of lipids. They are the derivatives of glycerophosphoric acid or more strictly Sn-glycerol 3-phosphate.

The fatty acid at Sn-3 position (see Fig.) is replaced with a phosphoric acid. And, the phosphoric acid in turn may be joined with another molecule. Like in the case of lecithin, phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, phosphatidyl helin etc. are attached.

These phospholipids are very important groups of lipids commonly found in the food materials. They contain hydrophilic or polar region (the phosphate and head group) together with a hydrophobic or non-polar region (the acyl residues and glycerol backbone).

And accordingly from the structure and function wise they are very important in the food processing or food chemistry.

**Waxes**

- Waxes (commonly called wax esters) are esters of FA and long chain alcohols.
- Simple waxes are esters of medium chain FA (16:0, 18:0, 18:1v9) and long-chain aliphatic alcohols (C8 to C18).
- Complex waxes also exist where either the FA or alcohol components have complex structures in their own rights (e.g., vitamin esters or sterol esters).

A wax.

Long-chain fatty acid


Long-chain alcohol

$$\text{CH}_3\text{-(CH}_2\text{)}_{30}\text{-COOH} + \text{HO-(CH}_2\text{)}_{33}\text{-CH}_3$$

$$\downarrow$$

$$\text{CH}_3\text{-(CH}_2\text{)}_{30}\text{-C(=O)-O(CH}_2\text{)}_{33}\text{-CH}_3$$

Carnauba wax




swayam

The other group of lipids is the waxes commonly called wax esters. These are the esters of fatty acids and long chain alcohol generally monohydric alcohol. Simple waxes are esters of medium chain fatty acid (16:0, 18:0, 18:1v9) and long-chain aliphatic alcohols (C8 to C18). Complex waxes also exist where either the fatty acid or alcohol components have complex structures in their own rights; for example, vitamins esters or sterol esters etc.

**Occurrence of waxes**

- In bacteria and marine organisms serve as short-term storage lipids or aid in buoyancy.
- Simple waxes are found on surfaces of animals, plants and insects and prevent water loss.
- Compounds with C21 to C44 have been reported from marine organisms.
- FA involved may include PUFA, although 16:1 and 20:1 are major components.
- Important in foods as additives (beeswax, carnauba wax, candelilla wax, etc.)



swayam

Waxes generally occur in bacteria and marine organisms and they serve as short term storage lipids or aid in their buoyancy. Simple waxes are found on surfaces of animals, plants and insects and they prevent water loss. Compounds with C21 to C44 have been



reported from marine organisms. Fatty acid involved in the waxes may include polyunsaturated fatty acids (PUFA), although 16:1 and 20:1 are major components.

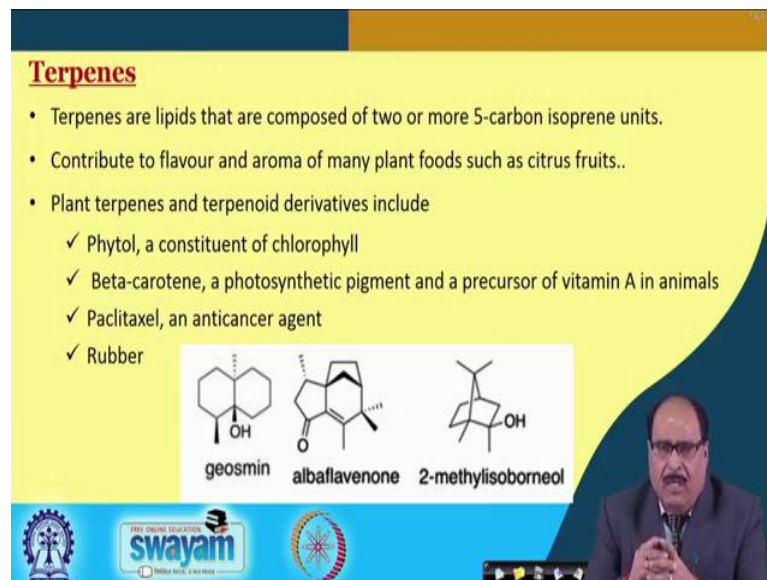
Important waxes in food as additives are beeswax, carnauba wax, candelilla wax, etc. They are used for several processes like edible coating application etc. and in food processing for different functions to perform different operations.

**Terpenes**

- Terpenes are lipids that are composed of two or more 5-carbon isoprene units.
- Contribute to flavour and aroma of many plant foods such as citrus fruits..
- Plant terpenes and terpenoid derivatives include
  - ✓ Phytol, a constituent of chlorophyll
  - ✓ Beta-carotene, a photosynthetic pigment and a precursor of vitamin A in animals
  - ✓ Paclitaxel, an anticancer agent
  - ✓ Rubber

C1=CC2=C(C1)C(C)C(C)C2   C1=CC2=C(C1)C(=O)C(C)C2   CC1=C(C)C(O)C1

geosmin   albaflavenone   2-methylisoborneol



Another important category is Terpenes. They are lipids that are composed of 2 or more 5-carbon isoprene units. They contribute to the flavour and aroma of many plant foods such as citrus foods. Plant terpenes and terpenoid derivatives include phytol (a constituent of chlorophyll), beta carotene (a photosynthetic pigment and precursor of vitamin A in animals). They are also found in rubbers etc. Geosmin, albaflavenone, 2-methylisoborneol borneol all these are the examples of terpenes.

## Isoprenoid lipids

- Major classes of compounds such as terpenoids, steroids, and carotenoids.
- Backbone structure from multiple, repeating, branched-chain unsaturated C-5 units called isoprene or isopentenyl units.
- Lipids can be easily identified by the ability to divide the compound structure neatly into its original isoprene synthetic units (isoprene rule).
- Subsequent cyclization and addition of functional groups may take place at sites of unsaturation.
- Large diversity and complex nomenclature of isoprenoid .

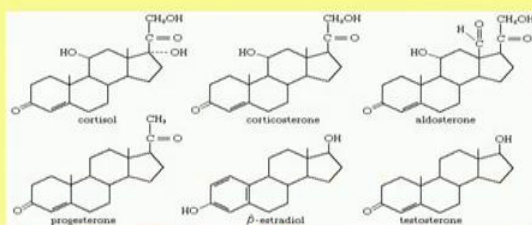
lipids.



Isoprenoid lipids are the major classes of compound such as terpenoids, steroids, carotenoids, etc. The backbone structure from multiple, repeating, branched chain unsaturated C-5 units called isoprene or isopentile units. And, lipid can be easily identified by the ability to divide the compound structure neatly into its original isoprene synthetic units. Their subsequent cyclization and addition of functional groups may take place at sites of unsaturation. Large diversity of complex nomenclature of isoprenoid is available there.

## Steroids and sterols

- Steroids are compounds of structural motif of C<sub>30</sub> (triterpenoid) derived isoprenoid lipids.
- Sterols are derivatives of steroids and are common in eukaryotic cells.
- Natural occurring sterols have a 1,2-cyclopentano-phenanthrene skeleton and 27–30 C atoms with a hydroxyl group at C-3 and side chain of at least seven carbon at C-17.

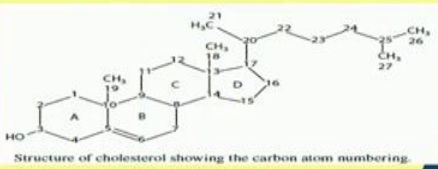


Another important group of the lipids include steroids and sterols. Steroids are compounds of structural motif of C<sub>30</sub> (triterpenoid) derived isoprenoid lipids. They are derivatives of steroids and are common in eukaryotic cells. Natural occurring sterols


have a have a 1,2-cyclopentano-phenanthrene skeleton and 27–30 C atoms with a hydroxyl group at C-3 and side chain of at least seven carbon at C-17.

### Cholesterol

- Cholesterol is the main animal sterol
- It contains 27 C- atoms arranged into 4 fused rings and a hydrocarbon tail.
- It is precursor of bile acids, vitamin D and steroid hormones.
- Is synthesized, primarily in liver and adrenal gland, from acetyl-CoA cholesteryl ester, which is formed by an ester link of a fatty acid to cholesterol.
- Cholesteryl esters are hydrophobic, and are used for storage and transport of cholesterol.



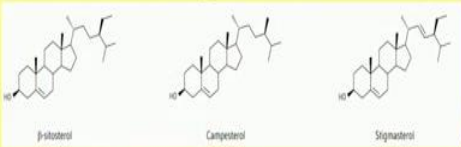
Structure of cholesterol showing the carbon atom numbering.




Cholesterol is another important group; the main animal sterol. Although it is a sterol, but it is found associated with the phospholipids in food materials. It contains 27-C atoms arranged into 4 fused rings and a hydrocarbon tail. It is the precursor of bile acids vitamin D and steroid hormones. It is synthesized primarily in liver and adrenal gland. Cholesteryl esters are hydrophobic, and are used for storage and transport of cholesterol. And, this cholesterol has important functions to perform in our diet. It is also synthesized in our body, but many times it needs to be regulated, because excess of cholesterol gets deposited in the body and may create some problems.

### Phytosterols

- Structurally related to cholesterol; differ from cholesterol in the structure of side chain.
- Phytosterols have been classified into two categories
  - ✓ Sterols which have double bond in the sterol ring, unsaturated compounds, and
  - ✓ Stanols which lack double bond in the sterol ring, saturated compounds.
- The most common phytosterols and phytostanols are sitosterol and brassica sterol.
- Phytosterols are isolated from vegetable oils.



β-sitosterol      Campesterol      Stigmasterol



Phytosterols constitute another group of lipids having structure related to cholesterol. Only difference which they have with the cholesterol is in the structure of side chain. Phytosterols are of two types; one is the sterol in which double bond is present in the sterol ring, generally unsaturated compound; other is the stanols which do not have any double bond; so they are saturated compound.

The most common phytosterol and phytostanols are sitosterol and brassica sterol. Phytosterols are isolated from vegetable oils.

**Fat soluble vitamins**

**Vitamin A**

- Most bioactive form is all-trans retinol, and cis forms created via light-induced isomerization.
- $\alpha$ - and  $\beta$ -carotenes have bio-potencies of about 8.7% and 16.7% of the all-trans retinol.
- The daily value (DV) for vitamin A is 1000 retinol equivalents (RE), represents 1000 mg of all-trans retinol or 6000 mg of  $\beta$ -carotenes .
- Animal liver is an excellent source of vitamin A, in cure of night blindness.

Another important components of lipids which are of nutritional importance are fat soluble vitamins.

### **Vitamin A**

- Most bioactive form is all-trans retinol, and cis forms created via light-induced isomerization.
- $\alpha$ - and  $\beta$ -carotenes have bio-potencies of about 8.7% and 16.7% of the all-trans retinol.
- The daily value (DV) for vitamin A is 1000 retinol equivalents (RE), represents 1000 mg of all-trans retinol or 6000 mg of  $\beta$ -carotenes .
- Animal liver is an excellent source of vitamin A, it helps in cure of night blindness.

**Vitamin D**

- Biologically active ergocalciferol (vitamin D<sub>2</sub>) and cholecalciferol (vitamin D<sub>3</sub>).
- Can be synthesized in humans from 7-dehydrocholesterol, which occurs naturally in the skin, via light irradiation.
- Hormonal forms of the D vitamins are the hydroxylated derivatives.
- Vitamin D is converted to 25-OH-D in kidney & further hydroxylated to 1,25-diOH-D in liver.
- The dihydroxy form is most biologically active form in humans.

Formation of vitamin D in vivo.

The diagram illustrates the synthesis of vitamin D. It starts with 7-Dehydrocholesterol, which is converted to Pre-vitamin D<sub>3</sub> upon exposure to UV light (hv). Pre-vitamin D<sub>3</sub> is then converted to Cholecalciferol (vitamin D<sub>3</sub>) through light irradiation (D).

## Vitamin D

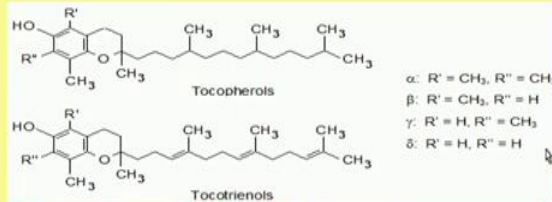
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The structure of 7-dehydro cholesterol gets converted into pro vitamin D<sub>3</sub> and vitamin D<sub>3</sub> cholecalciferol.



## Vitamin E

- Vitamin E compounds include the tocopherols and tocotrienols.
- Tocotrienols have a conjugated triene double-bond system in the phytyl side chain, whereas tocopherols do not.
- Methyl substitution affects bioactivity of vitamin E, as well as in vitro antioxidant activity.



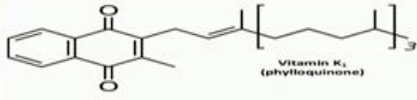
## **Vitamin E**

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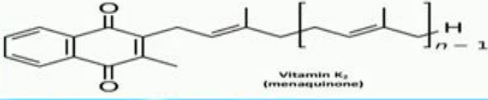
The structure depending upon the side chain, i.e. whether CH<sub>3</sub> or R-H-R, alpha, beta, gamma and delta tocotrienols and tocopherols are found, and their antioxidant properties vary significantly.

**Vitamin K**


- Vitamin K1 (Phylloquinone) is found in green leaves.
- Vitamin K2 (Menaquinone) is synthesized by intestinal bacteria.
- Involved in blood clotting as an essential cofactor in synthesis of  $\gamma$ -carboxyglutamate.
- Vitamin K deficiency is rare due to intestinal microflora synthesis.






Vitamin K<sub>1</sub>  
(phylloquinone)



Vitamin K<sub>2</sub>  
(menaquinone)



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So, lipids are very important in food processing, food science, food engineering and food products manufacturing or in human nutrition.