# Food Chemistry
# Lecture 1: Water and Food

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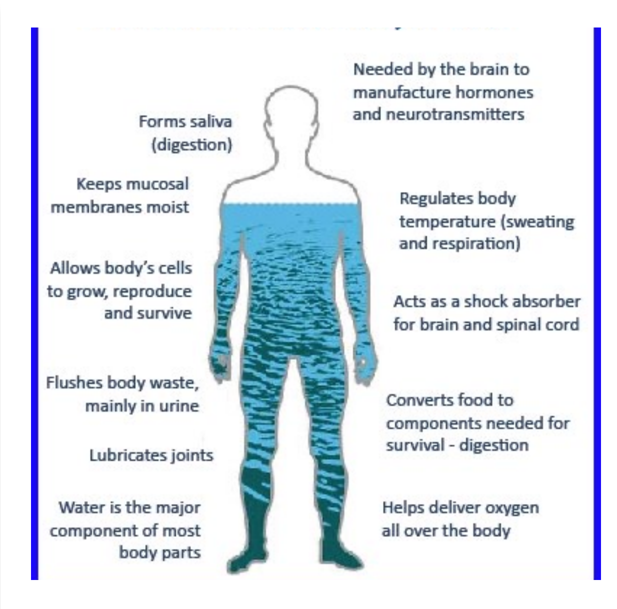
## Essential Roles of Water

**Water in life?**

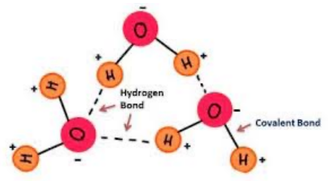
- **Water is a vital molecule for organic life, occurring abundantly in gas, liquid, and solid states.**
- **Water plays seven crucial roles in biological systems, including temperature regulation, nutrient transport, and as a reactant in biochemical processes.**

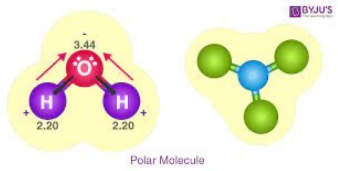


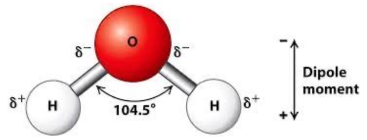
References:
Food Chemistry book: Satish Parmar, Amit Kumar Jain & K. D. Aparnathi
Department of Dairy Chemistry & Biocheistry

# Water Molecule Structure

- Water molecules consist of two hydrogen atoms forming covalent bonds with oxygen.
- Electronegativity of oxygen results in partial charges, creating a polar molecule with a bond angle of 104.5°.

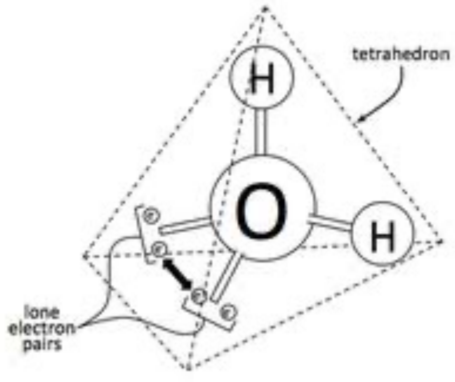






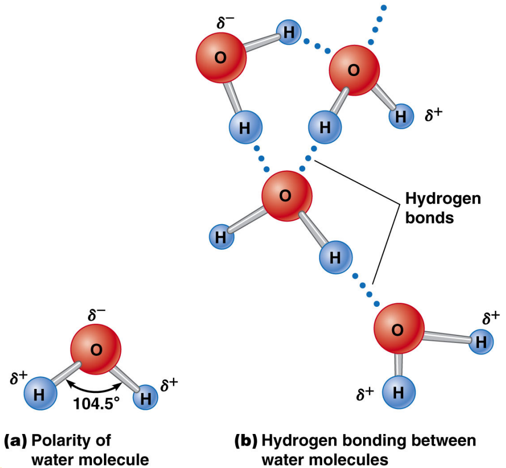
# Association of Water Molecules

- Hydrogen bonding between water molecules creates a three-dimensional structure.
- This structure influences water's unique properties, such as high heat capacity and surface tension.



The bent structure of a water molecule.

## Water as Solvent



**(a)** Polarity of water molecule

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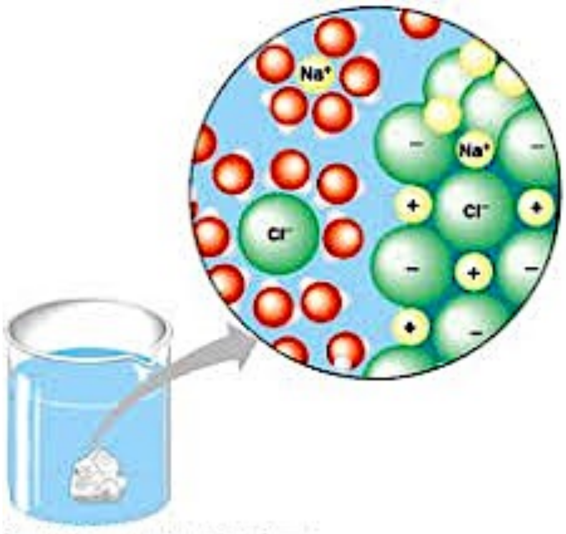
**(b)** Hydrogen bonding between water molecules

- Ions compete for water, altering its structure and influencing the permittivity of the medium.
- Nature and concentration of ions impact protein conformation and colloidal stability.

## Interaction with Hydrophilic Solutes

- Interactions between water and nonionic, hydrophilic solutes are weaker than water-ion interactions.
- Solutes capable of hydrogen bonding enhance or maintain water's normal structure.



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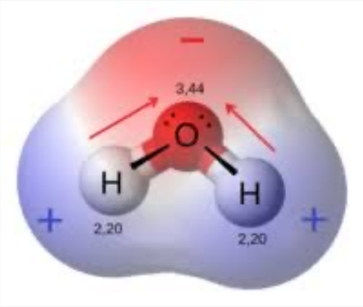
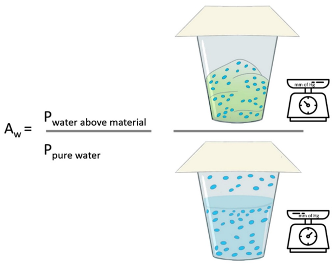
## Interaction with Non-Polar Substances

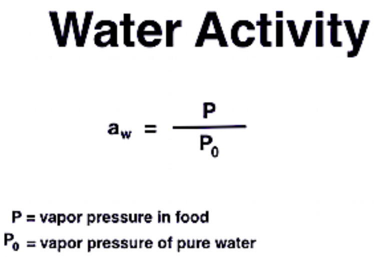
- Mixing water with hydrophobic substances is thermodynamically unfavorable.
- Hydrophobic hydration minimizes water's association with apolar entities, encouraging hydrophobic interactions.



## Water Activity (aw)

- Water activity is a measure of water's association with nonaqueous constituents.
- It closely relates to food stability, safety, and properties beyond water content alone.





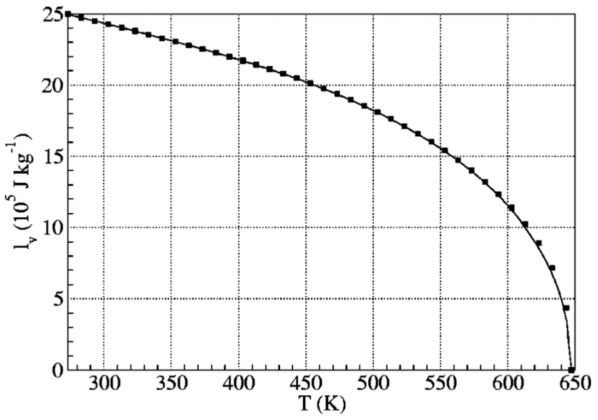
**Water Activity**

$$a_w = \frac{P}{P_0}$$

P = vapor pressure in food
$P_0$ = vapor pressure of pure water

## Water is a Temperature Dependence

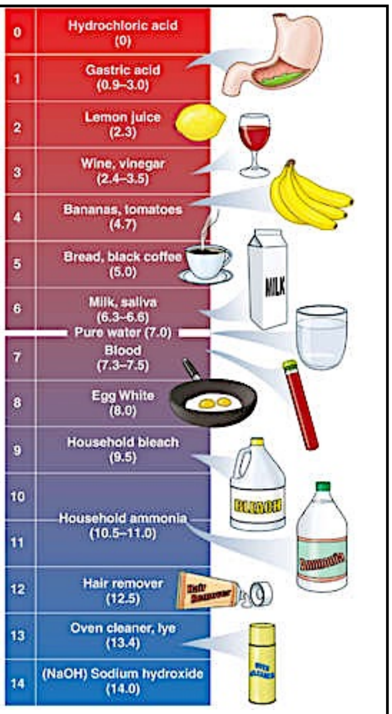
- **Relative vapor pressure, and therefore water activity, is temperature-dependent.**
- **This can be crucial for packaged foods, leading to changes in stability with temperature variations.**



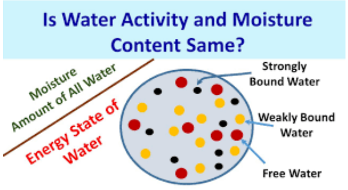
The temperature dependence of the heat of vaporization of water

## Effect of pH on food

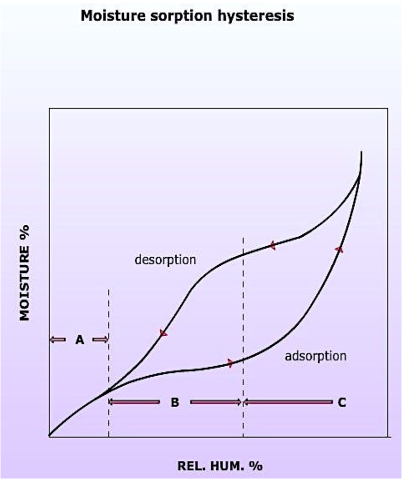
- **pH is a measure of acidity or alkalinity of food.**
- **Changes in pH effect quality.**
  - Color
  - Texture
  - Stability
- **Changes in pH effect safety**
  - Foods are generally acidic (pH less than 7.0)
  - Low acid foods have a pH between 4.6 and 7.0 (potentially hazardous food)
  - High acid foods have a pH of 4.6 or less. (non-potentially hazardous food)



## Moisture Sorption Isotherms


Is Water Activity and Moisture Content Same?

- **Moisture sorption isotherms depict the relationship between water content and water activity at a constant temperature.**
- **Different zones in the isotherm exhibit unique water properties influencing food stability.**
- **Water in foods can exist in three forms: free water, water absorbed on the surface of macromolecular colloids, and water in bound form (water of hydration).**
- **Determining water content in foods is a complex task with challenges in analytical procedures.**


Moisture sorption hysteresis

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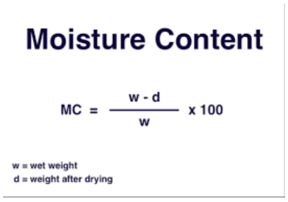
# Methods for Determination of Moisture in Foods:

1. **Drying Methods:**
   - Involves thermal drying methods where material is heated, and weight loss is measured.
2. **Distillation Methods:**
   - Two types involving distillation from immiscible liquids or distillation with an immiscible solvent.
3. **Chemical Methods (Karl Fischer Reagent Titration):**
   - Karl Fischer reagent is adaptable for moisture determination. Suitable for low moisture foods, intermediate moisture foods, and foods with high levels of volatile oils.
4. **Physical Methods:**
   - Infrared determination, gas chromatographic method, nuclear magnetic resonance, electric method, densitometric method, refractometric method, polarimetric method.

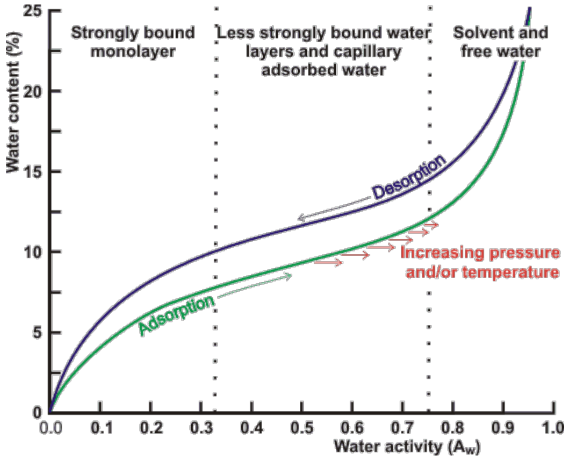

**Moisture Content**

$$MC = \frac{w - d}{w} \times 100$$

w = wet weight
d = weight after drying

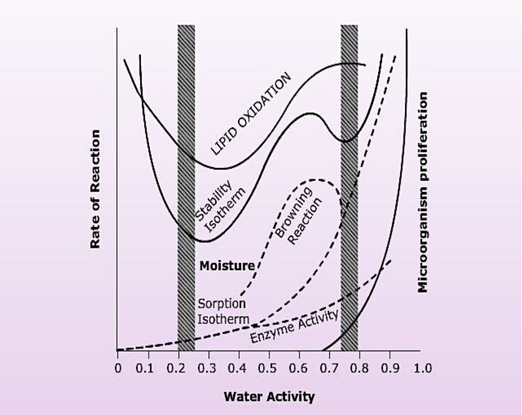
# Relation to Food Stability

- Water activity profoundly influences the rate of microbial growth, enzyme activity, and various chemical reactions in food.
- Optimal storage stability is observed at specific water activity levels.



# Water activity and a number of reaction rates

- Resorption (or adsorption) isotherms are prepared by adding water to previously dried samples.
- Desorption isotherms are isotherms prepared by removing water from samples Isotherms with a



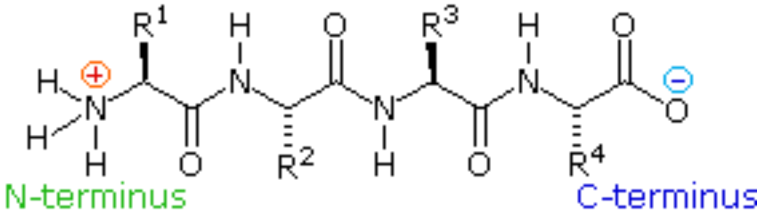
Sigmoidal shape are characteristic of most foods. Foods such as fruits, confections, and coffee extract that contain large amounts of sugar and other small, soluble molecules and are not rich in polymeric materials exhibit a J-type isotherm.

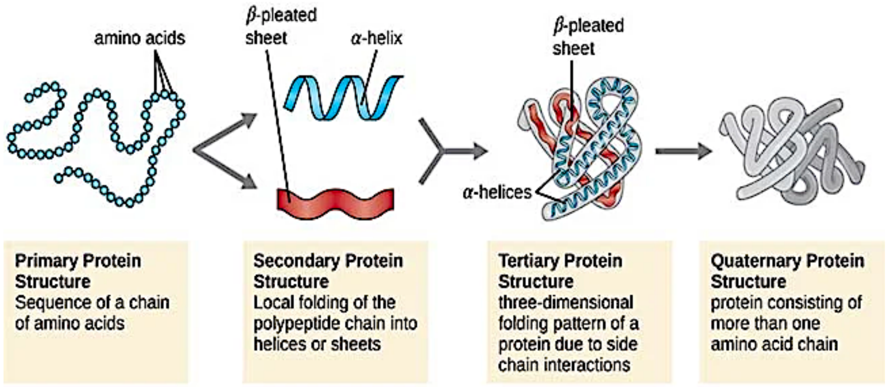
# 1 Food Protein

## 1.1 Classification and Physicochemical Properties of Food Protein

### 1.1.1. Introduction:

Proteins, essential constituents of all living cells, are complex nitrogenous organic compounds made up of amino acids linked together by peptide bonds. The primary structure, determined by amino acid composition, influences the secondary and tertiary structures, which, in turn, impact the functional properties of food proteins during processing.





## 1.1 On the Basis of Composition:

### 1.1.2. Simple Proteins: Consist only of amino acids.

### 1.1.3. Conjugated Proteins: Include amino acids and other compounds.

## 1.2 Classification of Proteins:

Proteins are classified based on composition, shape of molecules, and solubility.

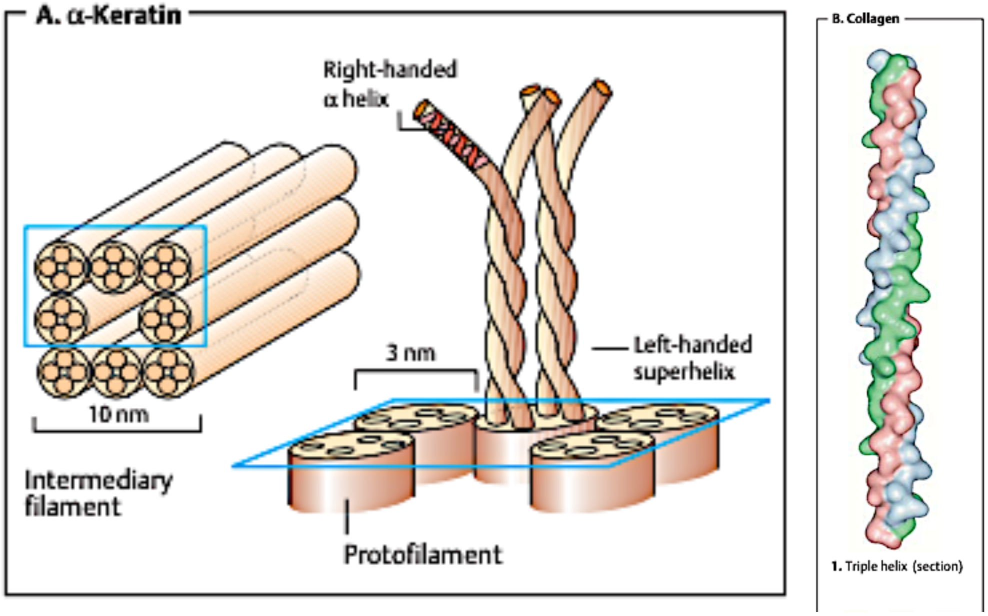
### 1.1.4. Table-4.1: Conjugated proteins

| Sr. No. | Class | Other compound present | Example |
|---|---|---|---|
| 1 | Chromoprotein | Coloured pigment | Haemoglobin |
| 2 | Glycoprotein | Carbohydrate | Mucin (in saliva) |
| 3 | Phosphoprotein | Phosphoric acid | Casein (in milk) |
| 4 | Lipoprotein | Lipid | Lipovitelin (in egg yolk) |
| 5 | Nucleoprotein | Nucleic acid | Viruses |
| 6 | Metalloprotein | Metal | Ciruloplasmin (Cu) |

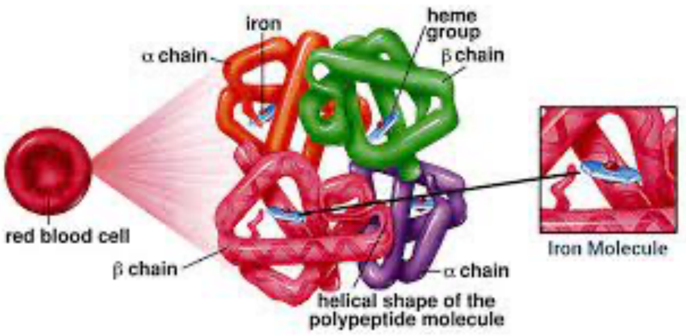
**1.1.5. - Derived Proteins: Result from hydrolytic cleavage of simple or conjugated proteins (e.g., proteoses, peptones, peptides).**

## 1.3 On the Basis of Shape of Molecules:

1. Fibrous Proteins: Long and thread-like, insoluble (e.g., keratin, myosin, collagen).



2. Globular Proteins: Spheroidal in shape, generally soluble (e.g., enzymes, hormones, haemoglobin).



## 1.4 On the Basis of Solubility:

a. **Albumins:** **Soluble in water, dilute salt, acid, and base solutions (e.g., lactalbumin, egg albumin).**

b. **Globulins:** **Insoluble in water but soluble in dilute salt, acid, and base solutions (e.g., serum globulins, β-lactoglobulin).**

c. **Protamine and Histones:** **Highly soluble in distilled water.**

d. **Glutelins:** **Insoluble in water and alcohol but soluble in dilute acid and base solution (e.g., glutenin in wheat).**

e. **Prolamins:** **Insoluble in water but soluble in dilute acid, base, and 70-80% alcohol (e.g., zein in corn, gliadin in wheat).**

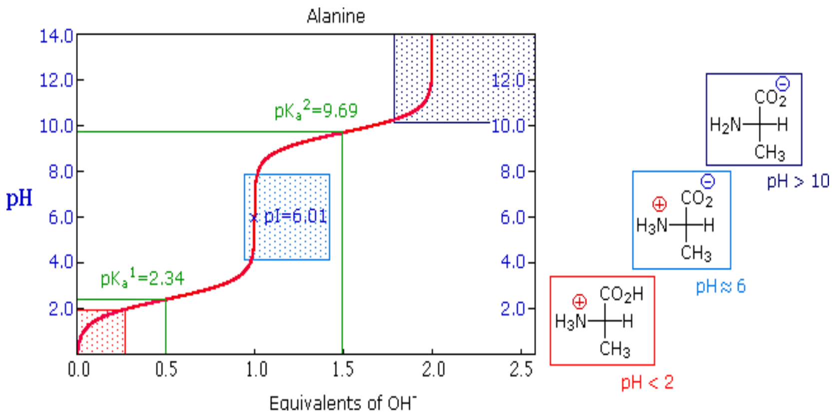
f. **Scleroproteins:** **Insoluble in most solvents, serving structural and binding purposes (e.g., collagen, elastin, keratin).**

## 1.5 Physicochemical Properties of Proteins:

Isoelectric Point:

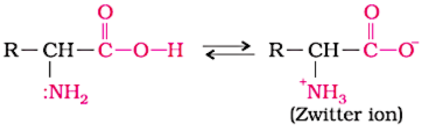
- The pH at which the net charge on the protein is zero.

- Important for protein isolation.



1. Amphoteric Behaviour:

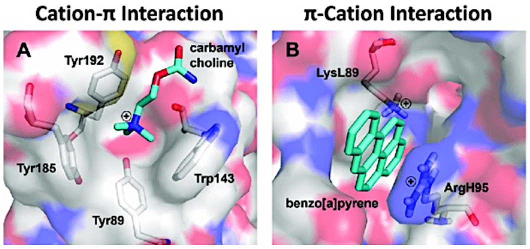
- Proteins act as both acids and bases.
- Buffering capacity varies with pH.



$$R-\underset{\underset{:NH_2}{|}}{CH}-\overset{\overset{O}{\|}}{C}-O-H \rightleftharpoons R-\underset{\underset{^{+}NH_3}{|}}{CH}-\overset{\overset{O}{\|}}{C}-O^{-}$$

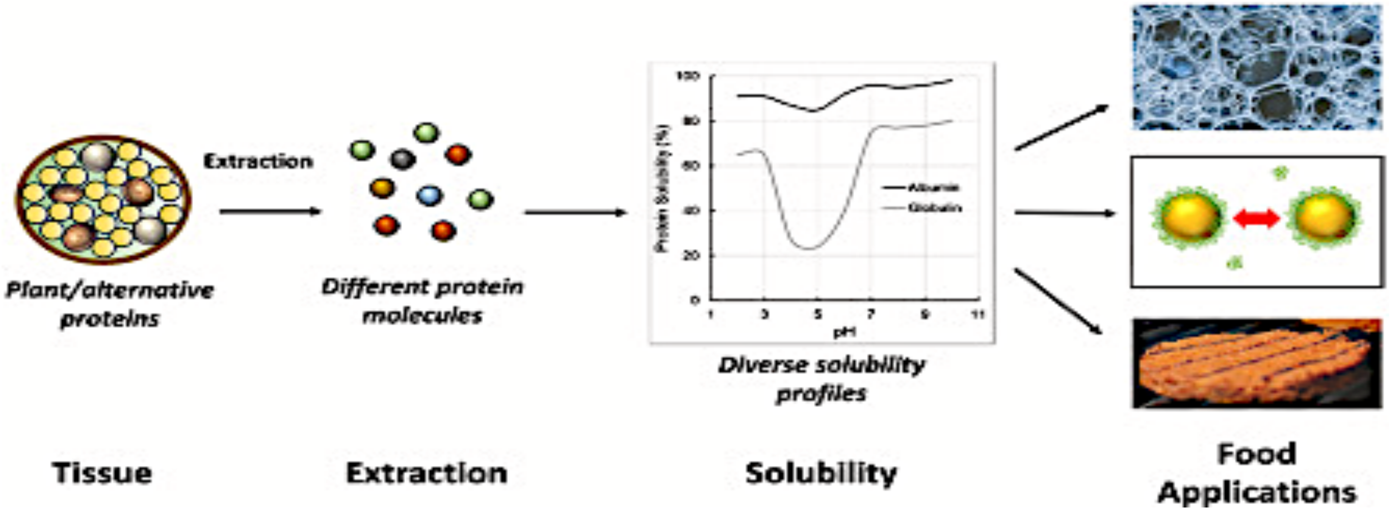
2. Ion Binding:

- Proteins can bind both anions and cations.
- Used to remove proteins from solutions.



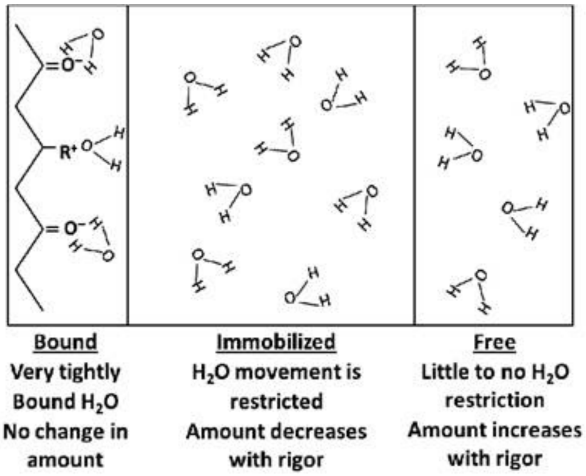
3. Solubility:

- Solubility depends on pH and ionic composition.
- Solubility is minimal at the isoelectric point.
- "Salting-in" and "salting-out" effects observed with salt concentration.



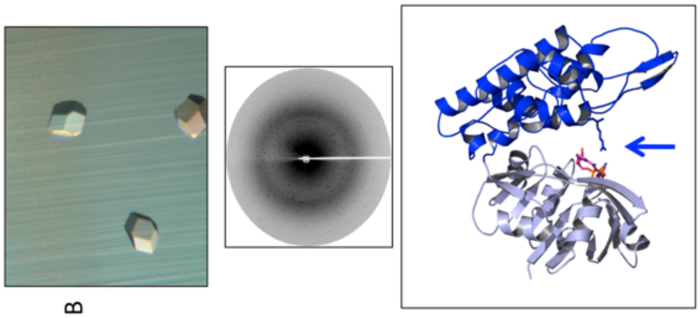
4. Swelling:

- Swelling mechanisms include osmotic and lyotropic swelling.
- Water holding or water binding capacity is associated with protein's ability to immobilize water.

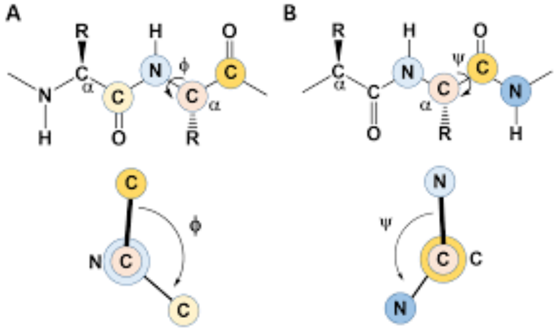


5. Crystallization:

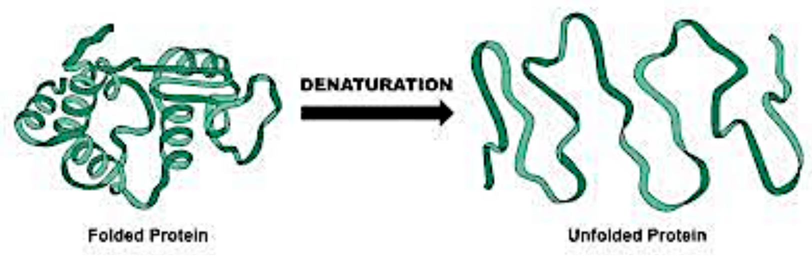
- Proteins can be obtained in crystalline condition.
- Crystallization affected by salt addition and adjustment to isoelectric pH.



6. Optical Activity: Specific rotations of proteins are negative and influenced by various factors.



- Denaturation leads to marked increases in optical rotation.

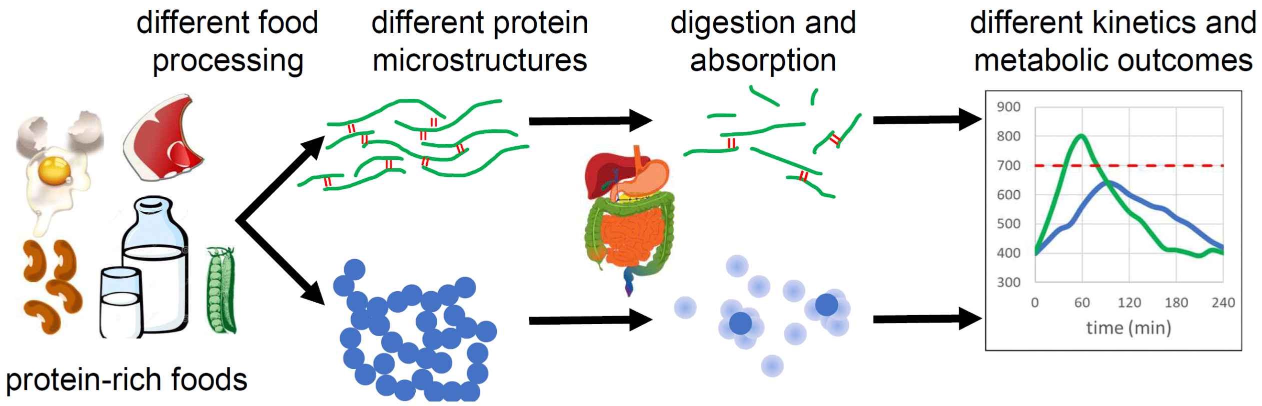


7. Absorption of Ultraviolet Light:

- Protein's absorption of UV light at 280 nm depends on aromatic amino acid content (tyrosine, tryptophan, phenylalanine).

8. Refractive Index:

- Refractive index of protein solutions increases linearly with concentration.
- Specific refractive increment is the difference between protein solution and solvent refractive indices. These physicochemical properties collectively define the behavior and functionality of food proteins in various applications.



## 1.6 Reactions Involved in Processing and Reactions with Alkali

### 1.1.6. Introduction:

Chemical changes in proteins during food processing and storage can be desirable or undesirable. Common treatments include heating, cooling, drying, fermentation, chemical use, and irradiation. Heating, often used to kill pathogens and inactivate enzymes, is the most common. However, it can lead to changes in protein nutritive value, formation of toxic compounds, loss of amino acids, and decreased digestibility.

### 1.1.7. Common Changes in Proteins:

### 1.1.8. Denaturation: Most food proteins are denatured when exposed to moderate heat treatments (60°-90°C/1 h or less).

- Involves transforming folded protein structures to unfolded states without changing the primary structure.

- Benefits include improved digestibility, inactivation of enzymes, and denaturation of anti-nutritional factors and toxins.

- Extensive denaturation may affect solubility and other functional properties.

### 1.1.9. Desulfuration:

- Occurs at high temperatures, leading to irreversible changes and potentially toxic amino acid derivatives.

- Loss of heat-labile amino acids and formation of gases like hydrogen disulphide.

- Sterilization at high temperatures can result in the formation of volatile compounds contributing to flavor.

- One of the first noticeable changes in proteins on heating at around 100°C is loss of heat-labile amino acids such as cysteine, cystine & lysine and the formation of gases like hydrogen disulphide ($H_2S$).

### 1.1.10. Deamidation:

- Takes place at temperatures above 100°C, releasing ammonia.

- Does not impair protein nutritive value but affects isoelectric points and functional properties.

-This reaction takes place during heating of proteins at temperatures above 100°C. The ammonia released comes mainly from the amide groups of glutamine and asparagine, and these reactions do not impair the nutritive value of the proteins.

### 1.1.11. Racemization:

- it is the chemical reaction that interconverts an amino acid into its alternative enantiomer or mirror-image form

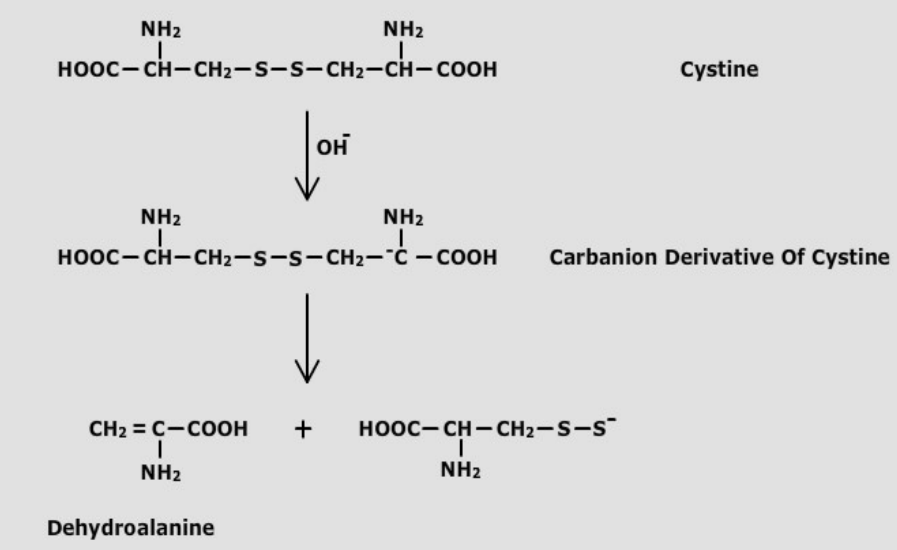
Heat treatment at high temperatures or alkaline pH leads to partial racemization of L-amino acid residues to D-amino acid residues.

- Reduces nutritional value and digestibility due to less efficient hydrolysis.

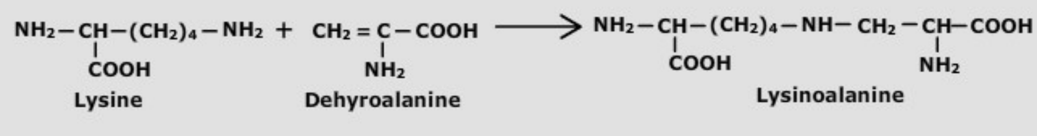
-Severe heat treatment at temperatures above 200ºC as well as heat treatment at alkaline pH (e.g. in texturized foods) invariably leads to partial racemization of L-amino acid residues to D-amino acid residues.

### 1.1.12. Effect of Heat Treatment at Alkaline pH:

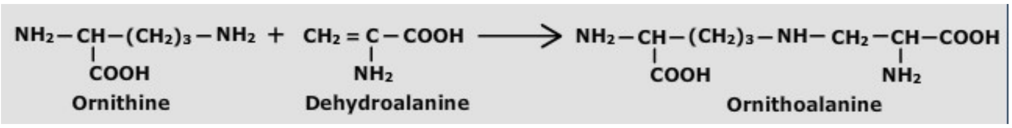
- Alkali treatment causes undesirable reactions, including β-elimination reactions.
- Results in the formation of cross-links (e.g., lysinoalanine) that decrease digestibility and biological value.
- pH, temperature, ionic strength, and protein nature affect these reactions.



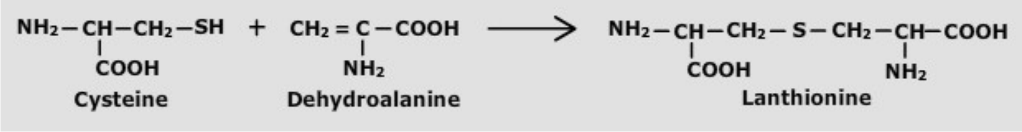
Formation of Dehydroalanine



Formation of Lysinoalanine



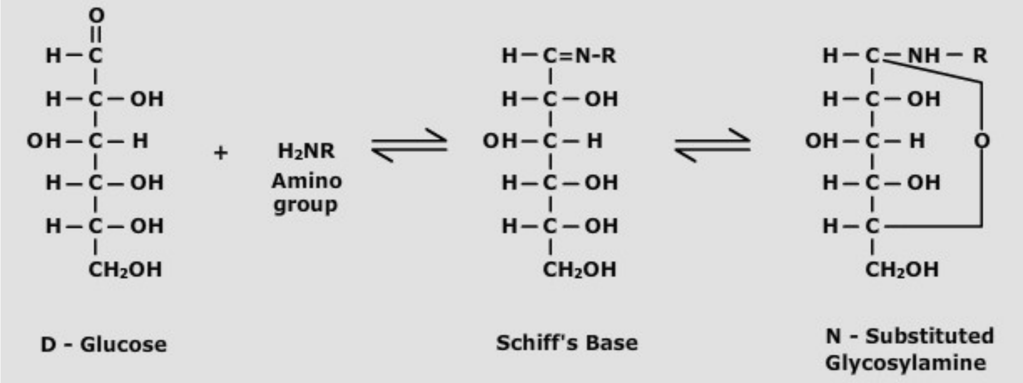
Formation of Ornithoalanine



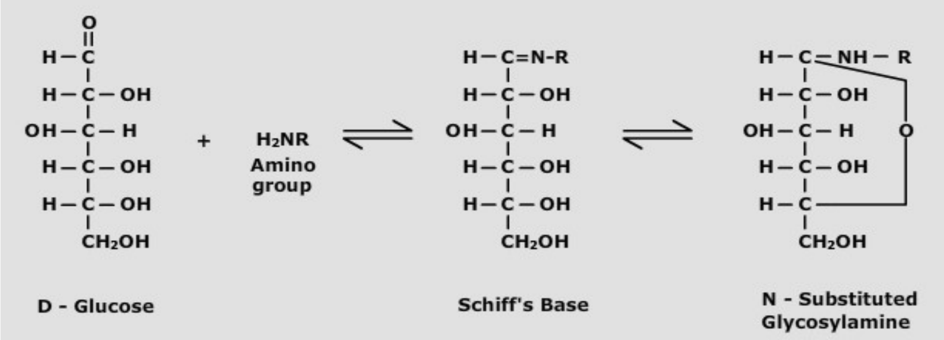
Formation of Lanthionine

### 1.1.13. Maillard Reaction (Interaction with Carbohydrates/Aldehydes):

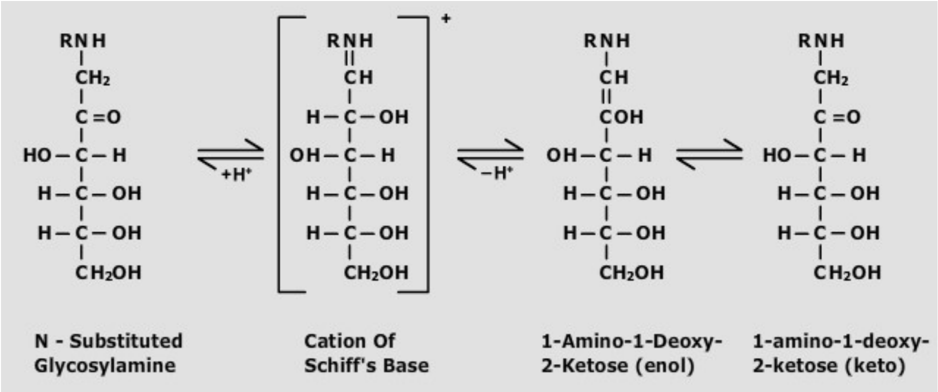
- Complex reactions initiated by the reaction between amines and carbonyl compounds, leading to nonenzymic browning.
- Proteins and amino acids provide the amino component, while reducing sugars and carbonyl compounds provide the carbonyl component.
- Significance in food processing includes color and flavor production, antioxidant properties, and nutritional implications.



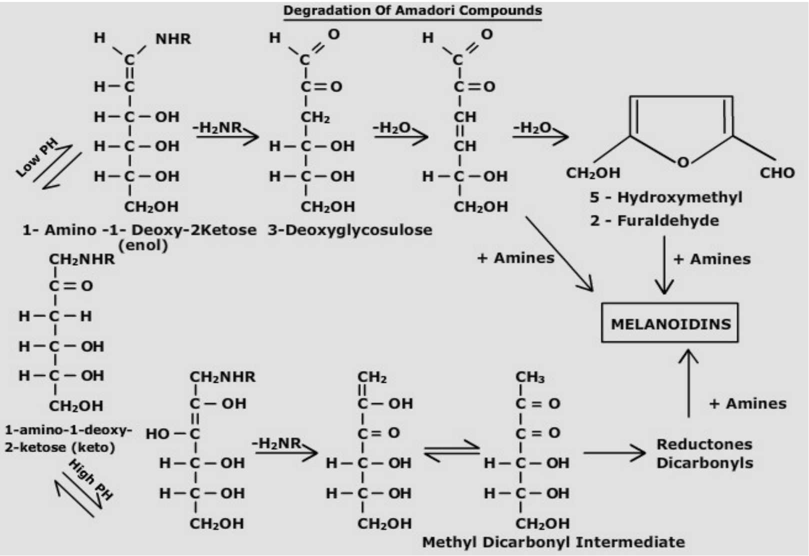
Sugar Amine Condensation



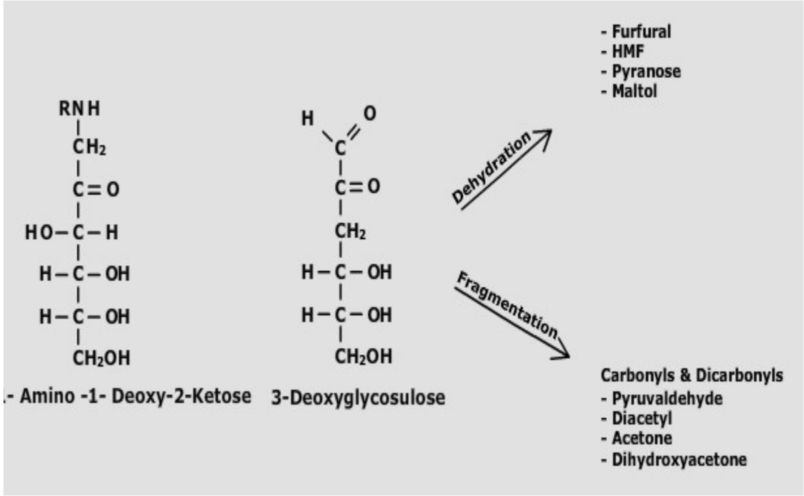
Sugar Amine Condensation)



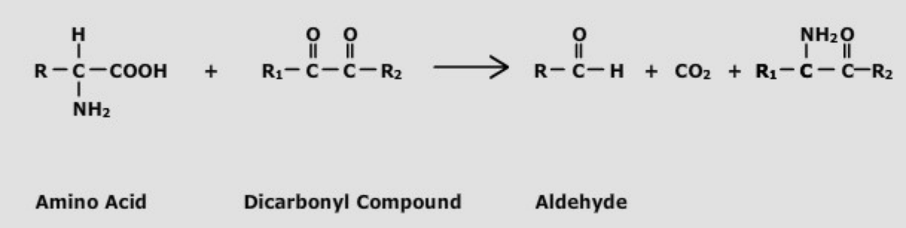
Amadori Rearrangement



Degradation of Amadori Compounds



Dehydration and Fragmentation)



Strecker Degradation of Amino Acids)

### 1.1.14. Significance of the Maillard Reaction:

1. Production of Color:

   - Desirable in certain foods (e.g., coffee, chocolate) but undesirable in milk products.

2. Production of Flavor:

   - Formation of volatile products contributes to flavor.

3. Antioxidant Properties:

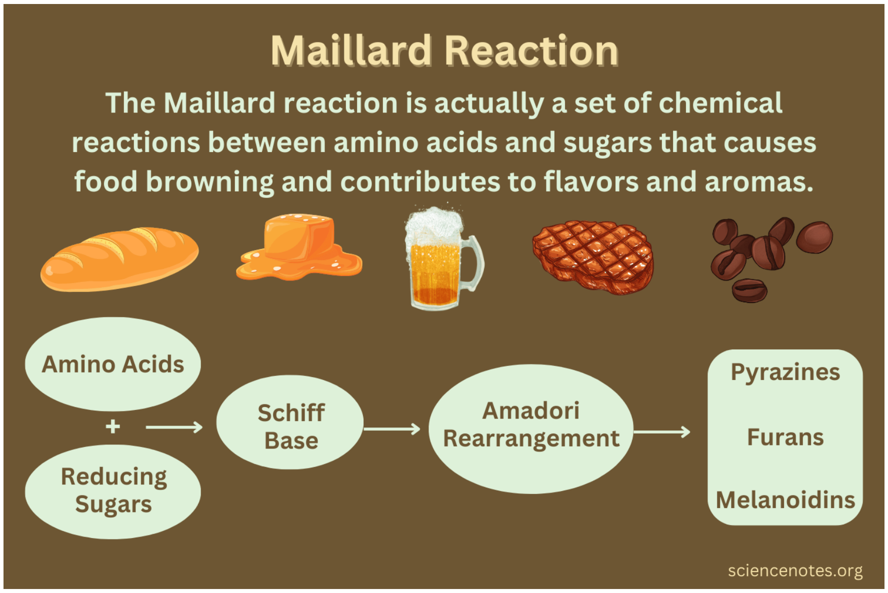
   - Maillard reaction products may have antioxidant properties.

4. Toxicity:

   - Formation of potentially carcinogenic compounds.

5. Nutritional Implications:

   - Reduction in nutritive value, loss of essential amino acids, inhibition of enzymes, and disturbed amino acid utilization.


Maillard Reaction

The Maillard reaction is actually a set of chemical reactions between amino acids and sugars that causes food browning and contributes to flavors and aromas.

### 1.1.15. Oxidation of Amino Acids:

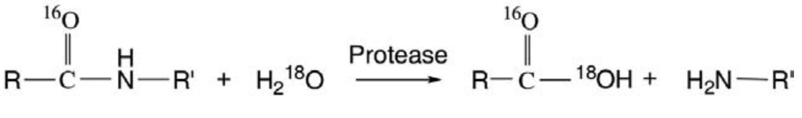
- Methionine is oxidized to methionine sulfoxide under various peroxides.
- Strong oxidizing conditions can further oxidize methionine sulfoxide to methionine sulfone or homocysteic acid.

These reactions highlight the complexity of protein changes during food processing and the impact on nutritional quality.

## 1.7 Enzyme Catalysed Reactions Involving Hydrolysis and Proteolysis

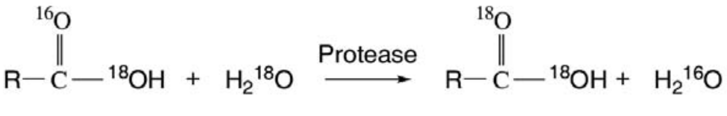
### 1.1.16. Introduction

Proteolysis processes are crucial in food production, driven by proteolytic enzymes from either the food itself or microbial sources. This group of enzymes is categorized into peptidases (exopeptidases) and proteinases (endopeptidases). Peptidases cleave amino acids or dipeptides stepwise from the terminal end of proteins, while proteinases hydrolyze peptide chain linkages without affecting terminal peptide bonds.



$$R-\overset{{}^{16}O}{\overset{\|}{C}}-\overset{H}{N}-R' + H_2{}^{18}O \xrightarrow{\text{Protease}} R-\overset{{}^{16}O}{\overset{\|}{C}}-{}^{18}OH + H_2N-R'$$

(peptide bond hydrolysis reaction)



$$R-\overset{{}^{16}O}{\overset{\|}{C}}-{}^{18}OH + H_2{}^{18}O \xrightarrow{\text{Protease}} R-\overset{{}^{18}O}{\overset{\|}{C}}-{}^{18}OH + H_2{}^{16}O$$

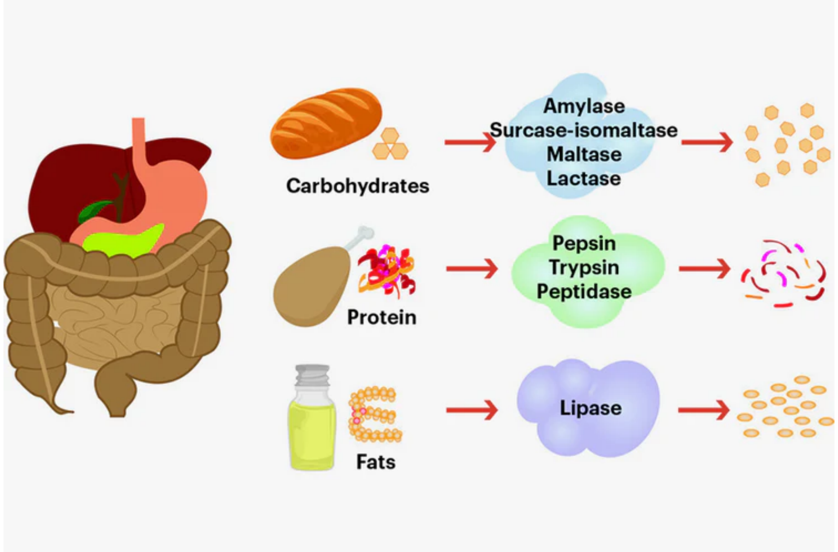
(carboxyl oxygen exchange reaction)

### 1.1.17. Types of Proteolytic Enzymes

Proteolytic enzymes are classified into acid proteases (e.g., pepsin, rennin), serine proteases (e.g., chymotrypsin, trypsin), sulfhydryl proteases (e.g., papain, ficin, bromelain), and metal-containing proteases (e.g., amino peptidases, carboxypeptidases). Each group has distinct properties and functions.

- Acid Proteases: Operate optimally at low pH, e.g., chymosin in cheese making.

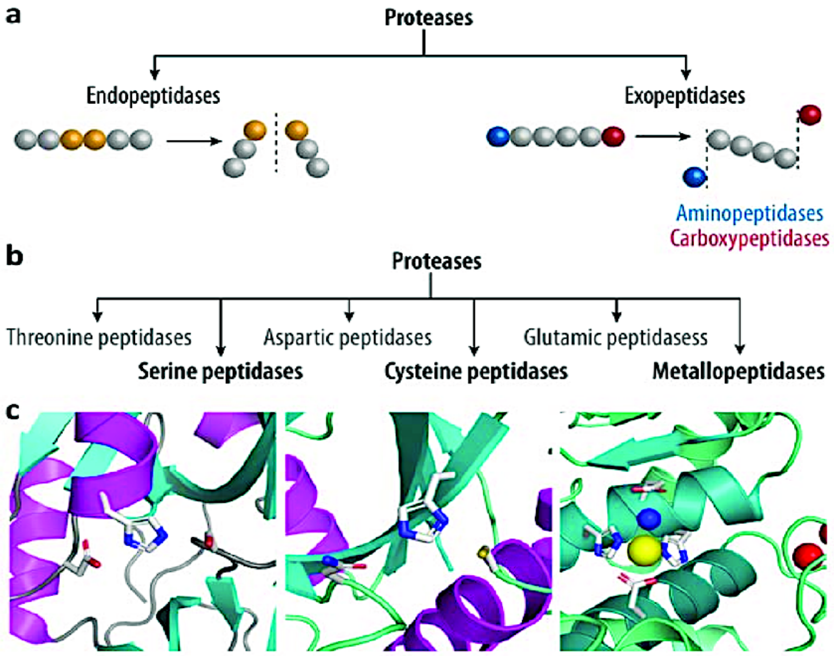
- Serine Proteases: Contain serine and histidine residues in their active sites, found in pancreatic enzymes like chymotrypsin and trypsin.
- Sulfhydryl Proteases: Derived from plants, require sulfhydryl groups (–SH) for activity, preventing haze formation in beer.
- Metal Containing Proteases: Exopeptidases requiring metals like zinc, involved in amino acid removal from peptide chains.



### 1.1.18. Application of Proteolytic Enzymes in Foods

Proteolytic enzymes find applications in various food processes:

1. Enzymatic modification of proteins to create a variety of proteins.
2. Enhancement of functional properties of proteins.
3. Solubilization of denatured proteins.
4. Maintenance of protein solubility in acidic media.
5. Increased digestibility.
6. Decomposition of proteins with undesirable properties.


a
Proteases
Endopeptidases
Exopeptidases
Aminopeptidases
Carboxypeptidases
b
Proteases
Threonine peptidases
Serine peptidases
Aspartic peptidases
Cysteine peptidases
Glutamic peptidasess
Metallopeptidases
c

## 1.8 Food Proteins

Theories of Formation of Texturized Proteins

### 1.1.19. Introduction

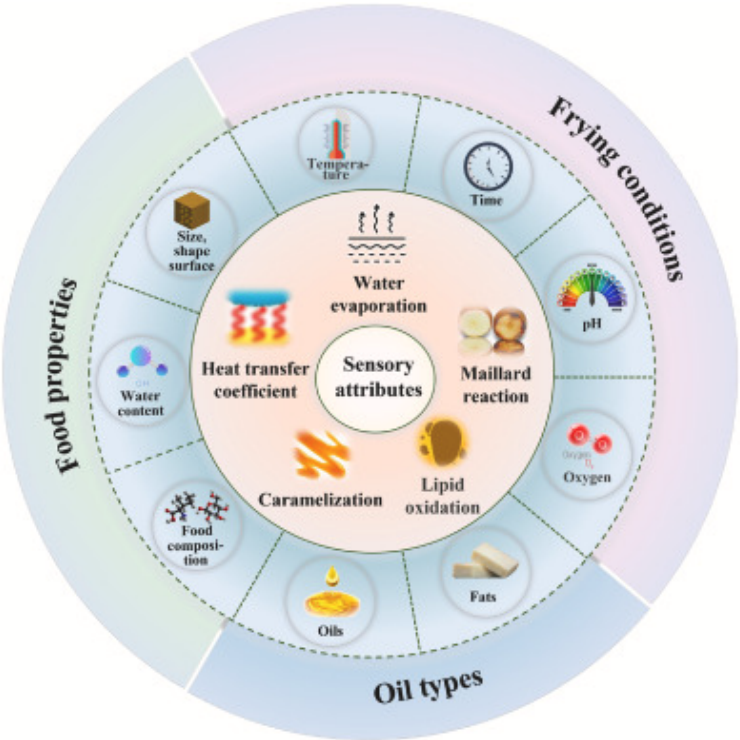
Texturization in plant proteins involves creating a structure resembling meat for improved sensory experience. Meat texture includes visual aspects, chewiness, elasticity, tenderness, and juiciness, primarily influenced by muscle fibers and connective tissue. Plant proteins, usually globular, can be texturized for use as meat substitutes or extenders.

### 1.1.20. Process of Texturization

Texturization methods include spinning processes and thermoplastic extrusion:

- Spin Process/Fiber Spinning: Involves protein solution preparation, streaming orientation, coagulation, stretching, compression, and additional treatments.

- Extrusion Method/Thermoplastic Extrusion: Utilizes high pressure and temperature to transform proteins into fibrous, porous granules with chewy texture upon rehydration.



## 1.9 Food Lipids

### 1.1.21. Edible Fats and Oils - Classification and Chemical Composition

### 1.1.22. Introduction

Lipids encompass fats, waxes, sterols, fat-soluble vitamins, triglycerides, diglycerides, monoglycerides, phospholipids, and more. They provide energy, essential fatty acids, and fat-soluble vitamins, influencing nutrition and physiological functions.

### 1.1.23. Classification of Lipids

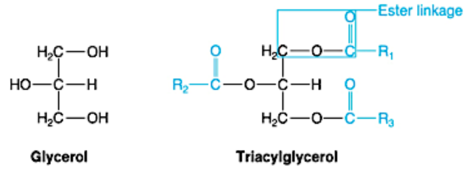
Based on structure, lipids are categorized as simple, compound, and derived. They are also classified by polarity (polar and non-polar) and saponification ability (saponifiable and unsaponifiable).

### 1.1.24. Traditional Classification of Edible Fats/Oils

Classified by source and constituent fatty acids, including milk fat, lauryl acid fat, vegetable butters, oleic-linoleic acid fats, linolenic acid fats, animal body fats, and marine oils.

### 1.1.25. Chemical Composition

Provides the gross chemical composition of fats from various species, outlining the percentage composition of triacylglycerols, diacylglycerols, monoacylglycerols, cholesterol, cholesterol esters, phospholipids, and free fatty acids.



### 1.1.26. Unsaponifiable Matter of Various Fats and Oils

Describes the unsaponifiable fraction of fats, including hydrocarbons, sterols, tocopherols, tocotrienols, and carotenoids.

Table 8.2 details the composition of unsaponifiable matter in different fats and oils.

| Fats/Oils | Hydrocarbons | Squalene | Aliphatic Alcohols | Terpenic Alcohols | Sterols |
|---|---|---|---|---|---|
| Olive | 2.8-3.5 | 32-50 | 0.5 | 20-26 | 20-30 |
| Linseed | 3.7-14.0 | 1.0-3.9 | 2.5-5.9 | 29-30 | 34.5-52 |
| Teaseed | 3.4 | 2.6 | - | - | 22.7 |
| Soybean | 3.8 | 2.5 | 4.9 | 23.2 | 58.4 |
| Rapeseed | 8.7 | 4.3 | 7.2 | 9.2 | 63.6 |
| Corn | 1.4 | 2.2 | 5.0 | 6.7 | 81.3 |
| Lard | 23.8 | 4.6 | 2.1 | 7.1 | 47.0 |
| Tallow | 11.8 | 1.2 | 2.4 | 5.5 | 64.0 |

## 1.10 Reactions Involved During Deep Frying of Food

### 1.1.27. Introduction:

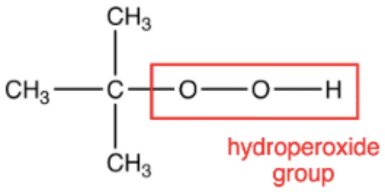
- Deep frying is a common food preparation method used in homes and industries.
- Food items like potato chips, meat, and fish are fried in fat/oil at around 180°C.
- Prolonged heating at high temperatures causes significant changes in the chemical and physical properties of the fat/oil.
- Changes in the frying medium affect both the quality of the fat/oil and the finished foods.

### 1.1.28. Behavior of Frying Oil:

Various compounds are produced from oil during deep fat frying.

### 1.1.29. Volatiles:

Formed through oxidative reactions, including hydroperoxides, leading to aldehydes, ketones, hydrocarbons, lactones, alcohols, acids, and esters.



#### 1.1.30. Nonpolymeric Polar Compounds:

Includes hydroxyl and epoxy acids produced through oxidative pathways.

#### 1.1.31. Dimeric and Polymeric Acids and Glycerides:

Result from thermal and oxidative free radicals, leading to an increase in viscosity.

#### 1.1.32. Free Fatty Acids:

Arise from hydrolysis of triacylglycerol, causing changes in viscosity, color, flavor, and other properties.

#### 1.1.33. Behavior of Food During Frying:

Water release from food into hot oil leads to steam distillation effect, agitating the oil and hastening hydrolysis.

### 1.11 Changes in Frying Medium:

- Hydrolysis, oxidation, and polymerization are key chemical reactions during deep fat frying.
- Factors influencing breakdown components include temperature, method of heat transfer, presence of O2, metals in contact with oil, heating time, turnover, frying capacity, and nature of food being fried.

### 1.12 Oxidation and Decomposition:

- Release of moisture, high temperature, and exposure to O2 favor the oxidation of frying medium.
- Autoxidation of unsaturated fatty acids leads to the formation of volatile compounds, contributing to flavor changes.

### 1.13 Thermal Oxidation:

- Occurs when oil is heated at high temperature in the presence of O2.

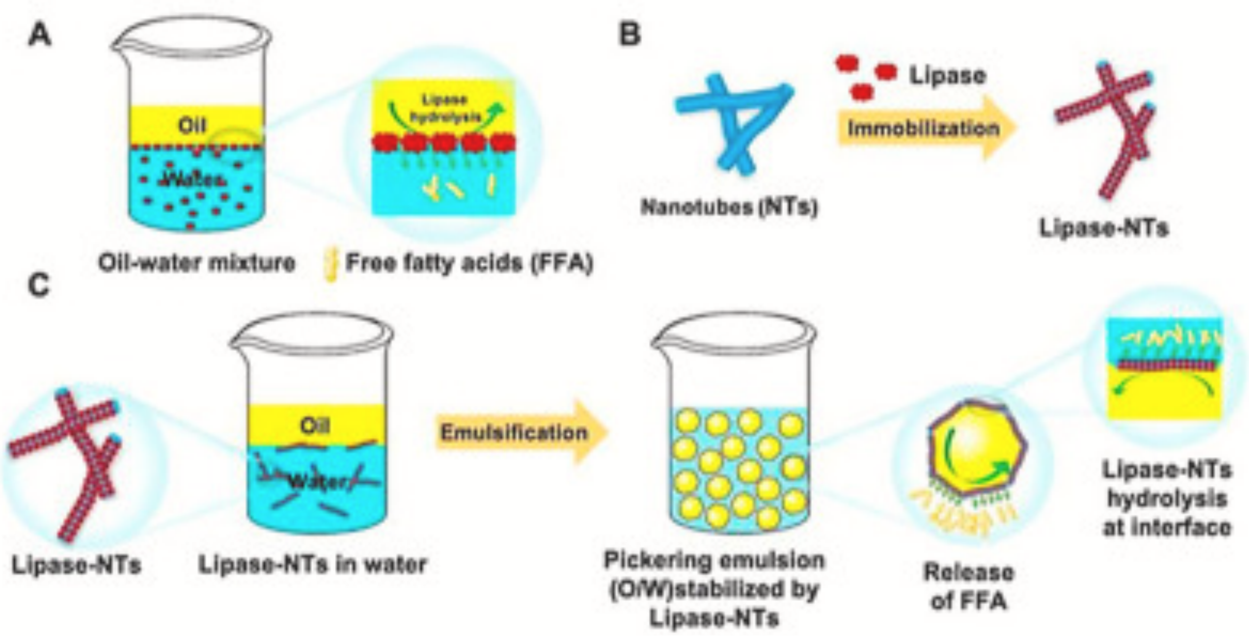
- Results in the formation of free fatty acids, hydroperoxides, aldehydes, acids, ketones, and various oxidative products.

### 1.14 Polymerization:

- Oxidation and thermal alteration products undergo polymerization, forming gums and residues.
- Polymerization leads to changes in molecular weight, viscosity, heat transfer rate, foaming, color darkening, and gum accumulation.

### 1.15 Hydrolysis:

- Continuous release of moisture from food leads to the hydrolysis of fat.
- Accumulation of free fatty acids (FFAs) causes changes in acidity, viscosity, color, and other properties of the frying medium.



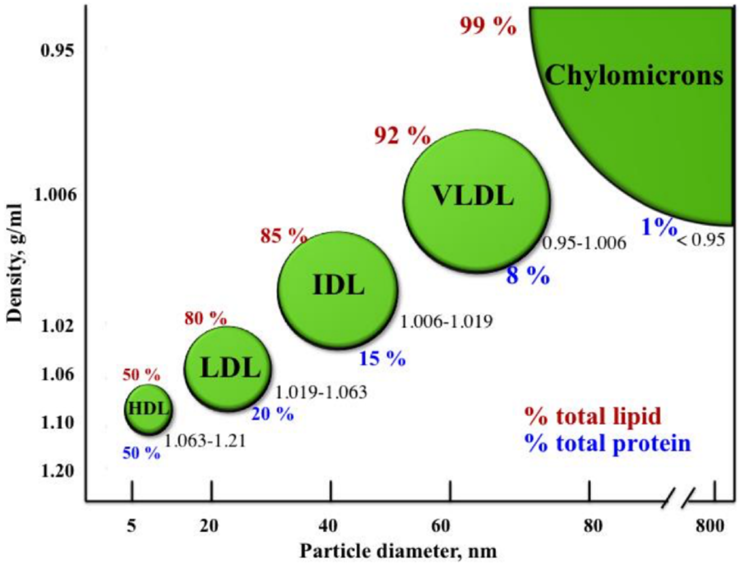
## 1.16 Lipoprotein – Definition, Classification, and Involvement in the Formation of Biological Membranes

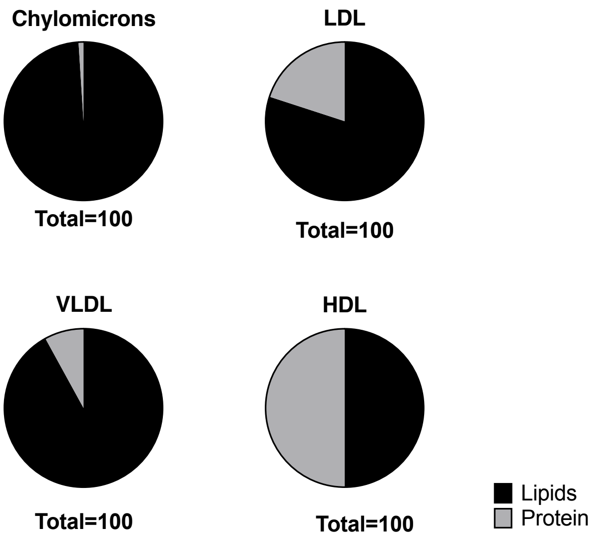
### 1.1.34. Introduction:

- Lipoproteins are aggregates of proteins, polar lipids, and triacylglycerols, water-soluble and separable into protein and lipid moieties.

- Stabilized by hydrophobic interactions and ionic forces, held together by non-covalent bonds.

### How much protein and lipid are in each?



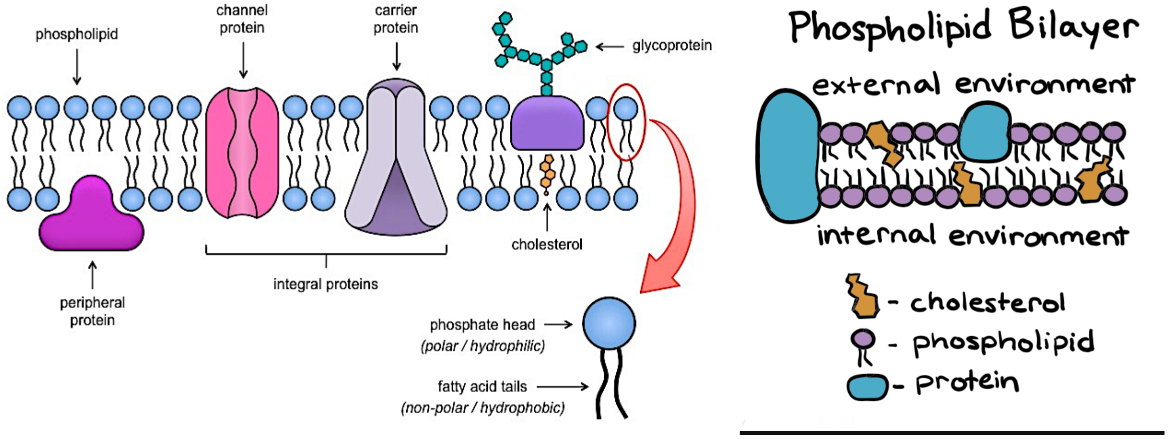


### 1.1.35. Classification:

- Exist as globular particles in an aqueous medium, characterized by ultracentrifugation.
- Blood plasma lipoproteins include VLDL, LDL, and HDL with different densities.
- Chylomicrons transport triacylglycerols; LDL is denoted as β-lipoprotein, and HDL as α-lipoprotein.

### 1.1.36. Involvement in the Formation of Biological Membranes:

- Membranes are formed from proteins and lipids, with glycerophospholipids as the main structural component.
- Glycerophospholipids are amphipathic molecules, forming bilayers in water.
- Model membranes are formed through hydrophobic interactions, leading to bilayer arrangements or globular micelles.
- Integral membrane proteins interact with lipid acyl tails and contribute to the fluid mosaic model.



**Structure of the Plasma Membrane (Fluid-Mosaic)**

# 2 Food Carbohydrates

## 2.1 Polysaccharide - Linear, Branched, and Modified

### 2.1.1 Introduction

Carbohydrates, one of nature's three most abundant classes of organic compounds, along with fats and proteins, are substances composed of carbon, hydrogen, and oxygen. Carbohydrates are broadly categorized into monosaccharides, oligosaccharides, and polysaccharides. Monosaccharides are the building blocks of more complex carbohydrates, while oligosaccharides include low molecular weight polymers like disaccharides and trisaccharides. Polysaccharides, the focus of this lesson, contain more than 10 monosaccharide units.

### 2.1.2 Classification of Carbohydrates

I. Monosaccharides
  1. Trioses (e.g., glyceraldehydes, dihydroxy acetone)
  2. Tetroses (e.g., erythrose, threose)
  3. Pentoses (e.g., arabinose, xylose, ribose, deoxyribose)
  4. Hexoses (e.g., glucose, galactose, fructose, mannose)

II. Oligosaccharides
  1. Disaccharides (e.g., sucrose, lactose, maltose)
  2. Trisaccharides (e.g., raffinose)
  3. Tetrasaccharides (e.g., Stachyose)

III. Polysaccharides
  1. Pentosans (e.g., araban, xylan)
  2. Hexosans (e.g., starch, glycogen, cellulose, mannan, gallactan)
  3. Complex polysaccharides (e.g., hemicelluloses, gums, pectins).

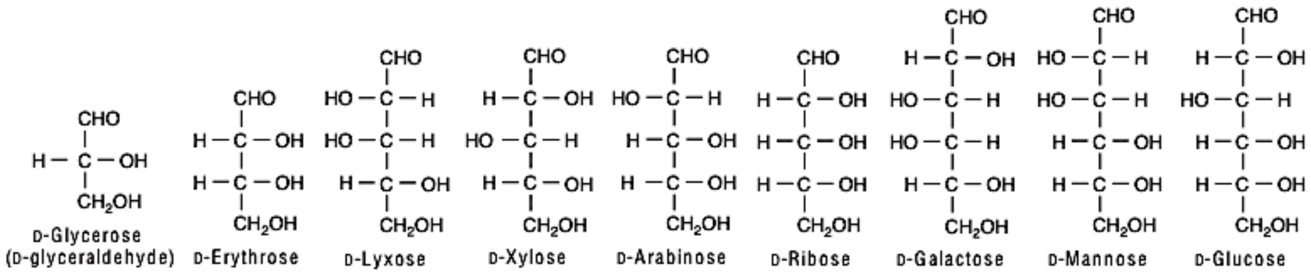


**FIGURE 14–6** Examples of aldoses of physiologic significance.

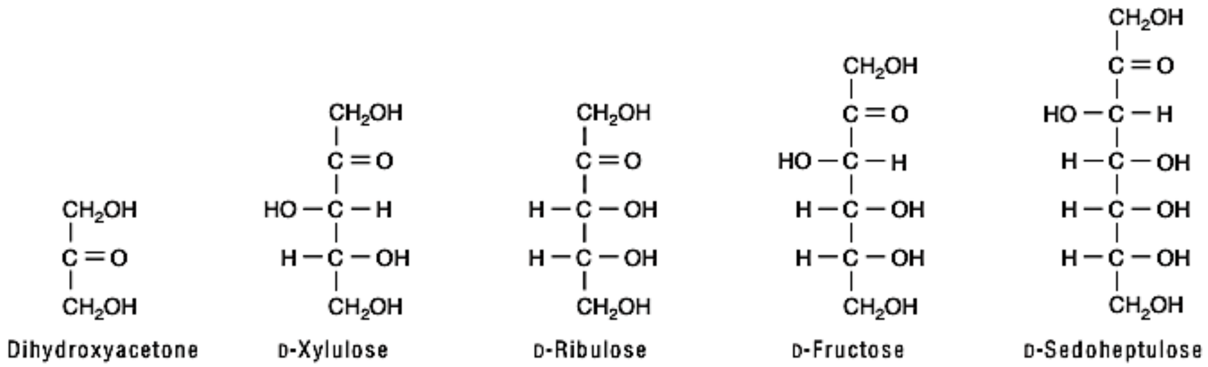


**FIGURE 14–7** Examples of ketoses of physiologic significance.

### 2.1.3 Polysaccharides

Polysaccharides consist of more than 10 monosaccharide units and can be hydrolyzed into hundreds or thousands of monosaccharide units. The suffix "-ose" in sugar changes to "-ans" to describe corresponding polysaccharides.

Examples:

1. Pentosans
   a. Arabans
   b. Xylans
2. Hexosans
   a. Glucans (starch, dextrin, glycogen, cellulose, inulin)
   b. Mannans
   c. Galactans
3. Complex polysaccharides

a. Pectins or pectic substances

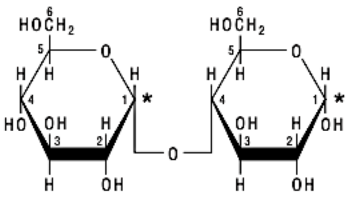
b. Gums

c. Mucilages

d. Algal polysaccharides (Alginic acid, carrageenan)

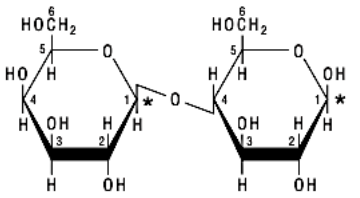
e. Bacterial polysaccharides (Xanthan gum)

Maltose



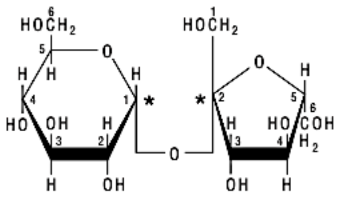
O-α-D-glucopyranosyl-(1 → 4)-α-D-glucopyranose

Lactose



O-β-D-Galactopyranosyl-(1 → 4)-β-D-glucopyranose

Sucrose



O-α-D-Glucopyranosyl-(1 → 2)-β-D-fructofuranoside

### 2.1.4 Classification of Polysaccharides

Polysaccharides can be broadly classified into homopolysaccharides and heteropolysaccharides.

1. Homopolysaccharides

- Contain the same structural units throughout.
- Examples: Glucans (starch, glycogen), fructans, mannans.

a. Perfectly linear polysaccharides
  - Insoluble in water, prone to retrogradation.

b. Branched polysaccharides
  - More soluble in water, lower viscosity.
  - Suitable as binders or adhesives.

c. Linearly branched polysaccharides
  - Combines properties of perfect linear and branched polymers.

- Modified Polysaccharides: Properties can be modified for specific purposes in the food industry through physical and chemical methods.

2. Heteropolysaccharides

- Contain two or more types of different monomer units.
- Examples: Arabinoxylans, glucomannans.

Table-Homopolysaccharides occurring or used in foodstuffs

(Type, Linkage, Structure, Polysaccharide, Occurrence)

| Type | Linkage | Structure | Polysaccharide | Occurrence |
|---|---|---|---|---|
| Glucans | α, 1 → 4 | Linear | amylose | Starchy material |
| | α, 1 → 4 α, 1 → 6 | Branched | amylopectin | Starchy material |
| | α, 1 → 4 α, 1 → 6 | Branched | glycogen | Animal liver |
| | β, 1→ 4 | Linear | Cellulose | Cell walls of all plants |
| | β, 1→ 3 β, 1→ 4 | Linear | β - glucan | Cereal grains |
| | | | | (oats, barley) |
| Fructans | β, 2→ 6 β, 2→ 1 | Branched | Fructans | Various plants (wheat endosperm) |
| | β, 2→ 1 | Linear | Inulin | Jerusalem artichokes |
| Arabinans | α, 1 → 3 α, 1 → 5 | Branched | Pectic substances | Sugar beet, citrus pectins |
| Xylans | β, 1→ 4 | Linear | Xylans | Cell walls of plants |

Table-Heteropolysaccharides occurring or used in foodstuff

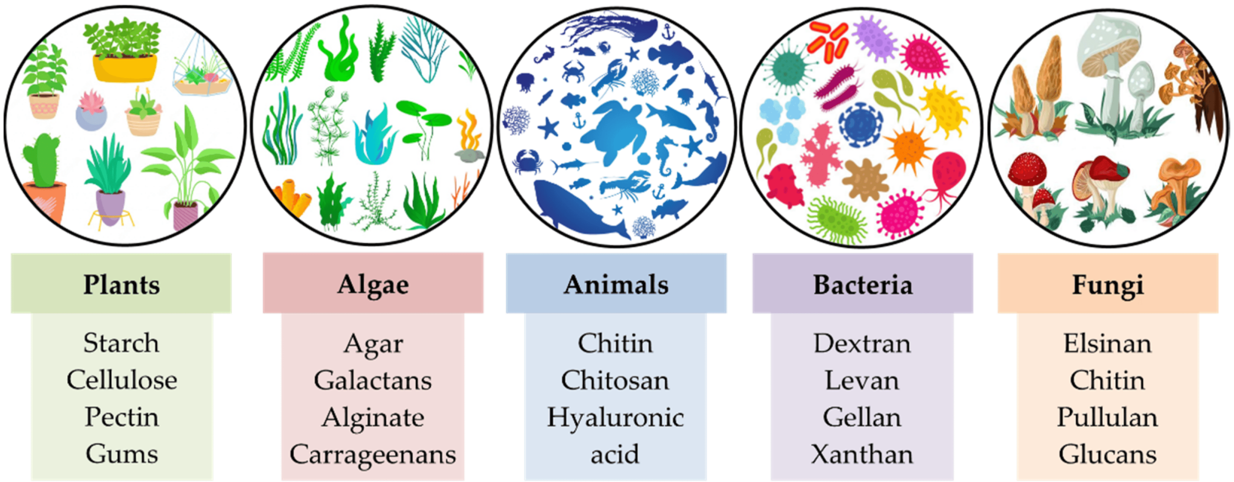
(Units, Structure, Polysaccharide, Occurrence)

| Units | Structure | Polysaccharide | Occurrence |
|---|---|---|---|
| Ara; Xyl | Branched | Arabinoxylans | Plant cell walls (wheat flour) |
| Glu A; Xyl | Branched | Glucuronoxylans | Plant cell walls |
| Glu; Man | Linear | Glucomannans | Seeds |
| Glu A ; Man A | Linear | Alginic acid | Brown seaweeds |
| Gal; Man | Branched | Guar/carbo gum | Leguminous seeds |
| Anhydro Gal; Gal sulphate | Linear | carrageenan | Brown seaweeds |
| Gal A; Rha | Linear | Pectic materials | All plant material |
| Ara; Rha; Gal; Glu A; Glu | Branched | Gum arabic | Trees (Acacia spp.) |
| Gal A; Xyl; Gal; Fuc | Branched | Gum tragacanth | Trees (Astragalu spp.) |

## 2.2 Properties and Utilization of Common Polysaccharides – Cellulose, Glycogen, Hemicellulose, Pectin, Agar, Alginate, Carrageenan, Gums, and Starch

### 2.2.1 Introduction

Polysaccharides, containing more than 10 monosaccharide units, are prevalent in food, including starch, glycogen, cellulose, hemicellulose, pectic substances, gums.

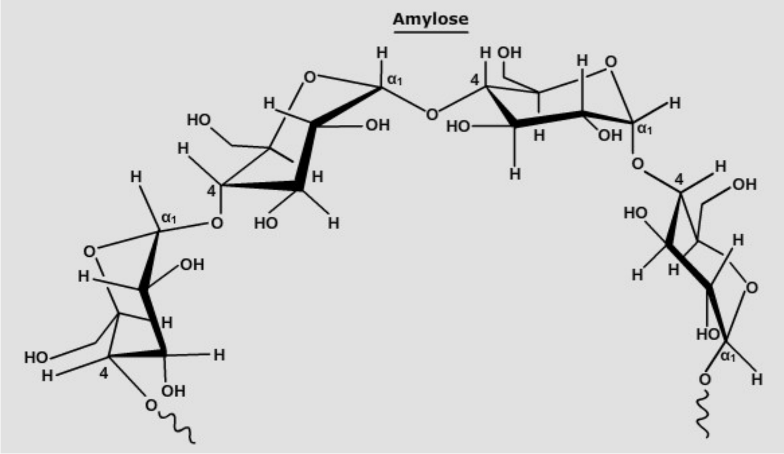


### 2.2.2 Starch

Starch, a natural polymer of D-glucose, is widespread in the plant kingdom, providing a significant portion of the world's food energy. It consists of microscopically small granules with distinct crystalline structures. Starch includes linear amylose and branched amylopectin.

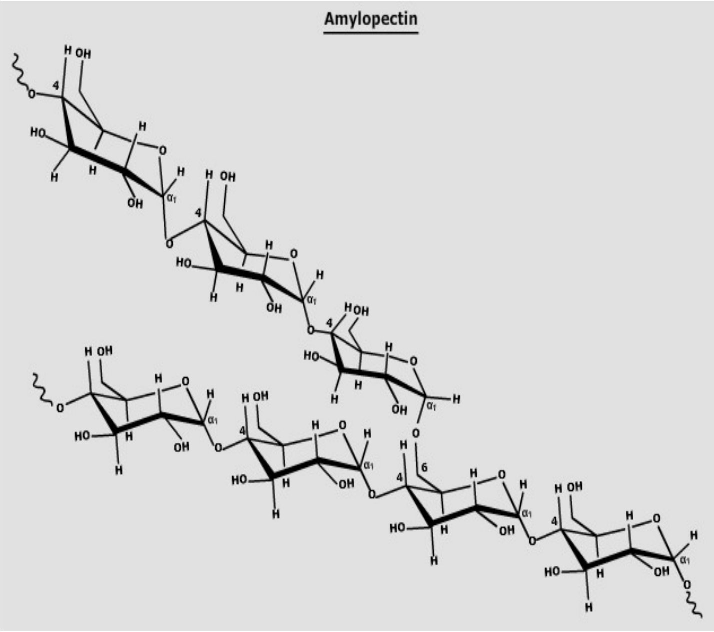
### 2.2.3 Amylose

- Long unbranched chain of D-glucose molecules linked by α-1,4 linkage.
- Molecular weight ranges from 105 to 106 daltons.
- Contributes to the stiffening of cooked rice.



### 2.2.4 Amylopectin

- Branched chain polysaccharide with short chains of D-glucose linked by α-1,4 linkages.
- Branches connected by α-1,6 linkages.
- Molecular weight ranges from 107 to 108 daltons.
- Gives a purple color with iodine.



### 2.2.5 Gelatinization of Starch

- Process breaking down intermolecular bonds of starch molecules in the presence of water and heat.

- Irreversibly dissolves starch granules, leading to a gel-like structure.

### 2.2.6 Retrogradation of Starch

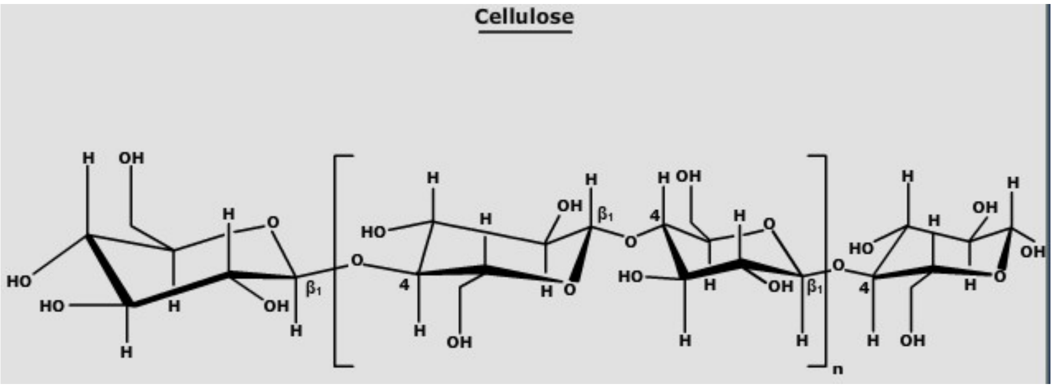
- Precipitation of starch molecules in dilute solutions, making them less soluble.
- Amylose retrogrades more rapidly than amylopectin.
- Bread staling is attributed to starch retrogradation.

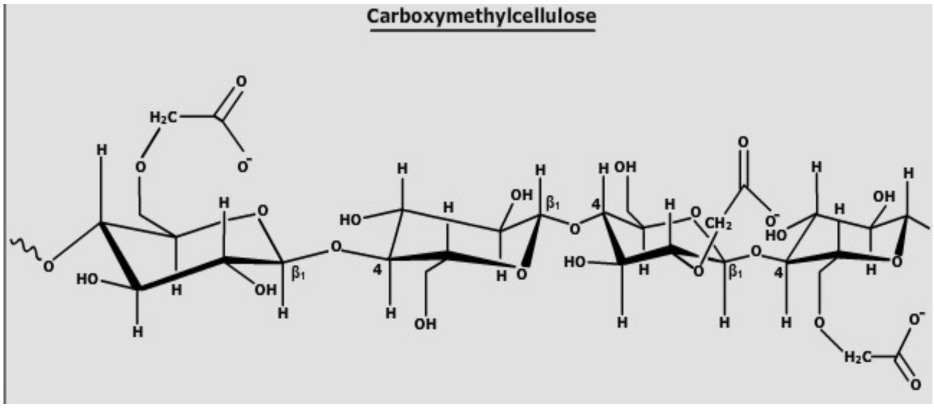
### 2.2.7 Modified Starches

- Modified starches with improved stability characteristics have been developed.
- Types include acid-modified, pre-gelatinized, cross-linked, esters & ethers, starch phosphates, hydroxyalkyl substituted starch.

### 2.2.8 Cellulose

- Abundant linear polymer of D-glucose units linked in β-configuration.
- Forms a rigid and straight chain due to β-linkages.
- Insoluble in water, unaffected by cooking processes.





### 2.2.9 Glycogen

- Reserve carbohydrate found in animal bodies, especially in muscles and liver.

- Branched chain polysaccharide resembling amylopectin.

### 2.2.10 Hemicellulose

- Structural component of plant cell walls.

- Water-insoluble, non-starchy polysaccharides.

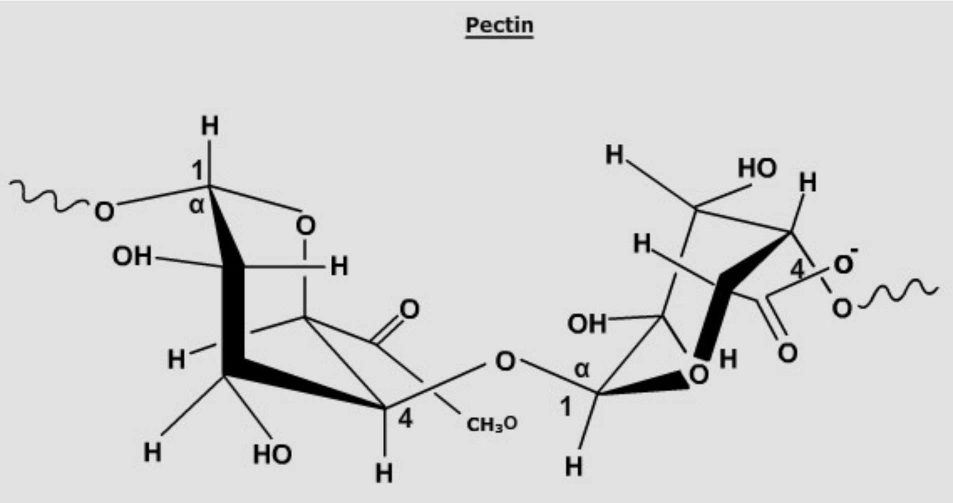
- Heteropolysaccharides with monosaccharide units like xylose, arabinose, galactose, glucose, glucuronic acid.

### 2.2.11 Pectin

- Found in plant cell walls and fruits.

- Complex polysaccharides with D-galacturonic acid as the principal constituent.

- High-methoxyl and low-methoxyl pectins with different gelling properties.

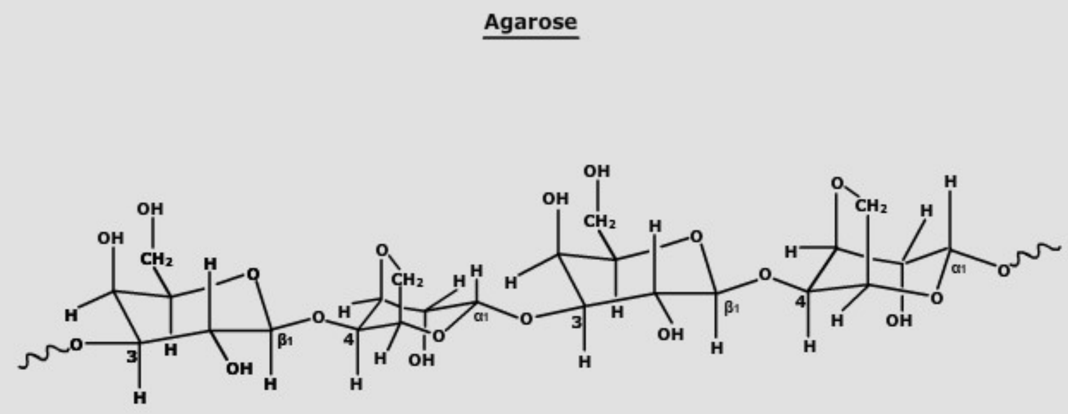


### 2.2.12 Agar

- Extracted from certain red algae.

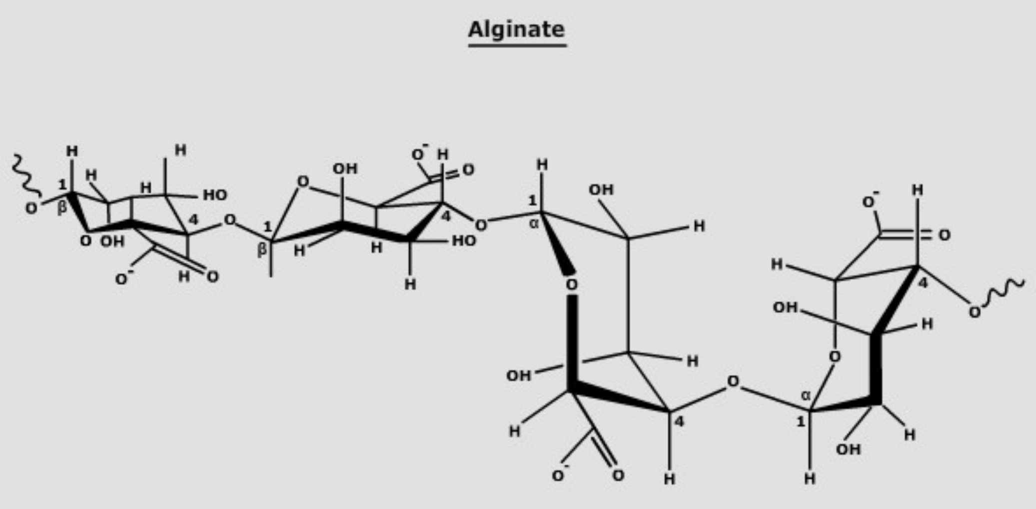
- Used as a gelling agent in microbiological media and food industry.

- Forms a gel at low concentrations.



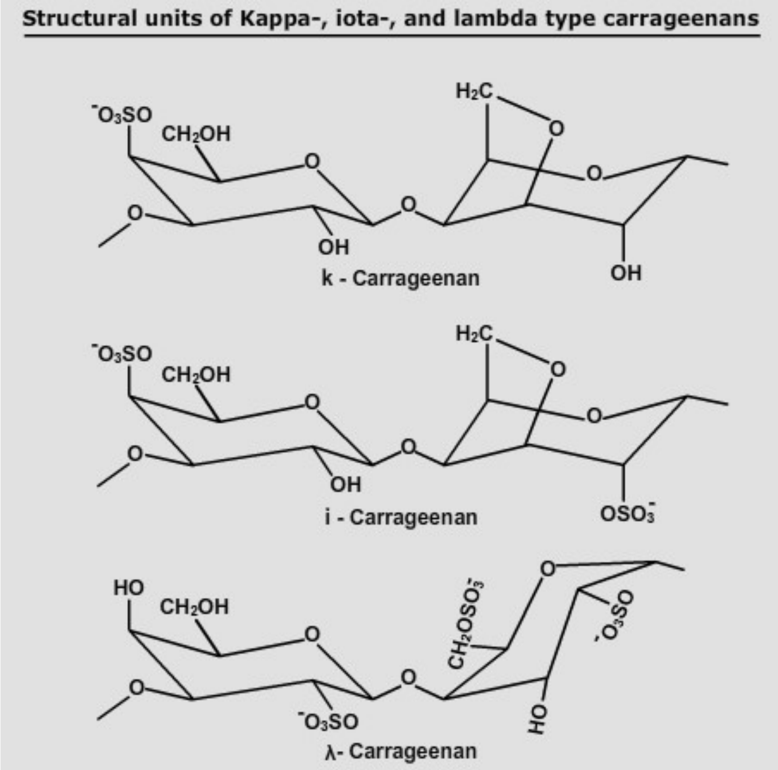
### 2.2.13 Alginate

- Derived from brown seaweed.
- Forms gels in the presence of divalent cations.
- Used in food as a thickening and gelling agent.



### 2.2.14 Carrageenan

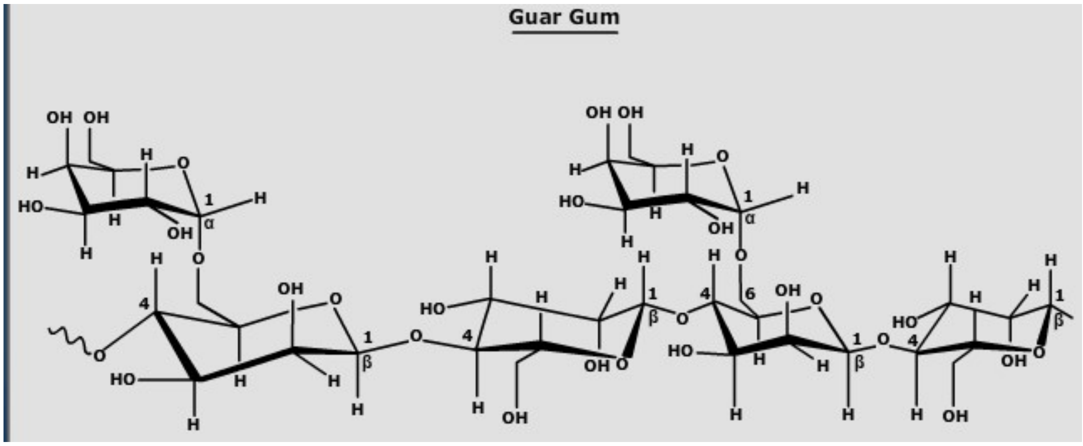
- Extracted from red seaweed.
- Used as a gelling and thickening agent in food and pharmaceutical industries.
- Three main types: kappa, iota, lambda.



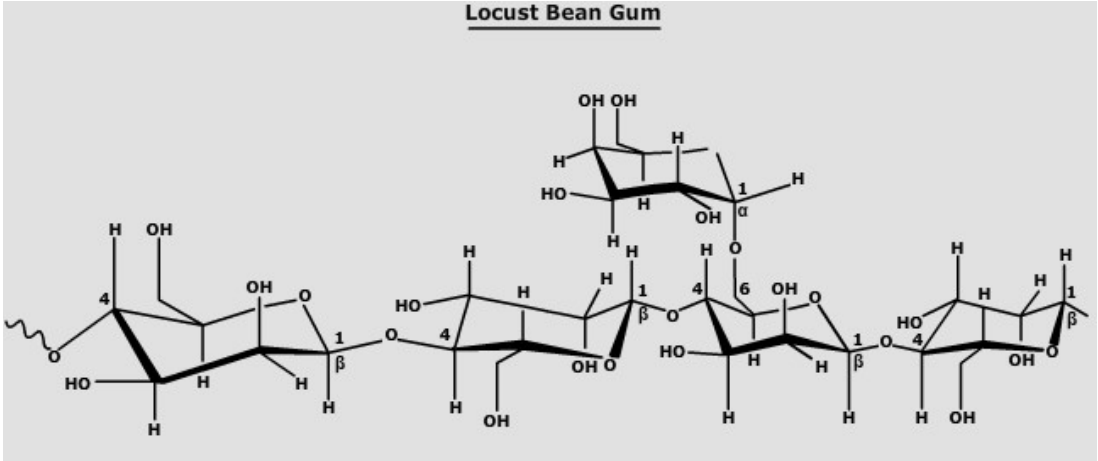
Structural units of Kappa-, iota-, and lambda type carrageenans

### 2.2.15 Gums

- Natural hydrocolloids with diverse applications.
- Examples: Guar gum, locust bean gum, xanthan gum.
- Used as thickeners, stabilizers, and emulsifiers.



Guar Gum


Locust Bean Gum

## 2.3 Applications and Functions of Polysaccharides in Food

### 2.3.1 Introduction

Polysaccharides play diverse roles in the food industry due to their unique physicochemical properties. Their applications range from thickening and gelling agents to stabilizers and emulsifiers.

### 2.3.2 Thickening Agents

- Increase viscosity and consistency of food products.
- Examples include starches, gums, pectins, and modified cellulose.

### 2.3.3 Gelling Agents

- Form gels in the presence of specific conditions (temperature, pH, ions).
- Starch, pectin, agar, alginate, and carrageenan are common gelling agents.

### 2.3.4 Stabilizers

- Enhance stability by preventing phase separation or settling of components.
- Polysaccharides like gums, pectins, and cellulose derivatives act as stabilizers.

### 2.3.5 Emulsifiers

- Improve the stability of emulsions by reducing interfacial tension between oil and water.
- Polysaccharides like lecithin, modified cellulose, and gums serve as emulsifiers.

### 2.3.6 Fat Replacers

- Polysaccharides can be used to mimic the texture and mouthfeel of fats in low-fat or fat-free products.

### 2.3.7 Film-Forming Agents

- Create protective films on food surfaces to extend shelf life.
- Modified starches, cellulose derivatives, and gums are used as film-forming agents.

### 2.3.8 Dietary Fiber

- Polysaccharides like cellulose, hemicellulose, and pectin contribute to dietary fiber content in food.

### 2.3.9 Texturizing Agents

- Improve the texture and mouthfeel of food products.
- Modified starches, gums, and pectins are used for texturization.

### 2.3.10 Encapsulation

- Polysaccharides can be used to encapsulate flavors, nutrients, or bioactive **Z**

### 2.3.11 Conclusion

Polysaccharides are versatile ingredients in the food industry, contributing to various functionalities that enhance the quality, stability, and sensory attributes of food products. Their diverse applications make them indispensable for formulating a wide range of processed foods.

## 2.4 Enzymatic Degradation of Polysaccharides – Starch Production of Dextrins and Maltodextrins

### 2.4.1 Introduction

- Starch is the most common storage carbohydrate in plants, utilized by plants, microbes, and higher organisms.
- Various enzymes catalyze the hydrolysis of starch, with acid hydrolysis being replaced by enzymatic processes due to efficiency.
- Acid hydrolysis poses challenges like corrosion, high color, salt, and ash content, requiring more energy and being difficult to control.

### 2.4.2 Amylases

- Amylases, belonging to hydrolases (Glycosidases), are crucial in starch degradation.
- Amylases hydrolyze starch into oligosaccharides and simple sugars.
- Amylopectin, with α-1,6-glycosidic branch points, presents a challenge for hydrolysis.
- Important enzymes include:
  - α-amylase: An endoenzyme that hydrolyzes α-1,4 glycosidic bonds randomly along the chain, producing oligosaccharides.
  - β-amylase: Hydrolyzes α-1,4 bonds, removing maltose units in an orderly fashion.
  - Glucoamylase: Used with α-amylase to produce D-glucose syrups.
  - Pullulanase: Hydrolyzes α-1,6 glucosidic bonds in polysaccharides like amylopectin.

### 2.4.3 **Production** of Dextrins and Maltodextrins

- **Dextrins:**
  - Low-molecular-weight carbohydrates produced by starch hydrolysis.

- Formed by enzymatic action or dry heat under acidic conditions.
- Used as binders, fillers, and in food processing for crispness enhancement.

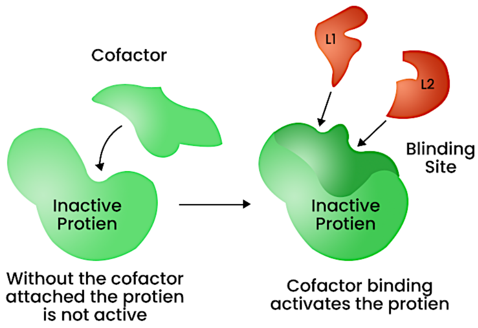
- **Maltodextrins:**
  - Polysaccharides produced from starch by partial hydrolysis.
  - Creamy-white, hygroscopic spray-dried powder.
  - Composed of D-glucose units linked by α(1→4) glycosidic bonds.
  - Classified by Dextrose Equivalent (DE) and used in various processed foods.

## 2.5 Other Important enzymes in carbohydrates and Lipids:

- Enzymes are proteinaceous biological catalysts with specific catalytic sites called active centers.

- Some enzymes have a nonprotein cofactor:

A cofactor is any non-protein substance required for a protein to be catalytically active.

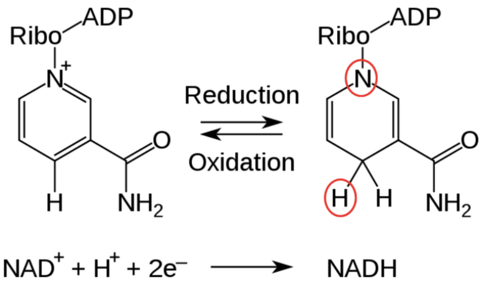


- Cofactors can be metallic ions or nonprotein organic compounds, known as prosthetic groups or coenzymes, respectively.

- Proenzymes or zymogens are inactive enzyme forms that can be converted into active enzymes.

  - Example: Pepsinogen (Proenzyme) → Pepsin (Enzyme)

Two common cofactors that are derived from the B vitamins, niacin and riboflavin, are nicotinamide adenine dinucleotide (NAD) and flavin adenine dinucleotide (FAD), respectively. The structure of NAD is shown below.



An example: The reduction of NAD to form NADH[3]

### 2.5.1 Properties of Enzymes:

1. Enzyme molecules are often larger than the molecules they catalyze.
2. Active sites on enzymes are specific and complementary to substrate structures.
3. Enzyme specificity depends on atomic structure and configuration of both substrate and enzyme.
4. Enzyme-catalyzed reactions are faster, occur at milder temperatures, and at nearly neutral pH compared to nonenzymatic reactions.
5. Enzymes are synthesized under gene regulation and exhibit saturation with substrate.

### 2.5.2 Nomenclature and Classification of Enzymes:

Enzymes are named trivially, systematically, and by Enzyme Commission (EC) numbers.

- Example: Alkaline Phosphatase
  - Trivial Name: Alkaline Phosphatase
  - Systematic Name: Orthophosphoric Monoester Phosphohydrolase
  - EC Number: **EC 3.1.3.1**

The first digit (3) for the class name (hydrolases)

The second digit (1) for the subclass (acting on ester bonds)

The third digit (3) for the sub-subclass (phosphoric monoester)

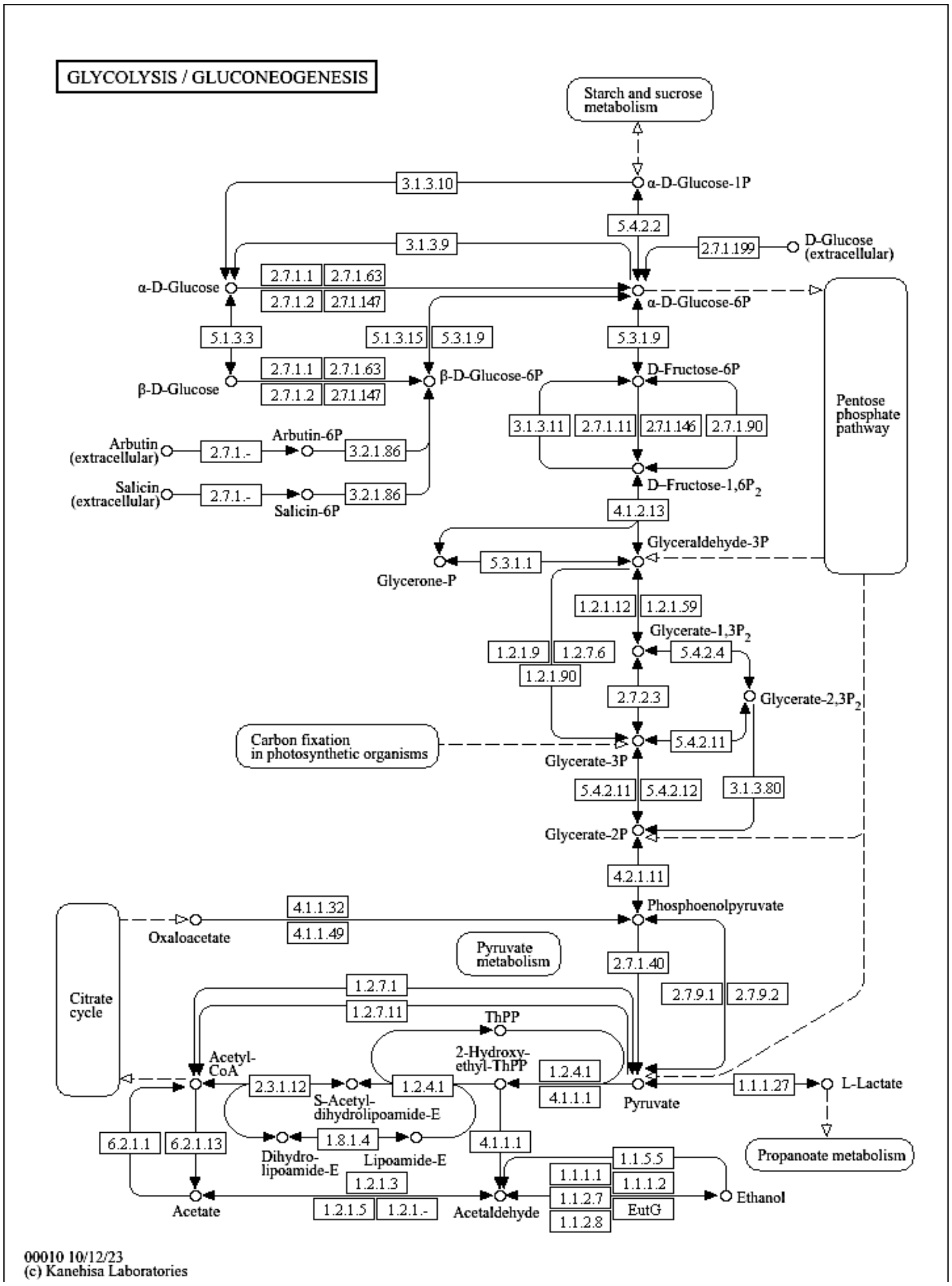
The fourth digit (1) designates alkaline phosphatase

- Classified by the International Union of Biochemistry into six major classes:

Enzymes are classified by the **Commission on Enzymes of the International Union of Biochemistry.**

By a systematic name: which identifies the reaction it catalyzes, and

By a number of the Enzyme Commission (EC): which is used where accurate & unambiguous identification of an enzyme is required, as in international research journals, abstracts and indexes.



1. **Oxido-reductases:** are involved in oxidation-reduction reactions. They oxidize or reduce substrates by transfer of hydrogen or electrons or by oxygen. An example is, catalase (EC 1.11.1.6).

2. **Transferases:** are involved in transfer of functional group. They remove groups from substrates and transfer them to acceptor molecules. An example is, glucokinase (EC 2.7.1.2).

3. **Hydrolases:** re involved in hydrolysis reactions. These enzymes catalyze hydrolysis of ester, thioester, peptide, glycosyl, acid anhydride by the addition of water. For a substrate XY, the reaction can be represented as follows: XY + HOH ------- HX + YOH

4. **Lyases:** are enzymes that catalyze the cleavage of C-C, C-O, C-N and other groups by elimination (not by hydrolysis), leaving double bonds, or conversely adding groups to double bonds. An example is fumarate hydratase (EC 4.2.1.2).

5. **Isomerases:** are involved in the catalysis of isomerizations within one molecule. An example is mutase (EC 5.4.2.1).

6. **Ligases**: are involved in the formation of bonds with ATP cleavage. They are involved in the biosynthesis of a compound with the simultaneous hydrolysis of a pyrophosphate bond in ATP. Alkaline phosphatase Trivial name : alkaline phosphatase

### 2.5.3 Hydrolases:

- Most enzymes in the food industry are hydrolases.

- Examples:

1. **Amylases: (α-amylase and β-amylase)**

-α-amylase and β-amylase in bread making and corn syrup production.

The α-amylase and β-amylase do not cleave the α-1,6-linkages in amylopectin.

Amylases, including α-amylase and β-amylase, break down starch molecules into smaller units.

α-amylase acts randomly on α-1,4-bonds, forming low molecular weight dextrins, while β-amylase removes maltose units in an orderly manner.

They are crucial in bread making, where α-amylase dextrinizes damaged starch during fermentation, and β-amylase converts dextrins to fermentable sugars.

This enhances bread quality by creating a softer crumb, deeper crust color, and improved texture.

2. **β-D-Fructo-furanosidase (Invertase):**

- It is involved in hydrolysis of sucrose. The products of hydrolysis, invert sugar consist of equimolar amounts of glucose and fructose and have a much sweeter taste than the original sucrose.

- Hydrolyzes sucrose in confectionery, producing invert sugar.

3. **Pectinolytic Enzymes:**

- Pectin methylesterase, polygalacturonase for fruit and vegetable juice clarification.

- Pectin methylesterase hydrolyzes the methyl ester bond of pectin to give pectic acid and methanol. Pectic acid flocculates in the presence of Ca2+ ions.

4. **Glucoamylase:**

-Cleaves glucose units from starch in enzymatic processes.

Glucoamylase is used in combination with an α-amylase to produce D-glucose syrups and crystalline D-glucose.

The enzyme acts upon fully gelatinized starch sequentially releasing single D-glucosyl units from the nonreducing ends of amylose and amylopectin molecules.

5. **β-D-Galactosidase (Lactase):**

   - Hydrolyzes lactose in dairy industry, aiding lactose-intolerant individuals.

6. **Proteases:**

   - Used in cheese making, bakery products, meat tenderization.

Proteases catalyse the hydrolysis of peptide bonds in proteins and are widely used in the food industry, mainly as endopeptidases.

They can be sourced from animal organs, plants, or microorganisms.

In cheese production, rennin, found in the fourth stomach, or chymosin is crucial for forming casein curd.

This coagulation process is facilitated by calcium ions. Rennin is preferred due to its specificity and suitability for cheese making.

7. **Lipases:**

Important in cheese manufacture, prevents hydrolytic rancidity in dairy products.

Lipases are crucial in cheese manufacturing, as they hydrolyse ester linkages in glycerides, contributing to flavour development during cheese ripening.

However, they can also cause hydrolytic rancidity in dairy products.

In bakery products, lipase activity helps slow staling, likely by releasing mono- and diacylglycerols.

Additionally, lipase-catalysed hydrolysis aids in the defatting of bones for gelatin production, operating under mild conditions.

### 2.5.4 Oxidoreductases:

#### 1. Glucose Oxidase:

Removes glucose and oxygen traces in food products.

Glucose oxidase removes glucose from foods and is used for glucose detection.
It oxidizes glucose to gluconic acid in the presence of oxygen, forming hydrogen peroxide.
Catalase then breaks down hydrogen peroxide into water and oxygen. It's sourced from fungi like Aspergillus Niger and Penicillium notatum.

#### 2. Catalase:

Decomposes hydrogen peroxide in conjunction with glucose oxidase. Catalase is used in combination with glucose oxidase.
Catalase catalyzes the decomposition of hydrogen peroxide into water and molecular oxygen.

#### 3. Ascorbic Acid Oxidase:

Ascorbic acid oxidase catalyses the following reaction.
L-Ascorbic acid + ½ $O_2$ ---------- dehydroascorbic acid + $H_2O$

Initiates browning reaction in fruits and vegetables.

#### 4. Lipoxygenase:

- Used in flour bleaching and improving dough rheological properties.

#### 5. Peroxidase:

- Catalyzes the decomposition of hydrogen peroxide in various substrates.

Peroxidase catalyzes the following reaction

$H_2O_2$ + $AH_2$ --------- $2H_2O$ + A
$AH_2$ is an oxidizable substrate.

## 6. Phenolases:

- Involved in enzymatic browning, oxidizing phenolic compounds to o-quinones.

These enzymes play crucial roles in various food processing applications, contributing to flavour development, texture enhancement, and preservation. Understanding their properties and applications is essential for optimizing food production processes

# 3 Food Additives: Vitamins, Amino Acids, Minerals, sweeteners, Colors, aroma, and Flavors.

## 3.1 Introduction

- Food additives are substances added to food for various purposes in production, processing, packaging, and storage.

## 3.2 Definition

- Food additives are chemical substances intentionally added to food in regulated quantities to assist in processing, preservation, or to improve flavour, texture, or appearance.

## 3.3 Functions of Food Additives

1. Enhance shelf life.
2. Improve and maintain nutritive value.
3. Reduce wastage and improve product yield.
4. Facilitate food processing/preparation.
5. Improve colour and appearance.
6. Enhance body and texture.
7. Improve aroma and taste.
8. Enhance consumer acceptability.

## 3.4 Classification of Food Additives

- Intentional (added deliberately) and Unintentional (contaminants).
- Further classified based on source: Natural, Synthetic, Nature Identical.

## 3.5 Considerations in the Use of Food Additives

1. Real need for use.
2. No adverse physiological effects.
3. Does not reduce nutritive value.
4. Confirms agreed specifications.

- Use at the minimum level necessary.

## 3.6 Safety Aspects of Food Additives

- ADI (Acceptable Daily Intake) determines the amount safe for daily consumption.

- GRAS (Generally Recognized as Safe) for substances with a history of safe use.

## 3.7 Various Categories of Food Additives

1. Nutrient supplements such as Vitamins and Amino acids
2. Coloring agents
3. Flavor enhancers
4. Leavening agents
5. Emulsifiers
6. Stabilizers
7. Preservatives
8. Antioxidants
9. Humectants
10. Sugar substitutes
11. Appearance control agents
12. Buffers

We will explain each in the following………

## 3.8 Nutrient supplements such as Vitamins and Amino acids:

### A. Vitamins:

- Vitamins are essential organic compounds that are required in small
- amounts for metabolism.
- The animal organism is not capable of forming them.
- Most vitamins are coenzymes; in some cases, they are also hormones or act as antioxidants.

### In Food content:

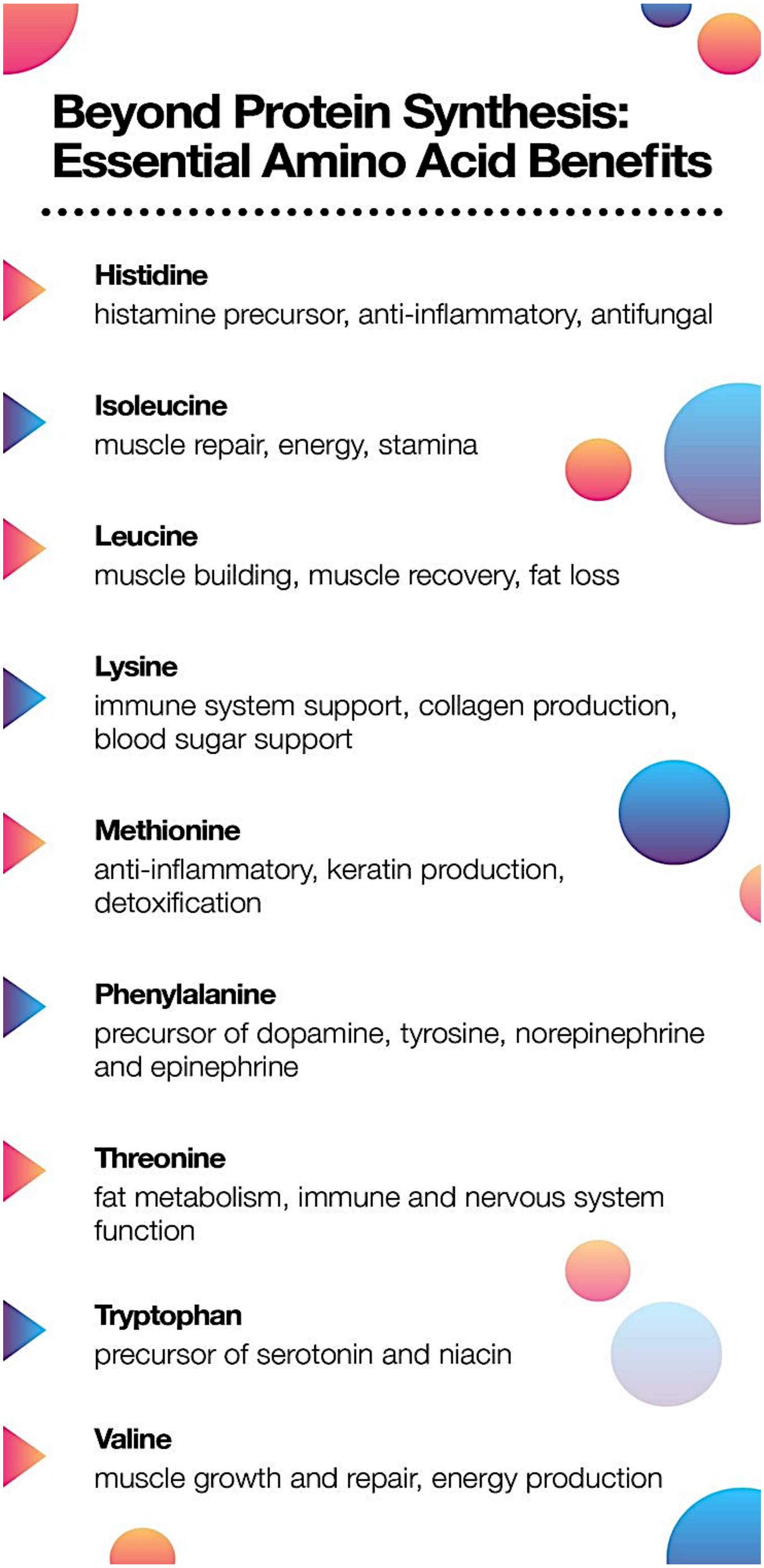
- Enrichment of food products with vitamins to compensate for processing losses.

- Examples of vitamin fortification in various food products.

| VITAMIN | WHAT WE USE IT FOR | GOOD SOURCES |
|---|---|---|
| A | For healthy vision, skin, bones, teeth & reproduction | Liver, Eggs, Fish, Milk, Carrots, Sweet Potato, Pumpkin, Spinach |
| B1<br>THIAMIN | Helps convert food into energy and is critical for nerve function | Pork, Soy, Watermelon, Tomato, Spinach |
| B2<br>RIBOFLAVIN | Helps convert food into energy and supports healthy skin, hair, blood & brain | Dairy, Meat, Green Leafy Veggies, Enriched Wheat, Oysters |
| B3<br>NIACIN | Helps convert food into energy and is essential for healthy nervous system | Beef, Chicken, Shrimp, Avocado, Peanuts, Tomato, Spinach |
| B6<br>PYRIDOXINE | Helps make red blood cells and improves sleep, appetite & mood | Chicken, Tofu, Banana, Watermelon, Fish, Legumes |
| B7<br>BIOTIN | Helps convert food to energy & break down glucose | Whole Grains, Eggs, Almonds, Soybeans, Fish |
| B9<br>FOLATE | Vital for new cell creation and DNA synthesis | Legumes, Spinach, Leafy Greens, Chickpeas, Tomato, Asparagus |
| B12 | Breaks down fatty acids & amino acids, helps make red blood cells | Dairy, Beef, Pork, Poultry, Fish, Eggs |
| C | Acts as an antioxidant, helps make new cells, & improves immune system | Fruit & Fruit Juices, Pepper, Broccoli, Tomato, Spinach |
| D | Strengthens and helps form bones & teeth via calcium & phosphorus | Egg Yolk, Fatty Fish, Liver, Sunlight |
| E | Acts an an antioxidant, helps stabilize cell membranes | Nuts, Avocado, Tofu, Whole Grains, Seeds |
| K | Essential for blood clotting and helping to regulate blood calcium | Broccoli, Brussels Sprouts, Liver, Leafy Greens |

## 3.9 Amino Acids as nutrients.

- Essential for protein biological value.
- Fortification of food with essential amino acids to increase nutritional value.



## Beyond Protein Synthesis: Essential Amino Acid Benefits

**Histidine**
histamine precursor, anti-inflammatory, antifungal

**Isoleucine**
muscle repair, energy, stamina

**Leucine**
muscle building, muscle recovery, fat loss

**Lysine**
immune system support, collagen production, blood sugar support

**Methionine**
anti-inflammatory, keratin production, detoxification

**Phenylalanine**
precursor of dopamine, tyrosine, norepinephrine and epinephrine

**Threonine**
fat metabolism, immune and nervous system function

**Tryptophan**
precursor of serotonin and niacin

**Valine**
muscle growth and repair, energy production

## Nonessential Amino Acid Benefits

**Alanine**
helps metabolize and clear toxins from the body

**Arginine**
boosts nitric oxide production for better blood pressure and blood flow

**Asparagine**
for healthy brain cells and central nervous system support

**Aspartic Acid**
produces other amino acids and essential enzymes

**Cysteine**
stimulates collagen production and makes the antioxidant glutathione

**Glutamic Acid**
provides energy for the brain and keeps ammonia levels in check

**Glutamine**
for digestion, cognitive function, and immune health

**Glutamine**
for digestion, cognitive function, and immune health

**Glycine**
heals wounds and aids movements, vision, and hearing

**Proline**
repairs tissues and regenerates skin

**Serine**
for muscle metabolism, fat burning, immune health, and good moods

**Tyrosine**
helps alleviate hypertension, depression, and chronic pain

## 3.10 Sugar Substitutes and sweeteners - Sorbitol, Saccharin, Cyclamate

### 3.10.1 Introduction

Sugar substitutes are substances used for sweetening that are metabolized without the influence of insulin. Important sugar substitutes include sorbitol, xylitol, mannitol, and fructose.

### 3.10.2 Classification of Sweeteners

Sweeteners are divided into bulk and intense sweeteners. Bulk sweeteners provide body and texture, are metabolized, and contribute to energy. Intense sweeteners are not metabolized and are used at low levels.

### 3.10.3 Bulk Sweeteners (Nutritive)

- Sugars (sucrose, fructose, glucose, etc.)
- Sugar replacements/polyols/sugar alcohols (sorbitol, mannitol, xylitol, etc.)

### 3.10.4 Intense Sweeteners (Non-Nutritive)

- Natural (glycyrrhizin, steviosides, thaumatin)
- Synthetic (aspartame, acesulfame-K, saccharin, sucralose, cyclamate, etc.)

### 3.10.5 Nutritive Sweeteners

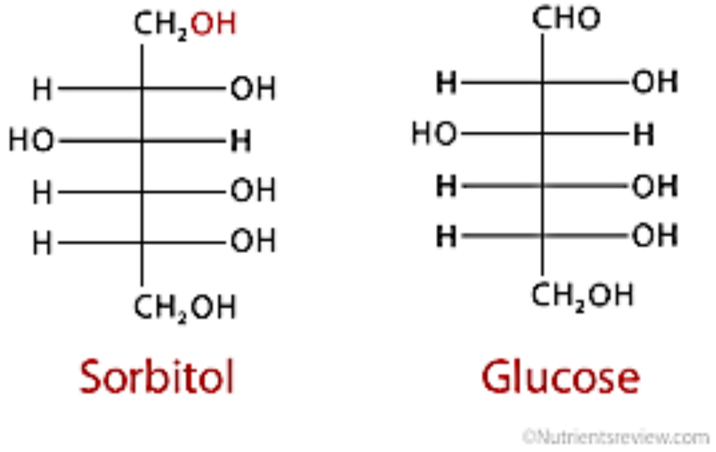
Have >2% of the calorific value of sucrose per equivalent unit. Examples: high fructose corn syrup, sorbitol, mannitol, erythritol, lactitol, iso malt, maltitol.

### 3.10.6 Non-Nutritive Sweeteners

Include saccharin, cyclamates, sucralose, acesulfame potassium (Ace-K).

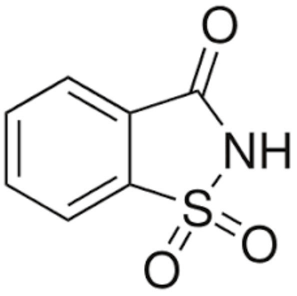
## - Sorbitol

- Sorbitol is a type of carbohydrate called a sugar alcohol, or polyol.
- Polyalcohol, half as sweet as sucrose.
- Hygroscopic, used in diabetic sweeteners and food canning.
- Commercially prepared by catalytic hydrogenation of glucose.



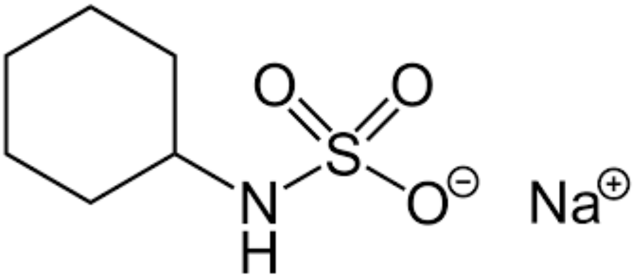
## - Saccharin

- It is one of the oldest artificial sweeteners. It is also called saccharine or benzosulfimide, or used in saccharin sodium or saccharin calcium forms, is a non-nutritive artificial sweetener. It is Primary non-nutritive sweetener.
- Sodium saccharin most common, about 300 times sweeter than sucrose.
- ADI value: 15 mg/kg of body weight.



## - Cyclamates

- It is an artificial sweetener. 30-40 times sweeter than sucrose, banned in some places due to carcinogenic concerns.
- Marketed as sodium or calcium salt.

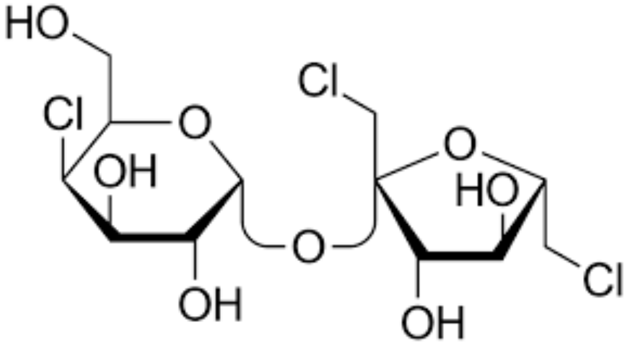


## - Sucralose

- it is a Sucralose is a synthetic organochlorine sweetener.

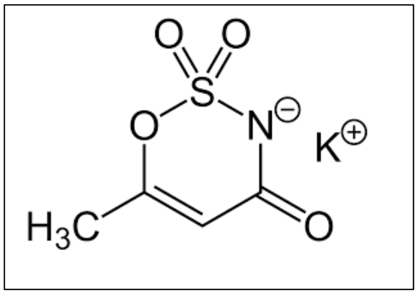
Non-caloric sweetener, 600 times sweeter than sucrose.

- Made from sugar, stable under various conditions.
- ADI: 5 g/kg body weight/day.



## - Acesulfame Potassium (Ace-K)

- Non-caloric sweetener, 200 times sweeter than sucrose.
- FDA-approved for non-alcoholic beverages.
- Synergizes well with other sweeteners.



### 3.10.7 Characteristics of an Ideal Sweetener

- Tastes like sugar, low/no calories.
- As sweet as or sweeter than sucrose.
- Pleasant taste, no aftertaste.
- Colourless, odourless.
- High solubility, stability, availability.
- Non-toxic, useful in weight reduction, diabetes management, cost-effective.

Are they good or bad for health? Discuss?

## 1.32 Minerals in Food (also considered as additives in foods)

Main Elements and Trace Elements in Eggs, Cereals & Cereal Products, Vegetables, and Fruits

### 3.1.8 Introduction

- Minerals, excluding C, H, O, and N, constitute about 1% of living systems.
- Mineral classification into major (e.g., calcium) and trace elements (e.g., iron).
- Bioavailability depends on food composition and interactions with other constituents.

### 3.1.9 Classification

- Major elements (Na, K, Ca, Mg, Cl, P, S) required in amounts >50 mg/day.
- Trace elements (Fe, I, F, Zn, Se, Cu, Mn, Cr, Mo, Co, Ni) essential in <50 mg/day concentrations.
- Ultra-trace elements (e.g., Al, As, Ba, Bi) also important.

### 3.1.10 Nutritional and Functional Roles of Minerals

- Main Elements:
  - Sodium: Activates enzymes, excessive intake leads to hypertension.
  - Potassium: Regulates osmotic pressure, deficiency from potassium-deficient foods.
  - Magnesium: Constituent and activator of enzymes, stabilizer of membranes.
  - Calcium: Essential for muscle contraction, blood clotting, and cell growth.
  - Chloride, Phosphorus, and Sulfur: Various roles in bodily functions.
- Trace Elements:
  - Iron: Essential in hemoglobin, enzymes, and daily diet.
  - Copper, Zinc, Manganese, Cobalt, Chromium, Selenium, Molybdenum, Nickel: Roles in enzymes and physiological functions.
  - Fluorine and Iodine: Involved in tooth health and thyroid function.

- Ultra-trace Elements:

- Tin, Aluminum, Boron, Silicon, Arsenic: Roles in food processing, bone formation, and metabolic processes.

### 3.1.11 Minerals

- Fortification considered for minerals like iron, calcium, magnesium, copper, and zinc.

- Iodization of salt as a preventive measure against goiter

| MINERAL | WHAT WE USE IT FOR | GOOD SOURCES |
|---|---|---|
| CALCIUM | The most abundant in the body. For strong bones and blood clotting | Dairy, Leafy Greens, Seeds, Nuts, Dates, Tofu |
| MAGNESIUM | Helps maintain normal nerve and muscle function & a healthy immune system | Nuts, Spinach, Fish, Avocado, Whole Grains |
| PHOSPHORUS | Used in all cell functions- used for more than any other mineral | Fish, Poultry, Eggs, Leafy Greens, Avocado, Oats, Legumes |
| POTASSIUM | Regulates major biological processes, muscle contraction, regulates heartbeat | Most Fruits & Veggies, Nuts, Seeds, Fish |
| SODIUM | Maintains water balance, produces digestive juices, other biological processes | Table Salt, Fish, Nuts, Seeds, Added to many foods |
| CHLORIDE | Acts as an electrolyte, aids digestion, regulates blood pH | Table Salt, Olives, Tomato, Celery, Rye, Seaweed |
| SULFUR | Helps with digestion, waste elimination, & bile secretion | Eggs, Avocado, Garlic, Cabbage, Poultry, Fish, Soy |
| IRON | Essential for red blood production (hemoglobin) | Legumes, Dried Fruit, Whole Grains, Spinach, Liver, Tofu |
| COPPER | Helps with the absorption and metabolism of iron | Nuts & Seeds, Shellfish, Potatoes, Dried Fruit |
| ZINC | Supports the immune system & aids in the healing of wounds | Shellfish, Nuts & Seeds, Dairy, Meat |

*MACRO MINERALS / ELECTROLYTES
*MICRO MINERALS / TRACE MINERALS

Other trace minerals include Manganese, Iodine, Chromium, Cobalt, Selenium, @CheatDayDesign, & Fluoride

## 1.33 Toxic Trace Elements and Radionuclides

### 3.1.12 Introduction:

- Unintentional incorporation of chemicals into food is widespread and may pose health hazards.

- Sources of contamination include radioactive fallout, agricultural chemicals, animal food additives, and accidental contaminants during food processing.

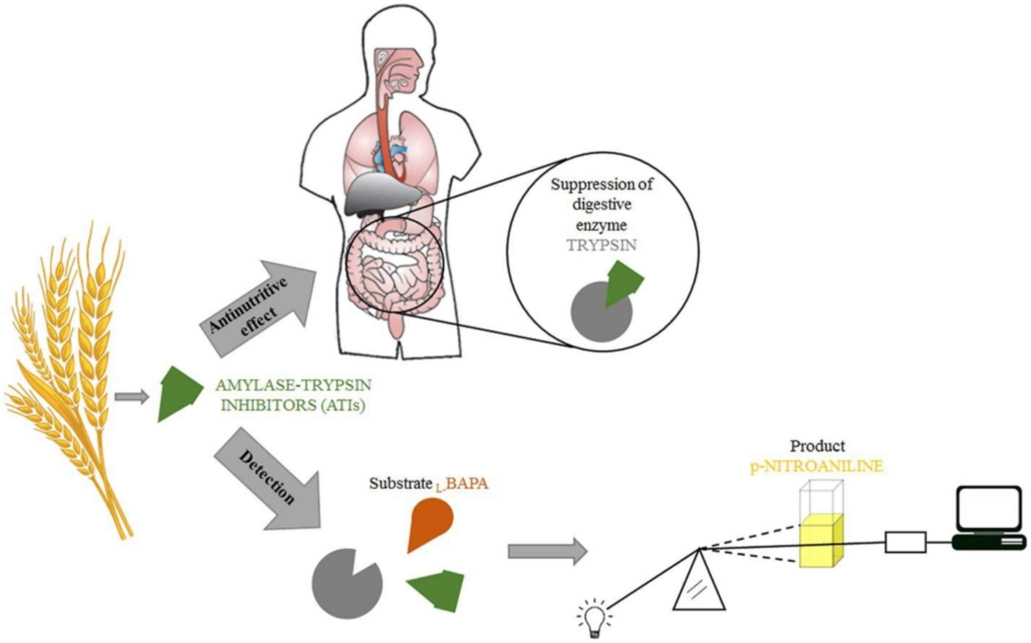
### 3.1.13 Antinutritional Factors:

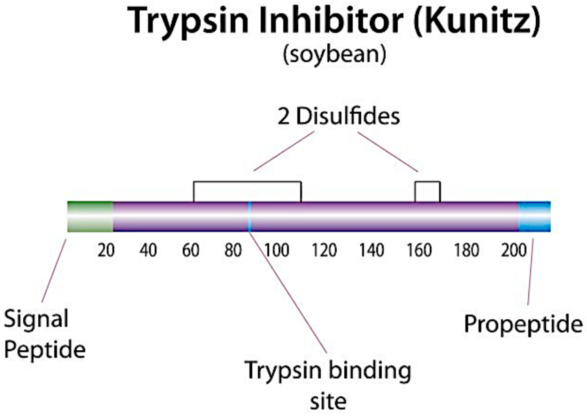
- Many foods, especially of plant origin, contain anti-nutritional factors interfering with nutrient assimilation.

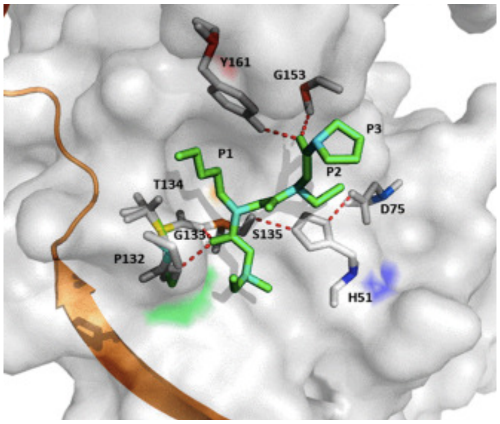
- Key factors: Trypsin inhibitors, phytates, oxalates, tannins, lectins, and goitrogens.

### 3.1.14 Trypsin Inhibitors:

- Found in legumes and certain animal foods, inhibiting trypsin in the gut.
- Heat labile; autoclaving at 120°C for 15-30 min inactivates them.

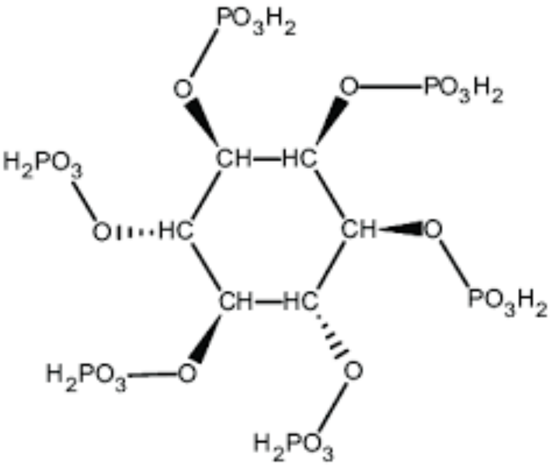






## 3.1.15 Phytate:

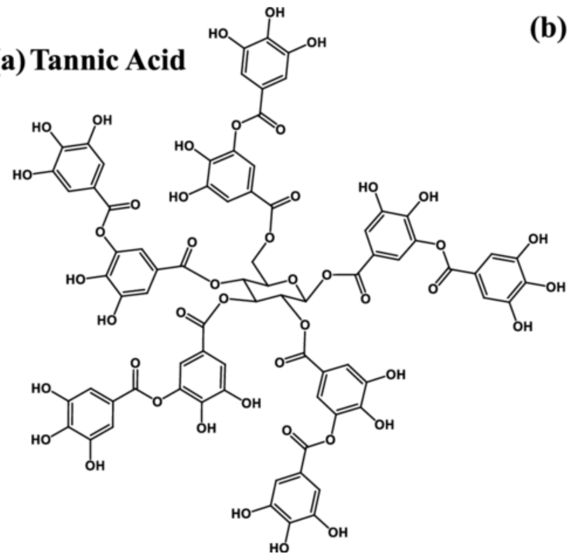
- Abundant in unrefined cereals and millets, binds iron, zinc, calcium, and magnesium.
- Reduction in phytate content during germination improves iron availability.



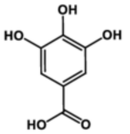
## 3.1.16 Tannins:

- Condensed polyphenolic compounds found in various plants.
- Bind iron, interfere with iron absorption, and reduce protein availability.

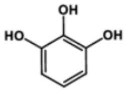
**(a) Tannic Acid**



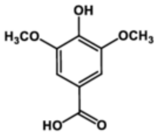
**(b) Gallic Acid**



**(c) Pyrogallol**

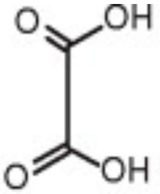


**(d) Syringic Acid**

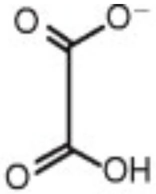


### 3.1.17 Oxalates:

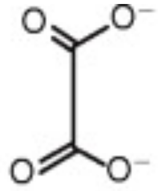
- Found in green leafy vegetables and legumes, interferes with calcium absorption.
- High oxalate foods advised to be avoided by stone patients.



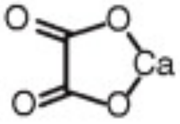
Oxalic acid



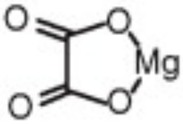
Acid oxalate ion



Oxalate ion



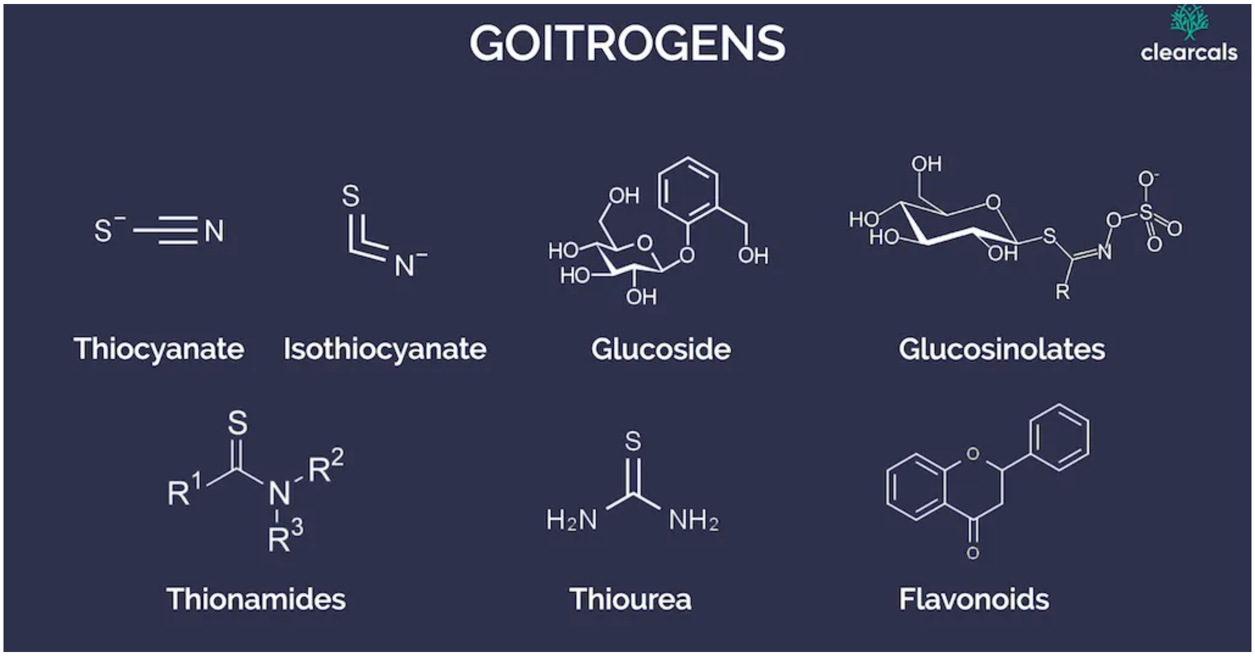
Ca oxalate (insoluble)



Mg oxalate (rather insoluble)

### 3.1.18 Goitrogens:

- Compounds in certain plant foods interfere with iodine uptake by the thyroid gland.
- Found in vegetables, legumes, soybeans, peanuts, and lentils.



### 3.1.19 Radionuclides:

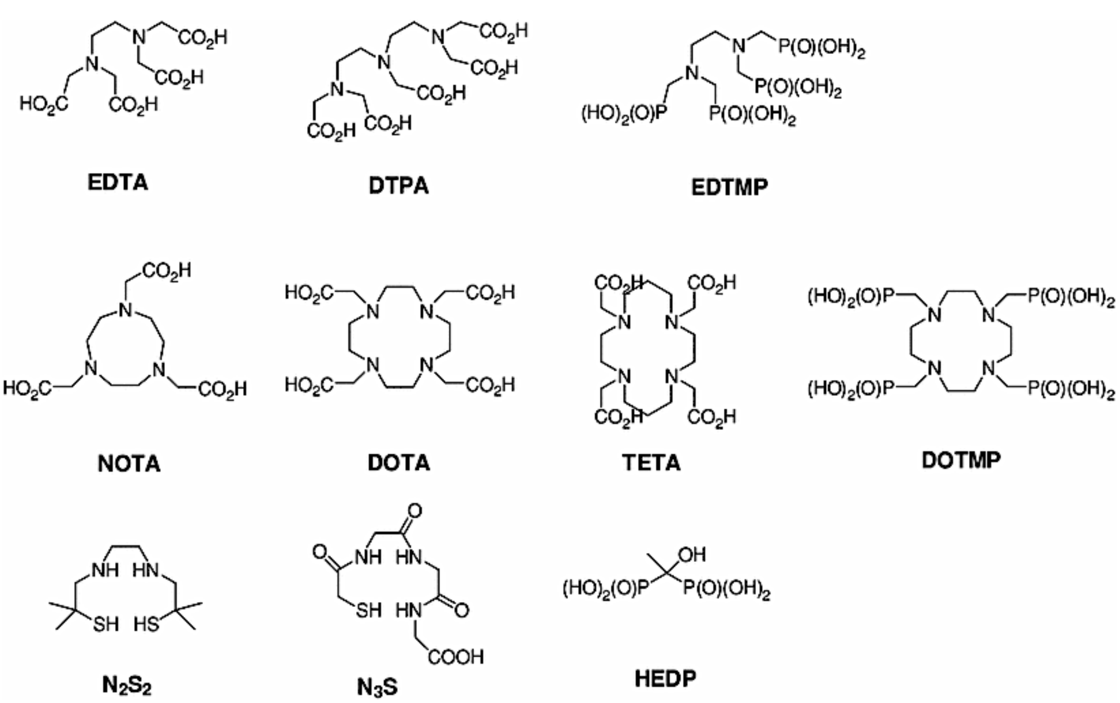
- Unstable chemical elements decay, emitting radioactivity as alpha, beta, or gamma particles.

- Sources: Naturally occurring radionuclides, nuclear weapons testing, and various applications of atomic energy.

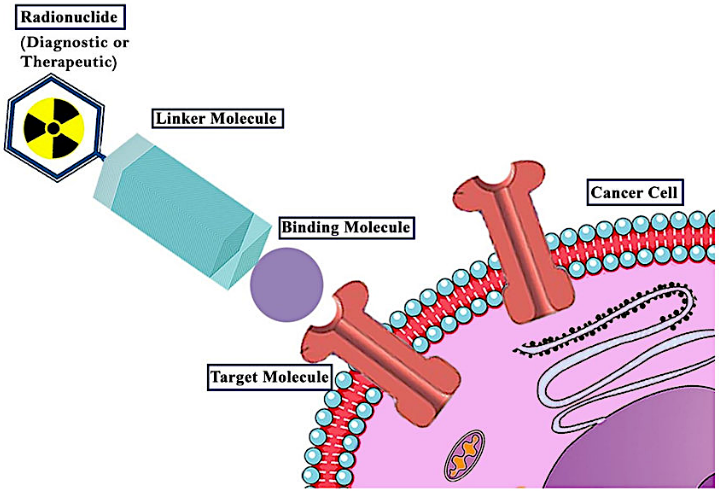
#### 1.33.1 Sources of Radionuclide Contamination:

- Naturally occurring radionuclides, nuclear weapons testing, and operation of reactors.
- Pathways include soil, atmosphere, vegetation, and dairy products.

**Below: Natural Radionuclides for Nuclear Medicine Therapy**



**Bifunctional chelating agents (BCA) commonly used for inorganic radionuclide labeling**



The general concept of theranostic radiopharmaceuticals. A radionuclide is combined with a targeting vector (Binding molecule).

### 1.33.1 Some Radionuclides:

- Strontium-90 (Sr-90), Cesium-137 (Cs-137), Iodine-131 (I-131), Carbon-14 (C-14).

### 3.1.20 Sr-90: Emits beta particles, accumulates in bones, particularly hazardous to children.

**3.1.21 Cs-137: Gamma emitter, absorbed like sodium, potential genetic harm.**

**3.1.22 I-131: Beta-gamma emitter, accumulates in the thyroid gland, hazardous for a short period.**

**3.1.23 C-14: Produced during nuclear explosions, slowly decays, incorporated into plant tissues.**

## 1.34 Toxic Trace Elements:

- Lead, mercury, cadmium, arsenic are significant to human health due to industrial usage.

### 3.1.24 Lead:

- Released into the environment through industrial use.
- Milk acts as a filter, diverting lead from feed to bones, minimal in milk.
- Clinical symptoms include anemia, mental deterioration, aggressive behavior, and kidney damage.

### 3.1.25 Mercury:

- Released by various industries, converted into toxic methylmercury in sediments.
- Accumulates in the liver and kidneys, neurotoxic, causing Minamata disease.

### 3.1.26 Cadmium:

- Inhaled from air and increased intake in cigarette smokers.
- Cow acts as a filter, minimal cadmium in milk.
- Chronic ingestion causes renal damage, bone disease, and enhances cancer rates.

### 3.1.27 Arsenic:

- Classified as a metalloid, sources include copper smelting and coal combustion.
- Inorganic and organic arsenic compounds cause chronic poisoning with various symptoms.

## 1.35 Food colors

### 3.1.28 Introduction

Colour is crucial in food perception. Natural and added Colours influence food acceptability. Colours result from natural pigments or added Colours with complex chemical and physical properties.

### 3.1.29 Importance of Food Colours

Colours define food quality, influence flavour identification, protect product identity, ensure uniformity, intensify colours, protect light-sensitive vitamins, indicate quality.

### 3.1.30 Why Food Products Need to be Coloured?

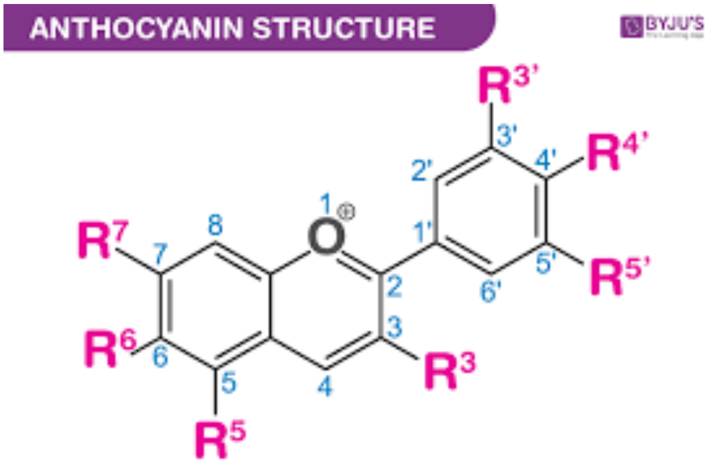
Choice of a dye should have no adverse reactions. Colour enhances food quality and flavour perception, overcomes processing damage, preserves product identity, ensures uniformity, intensifies colours, protects vitamins, indicates quality.

### 3.1.31 Classification of Food Colours

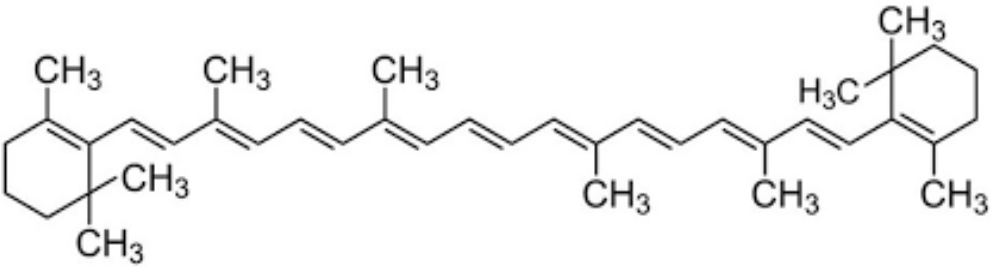
Regulated as food additives, Colours can be natural, nature-identical synthetic, or artificial. Natural Colours include carotenoids, chlorophyll, caramel, annatto, etc.

### 3.1.32 Natural Colours:

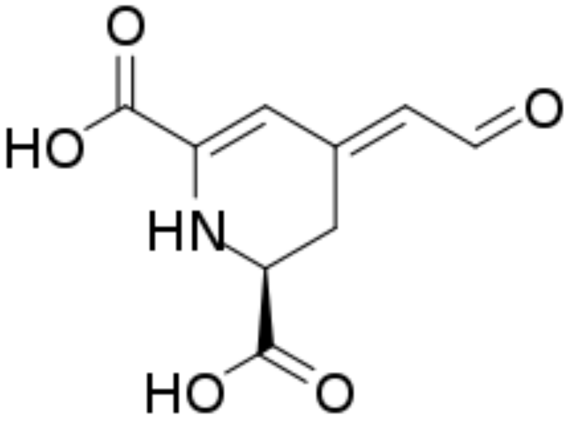
- Anthocyanins: Water-soluble compounds providing red to blue colours.



- Carotenoids: Yellow, orange, red pigments. Beta-carotene, canthaxanthin, annatto.



- Betalain: Water-soluble, indigoid pigments in fruits, vegetables, beet-root.



### 3.1.33 Synthetic Colours:

- Nature-identical synthetic colours, e.g., Ponceau 4R, Tartrazine, Indigo Carmine.

### 1.35.1 Artificial colours: FD and C dyes (Food, Drugs and Cosmetics)

- They are versatile food colours which can be blended to create nearly any colour imaginable.

### 3.1.34 Inorganic Colours:

- Prohibited, except titanium dioxide (max 1%) in chewing gum.

### 3.1.35 Food Colours Permitted by FSSA

- Natural colour principles: Carotenoids, chlorophyll, riboflavin, caramel, annatto, saffron, curcumin.
- Synthetic colours: Limited colours permitted.
- Inorganic matter prohibited, except titanium dioxide (max 1%) in chewing gum.

## 1.36 Aroma Compounds in Food & Flavor Enhancers

## 1.37 Introduction

- Flavours result from taste, odour, and texture interactions.

- Flavours classified into taste and aroma, with some compounds contributing to both.

## 1.38 Classification of Odors

- Seven primary odours based on site-fitting theory.

- Specific receptor sites for each odour class.

## 1.39 Odor Threshold

- The lowest concentration for odour recognition is the odour threshold value.

- Aroma value calculated as $Ax = Cx/ax$.

## 1.40 Impact Compounds of Natural Aroma

- Aroma compounds contribute to food aroma in low concentrations.

- Character impact compounds define the characteristic essence of the food.

### 3.1.36 Flavour Enhancers - Monosodium Glutamate, Nucleotides

- Flavour enhancers modify flavour in a desirable manner.

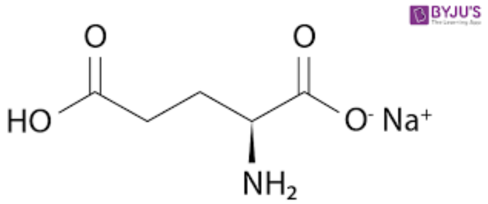
- Monosodium Glutamate (MSG) and 5'-nucleotides as examples.

### 3.1.37 Monosodium Glutamate (MSG)

- Flavour enhancer with umami taste.

- Used to improve flavour in various processed foods.

- Potential adverse effects in hypersensitive individuals.

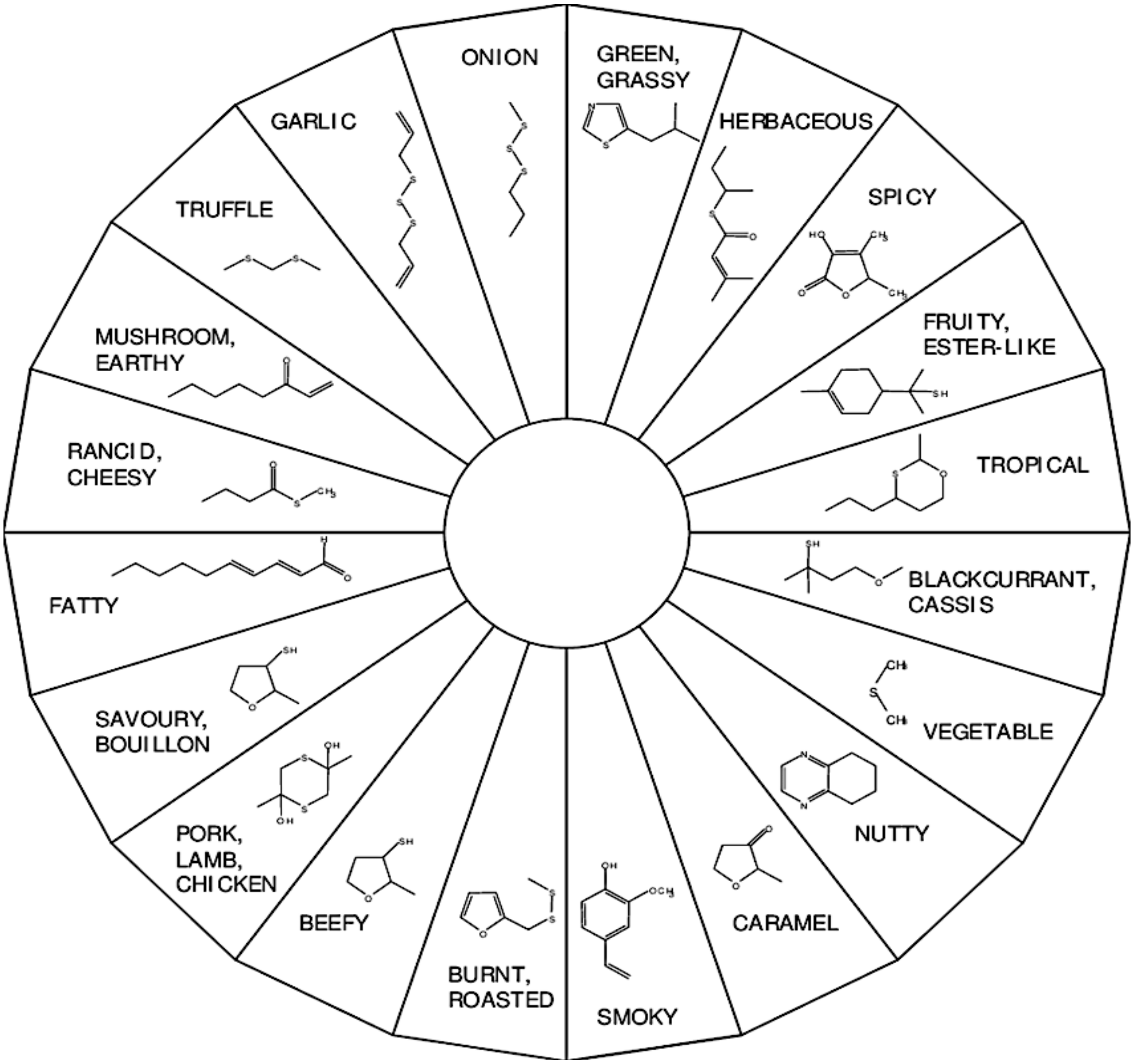


### 3.1.38 5'-Nucleotides

- Enhance flavour similarly to MSG.
- Improve viscosity of liquid foods.
- Synergistic effect in the presence of glutamate.

### 3.1.39 Other Flavour Enhancers

- Maltol and Ethyl maltol enhance sweetness perception.
- Ethyl maltol is more potent than maltol.
- Used in various food products for aroma and flavor enhancement.



### 3.1.40 Conclusion:

- Understanding the presence and effects of toxic trace elements and radionuclides is crucial for assessing and mitigating health risks associated with food contamination.

# Other Food additives:

**Various Categories of Food Additives**

1. Leavening agents
2. Emulsifiers
3. Stabilizers
4. Preservatives
5. Antioxidants
6. Humectants
7. Appearance control agents

## Leavening agents

Leavening agents are essential components in baking, facilitating the rise and light texture of baked goods. Yeast, a fungus that ferments sugars in dough, produces carbon dioxide gas, while baking powder, a combination of baking soda and an acid, releases gas when activated by heat and moisture. Baking soda $NaHCO3$, reacting with acidic ingredients, also generates carbon dioxide, while whipped egg whites add air and volume to batters.

Additionally, steam, produced during baking, creates pockets of air in some recipes. Understanding these leavening agents allows bakers to achieve the desired texture and structure in a variety of baked treats, from bread to cakes.

## Emulsifiers

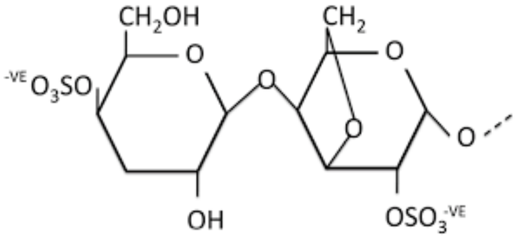
Emulsifiers are substances crucial in food preparation, stabilizing mixtures of ingredients to prevent separation. They reduce surface tension between immiscible phases like oil and water, ensuring even blending and sustained cohesion in products like salad dressings, mayonnaise, and margarine.

Common emulsifiers include lecithin, found in egg yolks and soybeans, mono- and diglycerides derived from plant or animal fats, polysorbates, and glycerol monostearate. These compounds, whether natural or synthetic, contribute to the smooth texture, uniformity, and extended shelf life of various food items like chocolate, baked goods, and ice cream.

## Stabilizers

Stabilizers are crucial additives in food production, ensuring the consistency and quality of various products. These substances help maintain texture, prevent separation, and extend shelf life by binding water molecules and controlling crystallization.

Common stabilizers include agar-agar, carrageenan, and guar gum, which are often used in dairy products, ice cream, and sauces. Their role in food manufacturing is vital for achieving desired textures and maintaining product integrity throughout storage and distribution.



Carrageenan structure

## Preservatives

Preservatives are additives used in food production to prolong shelf life and prevent spoilage caused by microbial growth, oxidation, or enzymatic reactions.

They inhibit the growth of bacteria, molds, and yeasts, helping to maintain the freshness and safety of various food products.

Common preservatives include salt, sugar, vinegar, and synthetic compounds like sodium benzoate and potassium sorbate. While controversial in some circles due to health concerns, when used within regulatory limits, preservatives play a crucial role in ensuring food safety and reducing food waste, allowing products to be stored for longer periods without degradation.

## Antioxidants

Antioxidants are compounds found in foods that help protect cells from damage caused by free radicals, unstable molecules that can harm cells and contribute to aging and disease.

They work by neutralizing free radicals, thus reducing oxidative stress and inflammation in the body. Common antioxidants include vitamins C and E, beta-carotene, and selenium, which are abundant in fruits, vegetables, nuts, and seeds. Incorporating antioxidant-rich foods into the diet can help support overall health and may reduce the risk of chronic conditions such as heart disease and cancer.

## Humectants

Humectants are additives used in food production to retain moisture, preventing products from drying out and maintaining their texture and freshness. These compounds attract and hold water molecules, helping to prolong shelf life and enhance the palatability of various foods.

Common humectants include glycerol, sorbitol, and propylene glycol, which are frequently used in baked goods, confectionery items, and processed meats. By preventing moisture loss, humectants contribute to the overall quality and appeal of food products, ensuring they remain moist, soft, and enjoyable for consumers.

# Appearance control agents

Appearance control agents are additives used in food production to enhance the visual appeal of products, improving their color, texture, and overall appearance. These agents may include colorants, such as natural or synthetic dyes, which impart vibrant hues to foods, making them more visually appealing. Additionally, texturizing agents like starches or gums can be used to modify the texture of foods, creating a smoother, creamier consistency or adding a desirable chewiness.

Certainly! Here are some examples of appearance control agents in foods:

1. Colorants: Natural colorants like beetroot extract or turmeric are used to give foods vibrant colors without artificial additives. Synthetic dyes etc.
2. Texturizing Agents: Starches, such as corn-starch or modified starches, are often used to thicken sauces and soups or to give a smooth texture to dairy products like yogurt. Gums like xanthan gum or guar gum are used as stabilizers and thickeners in salad dressings, ice cream, and other products to create a desired consistency.

# If you are an employee in quality control of food, how do you check the validity of a sample?

To check the validity of a food product in quality control, examine its labeling, packaging, and appearance for compliance with regulations and signs of spoilage or contamination. Conduct sensory evaluation tests for taste and aroma, along with chemical and microbiological analyses for composition and safety. Ensure the product meets established standards and specifications for safety, quality, and legality.