Introduction to Food Science and Engineering

Food Constituent: Carbohydrate

Prof. Dr. S M Iqbal Hossain
Dept. of Food Science and Engineering

Carbohydrates

- **Carbohydrates:** Carbohydrates are the most abundant organic molecules in nature which are the major constituents of food and supply energy and serve as structural constituents.
- Carbohydrates are primarily composed of the elements carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen–oxygen atom ratio of 2:1 (as in water); in other words, with the empirical formula $Cn(H_2O)n$ *or* $Cn(H_2O)n\text{-}1$. e.g. glucose ($C_6H_{12}O_6$) or sucrose ($C_{12}H_{22}O_{11}$)
- Carbohydrates may be defined as polyhydoxy aldehydes or ketones or compounds which produce them on hydrolysis.
  - Functional group of aldehyde = (–CHO), and
  - Functional group of ketone = (-C=O).
- Carbohydrate may be defined as aldehyde (-CHO) or ketone (-C=O) derivatives of polyhydric alcohol or compounds which produce these derivatives on hydrolysis.

Production of Carbohydrates (Sugar)

Photosysthesis: Photosynthesis of carbohydrates by green plants, in fact, supports the existence of all other organisms in the world. Chlorophyll of plant leaves makes carbohydrate (glucose) in their leaves and stored in the plants using carbon dioxide (CO_2) and water (H_2O) with the help of sun light and release oxygen in the air.

Sun light (energy)

$$6CO_2 + 12\,H_2O \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O \quad (1)$$

Carbon dioxide Water Glucose Oxygen Water

- Again at night plant leaves CO_2 in the air through cell respiration

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O \quad (2)$$

Glucose Oxygen Carbon dioxide Water

Function of Carbohydrates

Function of Carbohydrates: Carbohydrates participate in a wide range of functions such as-

1. They are the most abundant dietary source of energy (4 kcal/g) for all organisms
2. Carbohydrates are precursors (forerunner/originator) for many organic compounds (fats, amino acids)
3. Carbohydrates (as glycoproteins and glycolipids) participate in the structure of cell membrane and cellular functions such as cell growth, adhesion and fertilization.
4. They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.
5. Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.

Classification of Carbohydrates

Carbohydrates are often referred to as saccharides (Greek: Sakchram- sugar), a group that includes sugar, starch and cellulose. They are broadly classified into four major groups based on the number of sugar units present in the molecule as:

1. Monosaccharide, 2. Disaccharide,
3. Oligosaccharide, 4. Polysaccharides.

Monosaccharide, disaccharide and olygosaccharides are sweet to taste, crystalline in character and soluble in water, hence are commonly known as sugars.

1. Monosaccharides: Monosaccharides (Greek: mono-one) are the simplest group of carbohydrates with 3 to 9 carbon atoms; and are often referred to as simple sugar with a general formula $Cn(H_2O)n$ such as glucose ($C_6H_{12}O_6$),galactose ($C_6H_{12}O_6$), Mannose ($C_6H_{12}O_6$), fructose ($C_6H_{12}O_6$).

They can not be further hydrolysed (broken down).

DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are built up of the monosaccharides- deoxyribose and ribose, respectively. (Deoxyribose = $C_5H_{10}O_4$ and ribose = $C_5H_{10}O_5$).

Classification of Carbohydrates

2. **Disaccharides:** Disaccharides are the most important carbohydrates containing two monosaccharide units with a general formula $C_n(H_2O)_{n-1}$. e.g. disaccharides are: Sucrose (composed of D-glucose + D-fructose) ($C_{12}H_{22}O_{11}$) , Lactose (composed of D-glucose and D-galactose), Maltose (consists of 2 glucose molecules), and Cellobiose (consists of two β-glucose molecules linked by a β(1→4) bond.) ($C_{12}H_{22}O_{11}$).

3. **Oligosaccharides:** Oligosaccharides (Greek: oligo-few) contain 3 to 10 monosaccharide units linked by a glycosidic bond. These monosaccharides are liberated on hydrolysis. e.g. Maltotriose (a trisaccharide consisting of three glucose molecules linked with α-1,4 glycosidic bonds) ($C_{18}H_{32}O_{16}$), Raffinose (a trisaccharide composed of galactose, fructose, and glucose ($C_{18}H_{32}O_{16}$).

4. **Polysaccharides**: Polysaccharides (Greek: Poly - many) are polymers of monosaccharides containing several (more than ten to millions) monosaccharide units. Example of polysaccharides are starch $(C_6H_{10}O_5)n$, glycogen, cellulose, pectin and glycoprotein.

Polysaccharides

- **Starch** (or **amylum)** is a polymeric carbohydrate consisting of a large number of glucose units joined by glycosidic bonds $(C_6H_{10}O_5)n$. This polysaccharide is produced by most green plants as an energy store. It is the most common carbohydrate in human diets and is contained in large amounts in staple foods such as rice, potatoes, wheat, maize (corn), and cassava.
- **Glycogen** is a multibranched polysaccharide of glucose that serves as a form of energy storage in animals and fungi. In humans, glycogen is made and stored primarily in the cells of the liver and the muscles. Glycogen functions as the secondary long-term energy storage with the primary energy stores being fats held in adipose tissue. Muscle glycogen is converted into glucose by muscle cells, and Liver glycogen converts to glucose for use throughout the body including the central nervous system. Glycogen is the analogue of starch, but is more extensively branched and compact than starch.

Polysaccharides

- **Cellulose** is a polysaccharide with the formula $(C_6H_{10}O_5)n$, and consisting of a linear chain of several hundred to many thousands of β(1→4) linked D-glucose units. Cellulose is an important structural component of the primary cell wall of green plants. Cellulose is the most abundant organic polymer on Earth. The cellulose content of cotton fiber is 90%, that of wood is 40–50%. Cellulose is mainly used to produce paperboard and paper. Cellulose for industrial use is mainly obtained from wood pulp and cotton.
- **Pectin** is a structural heteropolysaccharide contained in the primary cell walls of terrestrial plants. It is produced commercially as a white to light brown powder, mainly extracted from citrus fruits, and is used in food as a gelling agent, particularly in jams and jellies. It is also used in dessert fillings, medicines, sweets, as a stabilizer in fruit juices and milk drinks, and as a source of dietary fiber.

Classification of Carbohydrates

Classification of Monosaccharide: Can be grouped into 2 ways.

1. Based on the functional groups, monosaccharides are divided into different categories, as:

a. Aldoses: Functional group in monosaccharides is an aldehyde (-CHO), known as aldoses. e.g. Glyceraldehyde, Glucose etc.

b. Ketoses: Functional group is ketone (-C=O), referred as ketoses, e.g. Dihydoxyacetone, Fructose etc.

2. Based on the number of carbon atoms, monosaccharides are regarded as:

-trioses (3C), tetroses (4C), Pentoses (5C), hexoses (6C) and heptoses (7C). These terms along with functional groups are used while naming monosaccharide: glucose-aldohexose, fructose-ketohexose

Dietary carbohydrates and their sources

Carbohydrates occur in food as sugars and starch which are the major sources of energy in the diet and as cellulose, the main component of dietary fibre. Plant produces sugar through photosynthesis using sunlight.

Carbohydrates	**Sources**
1. Monosaccharides: **Glucose and fructose**	**Honey, fruits.**
2. Disaccharides: **(i) sucrose** (D-glucose + D-fructose), **(ii) lactose** (D-glucose and D-galactose)	**Sugarcane, sugar beet, fruits, vegetables.** **Milk and other dairy products**
3. Oligosaccharides: **(i) Maltotriose, Rabinose, Raffinose**	**Cereals. Onion, malt, tubers.**
4. Polysaccharides: **(i) Starch and dextrins** **(ii) Cellulose** **(iii) Glycogen** **(iv) Glycoprotein**	**Cereals (rice, white) , roots, tubers,legumes.** **Plant cell wall and fibres,vegetables, fruits,** **Liver and animal tissue.** **Plant cell walls, cereals, nuts, flour and bran.**

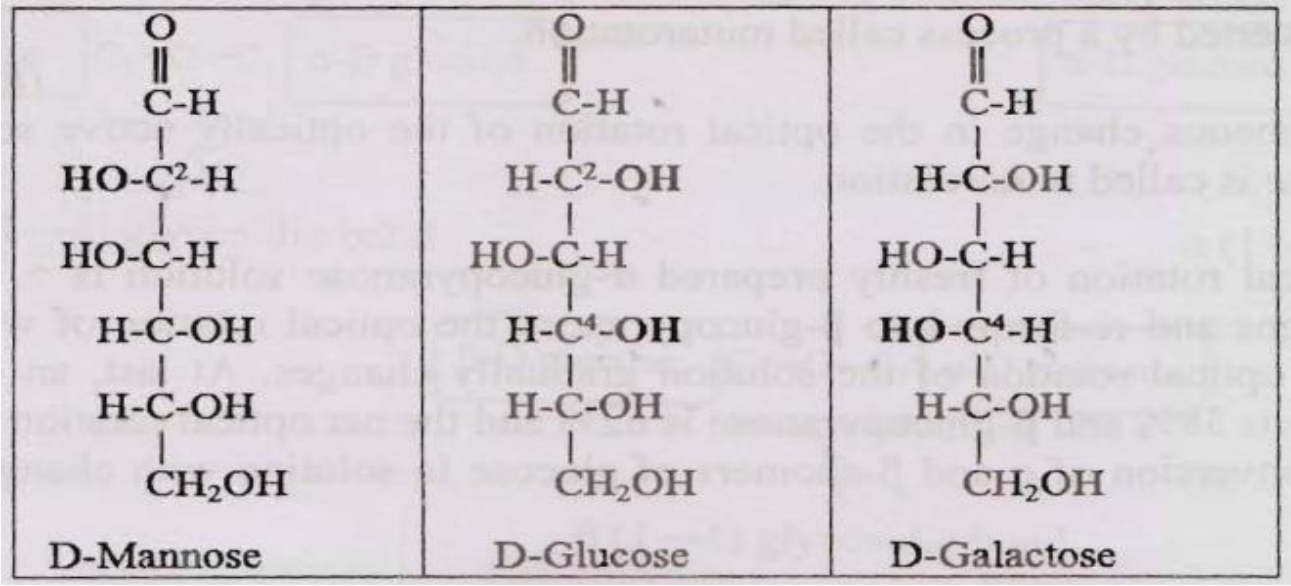
Isomerism and Sugar

Monosaccharide usually shows two types of optical stereoisomerism e.g.

D-L isomerism and α-β anomerism.

D-L isomerism:

- In case of D isomer, the -OH group on the penultimate (second to last) carbon adjacent to the terminal primary alcohol group is on the right side.
- In case of L isomer the -OH group on the penultimate carbon adjacent to the terminal primary alcohol group is on the left side. D-sugar are most common in nature. Our body can metabolize only D-sugars not L sugar.



Isomerism and Sugar

Aldose-Ketose Isomerism:

Isomers having the same molecular formula but different structural formula with either aldehyde or ketone group, are called aldose-ketose isomers.

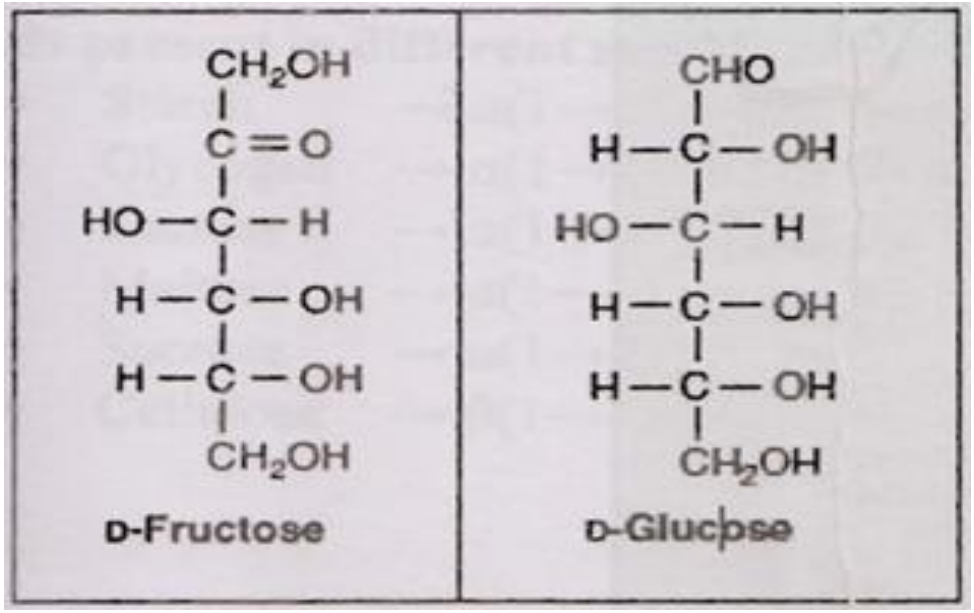


Fig.1 Fructose having ketone functional group

Fig. 2 Glucose having aldehyde functional group

Anomeric carbon (carbonyl carbon)

Anomeric carbon (carbonyl carbon) of sugar is carbon which contains the functional group (aldehyde or ketone group). In case of glucose or galactose it is the 1st carbon and in case of fructose it is the 2nd carbon. The α and β cyclic forms of D-glucose are known as anomers.

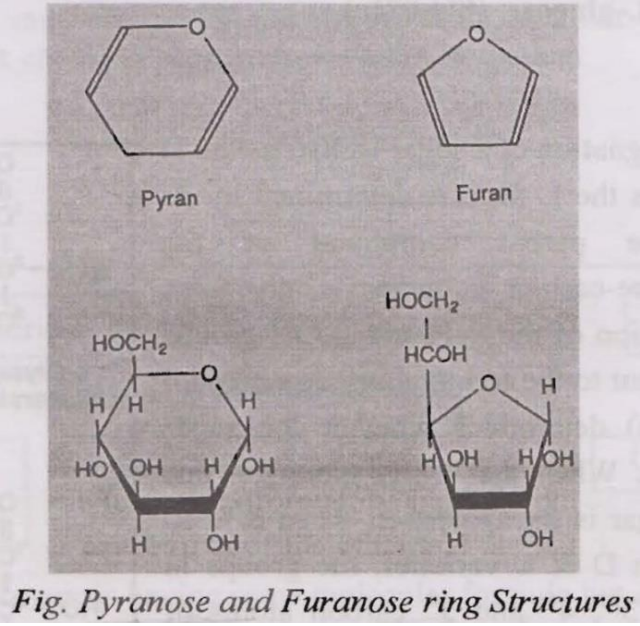
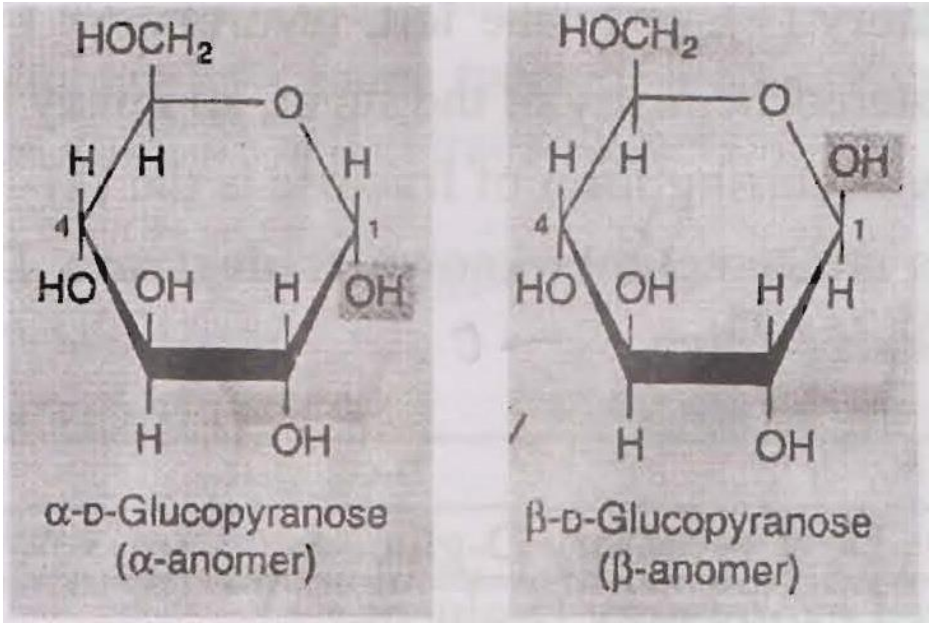
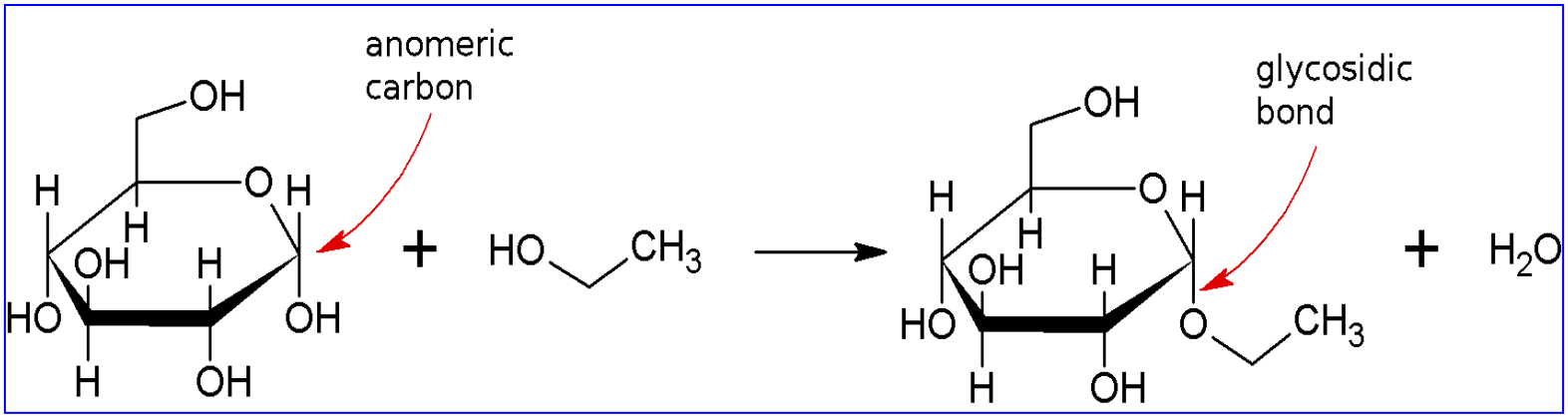


Fig. Pyranose and Furanose ring Structures



Glycosidic Bond

A **glycosidic bond** or **glycosidic linkage** is a type of covalent bond that joins a carbohydrate (sugar) molecule to another group, which may or may not be another carbohydrate.



Formation of ethyl glucoside: Glucose and ethanol combine to form ethyl glucoside and water. The reaction often favors formation of the α glycosidic bond as shown due to the anomeric effect.

The End