Fats and Oils

Natural fats are lipids obtained from plants and animals. They are mainly composed of **triglycerides (triacylglycerols)**, which consist of one glycerol molecule attached to three fatty acid molecules. They serve as an important source of energy and are essential for normal body functions.

Natural fats are naturally occurring esters of glycerol and fatty acids found in living organisms. They are insoluble in water but soluble in organic solvents such as ether, chloroform, and benzene.

Sources

Animal sources:

- Butter
- Ghee
- Milk and cheese
- Meat fat
- Fish oil

Plant sources:

- Coconut oil
- Olive oil
- Mustard oil
- Sunflower oil
- Groundnut (peanut) oil
- Sesame oil

Types of Natural Fats

1. **Saturated fats**
    - Contain no carbon-carbon double bonds.
    - Usually solid at room temperature.
    - Examples: Butter, ghee, coconut oil.
2. **Unsaturated fats**
    - Contain one or more carbon-carbon double bonds.
    - Usually liquid at room temperature.
    - Examples: Olive oil, sunflower oil, mustard oil.

Functions of Natural Fats

- Provide **9 kcal (37 kJ) of energy per gram**.
- Store energy for future use.

- Help absorb **fat-soluble vitamins (A, D, E, and K)**.
- Protect internal organs from injury.
- Provide insulation and help maintain body temperature.
- Form an important part of cell membranes.
- Supply essential fatty acids needed for normal growth and health.

Importance

- Essential for normal growth and development.
- Improve the taste and texture of food.
- Help in hormone production and other metabolic processes.

Harmful Effects of Excess Fat Intake

- Obesity
- High cholesterol
- Heart disease
- Fatty liver
- Increased risk of type 2 diabetes

Examples

- **Natural saturated fats:** Butter, ghee, coconut oil
- **Natural unsaturated fats:** Olive oil, mustard oil, sunflower oil, groundnut oil

Edible and Inedible Oils of Vegetable Origin

Vegetable oils are oils extracted from the seeds, fruits, nuts, or other parts of plants. They are classified into **edible oils** (safe for human consumption) and **inedible oils** (not suitable for consumption but useful for industrial, medicinal, or agricultural purposes).

1. Edible Oils

Definition:
Edible vegetable oils are oils that are safe for human consumption and are used in cooking, food preparation, and food processing.

Sources and Examples

Edible Oil	Source
Mustard oil	Mustard seeds
Groundnut (Peanut) oil	Groundnut seeds
Sunflower oil	Sunflower seeds
Soybean oil	Soybean seeds

Edible Oil	Source
Coconut oil	Coconut kernel
Olive oil	Olive fruits
Sesame (Til) oil	Sesame seeds
Rice bran oil	Rice bran
Corn oil	Maize germ
Palm oil	Fruit of oil palm

Characteristics

- Rich in triglycerides.
- Contain essential fatty acids (linoleic and linolenic acids).
- Source of fat-soluble vitamins (A, D, E, and K).
- Used for frying, baking, salad dressings, and food processing.

Uses

- Cooking and frying.
- Manufacture of margarine and shortening.
- Preparation of bakery products.
- Nutritional supplements.

2. Inedible Oils

Definition:
Inedible vegetable oils are oils that are **not suitable for human consumption** because of toxicity, unpleasant taste, or other harmful properties. They are mainly used for industrial and medicinal purposes.

Sources and Examples

Inedible Oil	Source	Main Uses
Castor oil	Castor seeds	Medicines, lubricants, cosmetics
Neem oil	Neem seeds	Biopesticide, soap, cosmetics
Linseed oil	Flax seeds	Paints, varnishes, printing inks
Tung oil	Tung seeds	Waterproof coatings, varnishes
Jatropha oil	Jatropha seeds	Biodiesel production
Karanja oil	Karanja seeds	Soap making, biofuel, pesticides

Characteristics

- May contain toxic compounds.
- Unsuitable for cooking.

- Often have strong odor or bitter taste.
- Used in industrial applications.

Uses

- Manufacture of paints and varnishes.
- Soap and cosmetic production.
- Lubricants.
- Biodiesel production.
- Agricultural pesticides and insect repellents.
- Pharmaceutical preparations (e.g., castor oil as a laxative after proper processing).

Differences Between Edible and Inedible Vegetable Oils

Feature	Edible Oils	Inedible Oils
Suitability	Safe for human consumption	Not suitable for human consumption
Main use	Cooking and food preparation	Industrial, medicinal, agricultural uses
Toxicity	Non-toxic	May contain toxic substances
Nutritional value	High	Generally not used as food
Examples	Mustard, sunflower, soybean, olive, coconut	Neem, castor, linseed, tung, jatropha

Common Fatty Acids

Fatty acids are long-chain carboxylic acids (R–COOH) that are the main components of fats and oils. They usually contain an even number of carbon atoms and may be **saturated** (no C=C double bonds) or **unsaturated** (one or more C=C double bonds).

Classification of Common Fatty Acids

A. Saturated Fatty Acids

These fatty acids contain **no double bonds**.

Fatty Acid	Molecular Formula	Carbon Atoms	Common Sources
Butyric acid	$C_4H_8O_2$	4	Butter
Caproic acid	$C_6H_{12}O_2$	6	Milk fat
Caprylic acid	$C_8H_{16}O_2$	8	Coconut oil

Fatty Acid	Molecular Formula	Carbon Atoms	Common Sources
Capric acid	$C_{10}H_{20}O_2$	10	Coconut and palm kernel oil
Lauric acid	$C_{12}H_{24}O_2$	12	Coconut oil
Myristic acid	$C_{14}H_{28}O_2$	14	Coconut oil, butter
Palmitic acid	$C_{16}H_{32}O_2$	16	Palm oil, meat, dairy
Stearic acid	$C_{18}H_{36}O_2$	18	Animal fat, cocoa butter
Arachidic acid	$C_{20}H_{40}O_2$	20	Peanut oil

Characteristics

- Solid at room temperature.
- More chemically stable.
- Excess intake may increase LDL ("bad") cholesterol.

B. Unsaturated Fatty Acids

These fatty acids contain **one or more double bonds**.

(i) Monounsaturated Fatty Acids (MUFA)

Fatty Acid	Formula	Double Bonds	Common Sources
Oleic acid	$C_{18}H_{34}O_2$	1	Olive oil, mustard oil, peanut oil

(ii) Polyunsaturated Fatty Acids (PUFA)

Fatty Acid	Formula	Double Bonds	Common Sources
Linoleic acid (Omega-6)	$C_{18}H_{32}O_2$	2	Sunflower, safflower, soybean oils
α-Linolenic acid (Omega-3)	$C_{18}H_{30}O_2$	3	Flaxseed, soybean, canola oil
Arachidonic acid	$C_{20}H_{32}O_2$	4	Meat, eggs, animal fats

Characteristics

- Usually liquid at room temperature.
- Beneficial for heart health.
- Essential fatty acids include **linoleic acid** and **α-linolenic acid** because the human body cannot synthesize them.

Essential Fatty Acids

These must be obtained from the diet.

- **Linoleic acid (Omega-6)**
- **α-Linolenic acid (Omega-3)**

Functions

- Maintain healthy cell membranes.
- Support brain development and function.
- Produce signaling molecules (eicosanoids).
- Promote normal growth and immunity.

Functions of Fatty Acids

- Major source of energy (9 kcal/g).
- Stored as triglycerides for energy reserve.
- Form components of cell membranes.
- Help absorb vitamins A, D, E, and K.
- Act as precursors of hormones and signaling molecules.
- Provide insulation and protect internal organs.

Important Examples for Examinations

Fatty Acid	Type	Carbon:Double Bond Notation
Palmitic acid	Saturated	16:0
Stearic acid	Saturated	18:0
Oleic acid	Monounsaturated	18:1
Linoleic acid	Polyunsaturated (Omega-6)	18:2
α-Linolenic acid	Polyunsaturated (Omega-3)	18:3
Arachidonic acid	Polyunsaturated	20:4

Glycerides

Glycerides (acylglycerols) are **esters of glycerol and fatty acids**. They are the major constituents of natural fats and oils and serve as the principal storage form of energy in plants and animals.

The general reaction is:

Glycerol + Fatty acids → Glycerides + Water

Classification of Glycerides

Based on the number of fatty acid molecules attached to one glycerol molecule, glycerides are classified into three types:

1. Monoglycerides (Monoacylglycerols)

- Contain **one fatty acid** attached to one glycerol molecule.
- Two hydroxyl (-OH) groups remain free.

General Formula:

C3H5(OH)2OOCR\text{C}_3\text{H}_5(\text{OH})_2\text{OOCR}C3H5(OH)2OOCR

Uses:

- Food emulsifiers.
- Pharmaceutical formulations.
- Cosmetics.

2. Diglycerides (Diacylglycerols)

- Contain **two fatty acid** molecules attached to one glycerol molecule.
- One hydroxyl (-OH) group remains free.

General Formula:

C3H5(OH)(OOCR)2\text{C}_3\text{H}_5(\text{OH})(\text{OOCR})_2C3H5(OH)(OOCR)2

Uses:

- Food additives and emulsifiers.
- Intermediate in fat metabolism.

3. Triglycerides (Triacylglycerols)

- Contain **three fatty acid** molecules attached to one glycerol molecule.

- All three hydroxyl groups are esterified.
- They are the **most abundant glycerides** found in nature.

General Formula:

C3H5(OOCR)3\text{C}_3\text{H}_5(\text{OOCR})_3C3H5(OOCR)3

Examples:

- Triolein
- Tripalmitin
- Tristearin

Types of Triglycerides

A. Simple Glycerides

All three fatty acids are **the same**.

Examples:

- Tripalmitin
- Tristearin
- Triolein

B. Mixed Glycerides

Contain **two or three different fatty acids**.

Example:

- Palmito-oleo-stearin (contains palmitic, oleic, and stearic acids)

Properties of Glycerides

Physical Properties

- Colorless, odorless, and tasteless when pure.
- Insoluble in water.
- Soluble in organic solvents such as ether, chloroform, and benzene.
- Oils are liquid at room temperature, while fats are generally solid.

Chemical Properties

1. **Hydrolysis**
    - Glycerides react with water (in the presence of acids, bases, or enzymes) to produce glycerol and fatty acids.
2. **Saponification**
    - Hydrolysis with alkali (NaOH or KOH) forms **soap** and glycerol.
3. **Hydrogenation**
    - Unsaturated glycerides react with hydrogen to form saturated fats (hardening of oils).
4. **Oxidation**
    - Unsaturated glycerides undergo oxidation, which can lead to rancidity.

Functions of Glycerides

- Main storage form of energy (**9 kcal/g**).
- Provide thermal insulation.
- Protect internal organs.
- Supply essential fatty acids.
- Aid in the absorption of fat-soluble vitamins (A, D, E, and K).

Importance

- Major component of edible oils and fats.
- Used in food, pharmaceutical, cosmetic, and soap industries.
- Essential for normal growth, metabolism, and maintenance of body tissues.

Difference Between Simple and Mixed Glycerides

Feature	Simple Glycerides	Mixed Glycerides
Fatty acids	All are identical	Two or more different fatty acids
Example	Tripalmitin, Tristearin	Palmito-oleo-stearin
Occurrence	Less common	More common in natural fats and oils

unsaturated oil and hydrogenation of unsaturated oil

Unsaturated Oils and Hydrogenation of Unsaturated Oils

1. Unsaturated Oils

Unsaturated oils are vegetable or animal oils that contain one or more **carbon-carbon double bonds (C=C)** in their fatty acid chains. They are usually **liquid at room temperature**.

Types of Unsaturated Oils

A. Monounsaturated Oils (MUFA)

- Contain **one double bond** in each fatty acid molecule.
- Example: **Olive oil, mustard oil, groundnut (peanut) oil**.
- Main fatty acid: **Oleic acid (C_{18}:1)**.

B. Polyunsaturated Oils (PUFA)

- Contain **two or more double bonds**.
- Examples: **Sunflower oil, soybean oil, safflower oil, flaxseed oil**.
- Main fatty acids:
  - **Linoleic acid (Omega-6)**
  - **α-Linolenic acid (Omega-3)**

Characteristics of Unsaturated Oils

- Liquid at room temperature.
- Lower melting point than saturated fats.
- Rich in essential fatty acids.
- More susceptible to oxidation and rancidity.
- Considered healthier than saturated fats when consumed in moderation.

Examples

- Mustard oil
- Olive oil
- Sunflower oil
- Soybean oil
- Sesame oil
- Groundnut oil

➢ Hydrogenation of Unsaturated Oils

Hydrogenation is the process of adding **hydrogen (H_2)** across the carbon-carbon double bonds (C=C) of unsaturated oils in the presence of a catalyst such as **nickel (Ni)**, converting them into saturated or partially saturated fats.

Chemical Equation

$$R-CH=CH-R+H2 \xrightarrow{Ni,\ 150-200^{\circ}C} R-CH2-CH2-R$$

(Oleic acid → Stearic acid)

Process of Hydrogenation

1. Unsaturated vegetable oil is heated to about **150–200°C**.
2. Hydrogen gas is passed through the hot oil.
3. Finely divided **nickel (Ni)** acts as a catalyst.
4. Hydrogen adds to the double bonds.
5. The liquid oil becomes a semi-solid or solid fat.

Types of Hydrogenation

A. Complete Hydrogenation

- All double bonds are converted into single bonds.
- Produces fully saturated fats.

B. Partial Hydrogenation

- Only some double bonds are hydrogenated.
- Produces semi-solid fats.
- May form **trans fats**, which are associated with an increased risk of cardiovascular disease.

Advantages of Hydrogenation

- Increases the melting point of oils.
- Converts liquid oils into solid or semi-solid fats.
- Improves texture and spreadability.
- Increases shelf life by reducing oxidation.
- Reduces rancidity.

Disadvantages

- Partial hydrogenation can produce **trans fats**.
- Excess consumption of trans fats may:
    - Increase LDL ("bad") cholesterol.
    - Decrease HDL ("good") cholesterol.
    - Increase the risk of heart disease and stroke.

Uses of Hydrogenated Oils

- Manufacture of margarine.
- Production of vanaspati (vegetable ghee).
- Bakery products such as cakes, biscuits, and pastries.
- Confectionery and processed foods.

- Frying fats and shortenings.

Difference Between Unsaturated Oils and Hydrogenated Oils

Feature	Unsaturated Oils	Hydrogenated Oils
Double bonds	Present	Reduced or absent
Physical state	Liquid	Semi-solid or solid
Melting point	Low	Higher
Oxidation	Easily oxidized	More stable
Examples	Olive, mustard, sunflower oil	Margarine, vanaspati

Production of Vanaspati and Margarine

Vanaspati and margarine are **hydrogenated vegetable fat products** made from edible vegetable oils. Although both are produced by hydrogenation, they differ in composition, processing, and use.

1. Production of Vanaspati

Vanaspati (vegetable ghee) is a **partially hydrogenated vegetable oil** that resembles animal ghee in appearance and texture.

Raw Materials

- Groundnut oil
- Soybean oil
- Cottonseed oil
- Palm oil
- Sunflower oil
- Mustard oil

Manufacturing Process

1. **Refining of Oil**
    - Crude vegetable oil is purified by removing gums, free fatty acids, pigments, and impurities.
2. **Hydrogenation**
    - The refined oil is heated to **150–200°C**.
    - Hydrogen gas is passed through the oil.
    - A finely divided **nickel (Ni)** catalyst is used.
    - Hydrogen adds to the double bonds, making the oil semi-solid.

3. **Catalyst Removal**
    - The nickel catalyst is filtered out after hydrogenation.
4. **Cooling and Blending**
    - The hydrogenated fat is cooled and blended to obtain the desired texture.
5. **Addition of Vitamins**
    - Vitamins **A and D** are commonly added to improve nutritional value.
6. **Packaging**
    - The finished vanaspati is packed in tins or pouches for sale.

Flow Diagram

```
Vegetable oil
      ↓
 Refining
      ↓
Hydrogenation (H₂ + Ni catalyst)
      ↓
Catalyst removal
      ↓
Cooling and blending
      ↓
Addition of Vitamins A & D
      ↓
Packaging
```

Uses

- Cooking
- Deep frying
- Bakery products
- Sweets and confectionery

2. Production of Margarine

Definition

Margarine is a **water-in-oil emulsion** prepared mainly from vegetable oils and is used as a substitute for butter.

Raw Materials

- Soybean oil
- Sunflower oil
- Palm oil
- Canola oil
- Water or skimmed milk
- Salt
- Emulsifiers (e.g., lecithin)

- Vitamins A and D
- Food colours and flavours

Manufacturing Process

1. **Oil Refining**
    - Vegetable oils are purified.
2. **Hydrogenation or Interesterification**
    - Oils are partially hydrogenated or modified by interesterification to obtain the required consistency.
3. **Preparation of Water Phase**
    - Water or skimmed milk is mixed with salt, preservatives, and vitamins.
4. **Emulsification**
    - The oil phase and water phase are mixed with emulsifiers to form a stable water-in-oil emulsion.
5. **Cooling and Crystallization**
    - The emulsion is rapidly cooled to develop a smooth, spreadable texture.
6. **Packaging**
    - Margarine is packed in tubs or wrappers.

Flow Diagram

```
Vegetable oil
      ↓
Refining
      ↓
Hydrogenation/Interesterification
      ↓
Preparation of water phase
      ↓
Emulsification
      ↓
Cooling and crystallization
      ↓
Packaging
```

Uses

- Bread spread
- Baking and confectionery
- Cooking
- Preparation of pastries and cakes

Difference Between Vanaspati and Margarine

Feature	Vanaspati	Margarine
Appearance	Similar to ghee	Similar to butter
Composition	Mainly hydrogenated vegetable oil	Water-in-oil emulsion of vegetable oils
Water content	Very low	About 15–20%
Texture	Semi-solid	Soft and spreadable
Main use	Cooking and frying	Bread spread, baking, cooking
Vitamins	Usually fortified with A & D	Usually fortified with A & D

Advantages

- Long shelf life.
- Less expensive than butter or ghee.
- Suitable for vegetarians.
- Can be fortified with vitamins A and D.

Disadvantages

- Traditional **partially hydrogenated** products may contain **trans fats**, which increase the risk of cardiovascular disease if consumed in excess.
- Modern manufacturers increasingly use **interesterification** or other processing methods to reduce or eliminate trans fats.