

Carbohydrates

Carbohydrates are the most abundant bio molecules that belong to the class of organic compounds found in living organisms. 100 billion metric tons of the CO_2 and H_2O are converted into the cellulose each year. Bio molecules consisting of water and complex polymers of nucleotide, lipids, Carbohydrates and amino acids up to larger extent made living matter. Carbohydrate remain associated with three other polymers mentioned.

- Carbohydrates linked with the proteins forming glycoprotein.
- Carbohydrates linked with the lipid forming glycolipids.
- Carbohydrates are also present in the RNA and DNA that are polymers of D-ribose-phosphate and 2-deoxy-D-ribose phosphate with which bases (purines and pyrimidines) are attached.

Carbohydrates made up more than 75% of the total dry weight of the plant world (particularly lignin, hemicellulose and cellulose).

Before life itself appeared on earth the existence of sugar is confirmed. The possibility of finding the carbohydrate in fossil is almost zero because they are unstable. As they caramelize and char at high temperature and they are capable of dehydrating and combining with the other molecules. It has been known from about a century that much carbohydrate (sugars) formed from formaldehyde in the alkaline solution. The synthesis of sugars may also be promoted at right temperature and pH by UV light and ionization radiation.

In metabolism of living organisms, the role of carbohydrates is well known. The breakdown of carbohydrates (combustion) supplies the principle part of energy that is needed by living organisms for many vital processes.

Definition of Carbohydrates:

Carbohydrates are “polyhydroxylated aldehydes and ketones and their products”. The word “carbohydrate” includes polymers and other compounds synthesized from polyhydroxylated aldehydes and ketones. they'll be synthesized within the laboratory or in living cells.

Simple carbohydrates or the complete carbohydrate family might also be called saccharides. In general carbohydrates have the formula $(\text{CH}_2\text{O})_n$.

They are generated from carbon and hydrate; though some also contain nitrogen, phosphorus, or sulfur. Chemically, carbohydrates are molecules that are composed of carbon, together with hydrogen and oxygen-usually within the same ratio as found in water (H_2O)

They originate as products of photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and also the pigment chlorophyll.



Typical carbohydrates are composed of strings or chains of monosaccharides - that's, the chains of individual sugars.

Classification of carbohydrates:

Carbohydrates are called saccharides or, if they are relatively small, sugars. The compounds carbohydrates have common same functional groups, glyceraldehyde and glucose (classified as aldoses and ribulose) and dihydroxyacetone (are classified as ketoses). With many hydroxyl groups all of these compounds are alcohols. They're polyhydroxylated and either aldehydes or ketones.

Monosaccharide:

The simplest and smallest unit of the carbohydrates is that the monosaccharide, (mono=one, saccharide = sugar) from which are constructed disaccharides, oligosaccharides, and polysaccharides. Monosaccharides are either aldehydes or ketones, with one or more hydroxyl groups

Oligosaccharides:

"A saccharide polymer containing a small number of monosaccharides". An oligosaccharide could be a saccharide polymer containing a little number (typically three to ten) of component sugars, and is

additionally called simple sugars. They're generally found either O- or N-linked to compatible amino alkanolic acid side chains in proteins or to the lipid's moieties. They (homo oligosaccharide and hetero-oligosaccharides) are liberated as intermediate products of saccharification by action of glycosidases on polysaccharides.

Disaccharides:

A disaccharide consists of two monosaccharides joined by an O-glycosidic bond. Sometimes it is classified as a separate group. Disaccharides is homo disaccharide and hetero disaccharide (Fig. 5). Three most abundant disaccharides are sucrose, lactose, and maltose. In sucrose the anomeric carbon atoms of a glucose unit and a fructose unit are joined. Lactose, the disaccharide of milk, consists of galactose joined to glucose by a β (1 \rightarrow 4) glycosidic linkage. In maltose, α (1 \rightarrow 4) glycosidic linkage joins two glucose units.

Sucrose and lactose are hetero saccharide and maltose is homo saccharides.

Trisaccharide:

Raffinose:

Systemic name: β -D-Fructofuranosyl-O- α -D-galactopyrnosyl-(1 \rightarrow 6)- α -D-glucopyranoside Molecular formula: $C_{18}H_{32}O_{11}$

Raffinose may be a trisaccharide composed of galactose, fructose, and glucose. It is found in beans, cabbage, brussels sprouts, broccoli, asparagus, and whole grains. Raffinose are often hydrolyzed to D-galactose and sucrose by the enzyme α -galactosidase (α -GAL), an enzyme not found in humans. α -GAL also hydrolyzes other α -galactosides like stachyose, verbascose, and galactinol, if present.

The enzyme doesn't cleave β -linked galactose, as in lactose. The raffinose families of oligosaccharides (RFOs) are alpha-galactosyl derivatives of sucrose, and therefore the most typical are the trisaccharide raffinose, the tetra saccharide stachyose, and Penta saccharide verbascose. RFOs are almost ubiquitous within the Plantae, being

found during a large type of seeds from many different families, and that they rank second only to sucrose in abundance as soluble carbohydrates. Raffinose is additionally used as a base substance for sucralose. Humans and other monogastric animals (pigs and poultry) don't possess the α -GAL enzyme to interrupt down RFOs and these oligosaccharides pass undigested through the stomach and upper intestine. Within the lower intestine, they're fermented by gas-producing bacteria which do possess the α -GAL enzyme and make carbonic acid gas, methane, and/or hydrogen -- resulting in the flatulence commonly related to eating beans and other vegetables.

Acarbose:

Systematic name: O-4,6-Dideoxy-4-[[[1S-(1 α ,4 α ,5 β ,6 α)]-4,5, 6-trihydroxy-3-(hydroxymethyl)-2-cyclohexen-1yl] amino]- α -D-glucopyranosyl-(1 \rightarrow 4)-O- α -D-glucopyranosyl-(1 \rightarrow 4)-D-glucose. Molecular formula: C₂₅H₄₃NO₁₈

Acarbose is an anti-diabetic drug accustomed treat type 2 diabetes and, in Some countries, prediabetes. It's an inhibitor of alpha glucosidase, an enteric. Enzyme that releases glucose from larger carbohydrates

Application:

- The functional oligosaccharides, act as nutrients for bifido bacteria, and the lactobacilli. Isomaltooligo-saccharides increase cecal Bifido bacterium population and soybean meal oligosaccharides (SMO) promote competitive exclusion of potential pathogens.
- The Bifidogenic bacteria transform soluble indigestible oligosaccharide to organic acids, mainly short-chain fatty acids (SCFA) like acetic, and n-butyric acids, being fermentable, improve gastrointestinal health. Acetate and propionate show anti-cholesterolemic effect; while butyrate prevents the proliferation of gut epithelial cells, showing anti-carcinogenic property.

Recent development of business prebiotic oligosaccharides and probiotic Bacteria generated the symbiotic concept. Probiotic yogurts are fortified with the prebiotic oligosaccharides to learn gut health. Probiotics suppress pathogenic microbes by lowering pH of big intestine, produce vitamins

(B complex, folic acid) and stimulate the system.

- Lacto-bacilli form biofilm on surface of vaginal mucosa and protect it pathogens. Qualit asfructo oligosaccharides (FOS) and (GOS) avoid urogenital infections by promoting p lactobacilli.

Polysaccharide:

Polysaccharides are relatively complex carbohydrates. They're polymers made of many monosaccharides joined together by glycosidic bonds. They are, therefore, very large branched, macromolecules. They have an inclination to be amorphous, insoluble in water, and haven't any sweet taste.

When all the monosaccharides during a polysaccharide are of identical type. The polysaccharide is named a homopolysaccharide and when quite one kind of monosaccharide is present, they're called heteropolysaccharides. Examples include storage polysaccharides like starch and glycogen and the structural polysaccharides like cellulose, and chitin. Xylan a hemicellulose could be a heteropolysaccharide. Polysaccharides have a general formula of $C_n(H_2O)_{n-1}$ where n may be any number between 200 and 2500. Considering that the repeating units within the polymer backbone are often six-carbon monosaccharides, the overall formula also can be represented as $(C_6H_{10}O_5)_n$ where $n = \{40...3000\}$

Polysaccharides, also called glycans, differ from each other in the identity of their recurring monosaccharide units, within the length of their chains, within the styles of bonds linking the units, and within the degree of branching.

They may be classified as homopolysaccharides and heteropolysaccharides counting on the variability of sugar meioties to the sugar chain. Some are linear polymers et al are branched.

Some typical polysaccharides are starches, glycogens celluloses, agar, gum chitin. Some homopolysaccharides function storage types of monosaccharides used as fuels. Starch and glycogen are homopolysaccharides of this kind. Other homopolysaccharides (cellulose and chitin) function structural elements in Plant cell walls and animal exoskeletons. Hetero polysaccharides provide extracellular support for organisms of all kingdoms.

The rigid layer of the bacterial cell envelope (the peptidoglycan) may be a heteropolysaccharide built from two alternating monosaccharide units. In

animal tissues, several heteropolysaccharides, occupy the extracellular space forming a matrix that holds individual cells together and provides protection, shape, and support to cells, tissues, or organs. Hyaluronic acid accounts for the toughness and suppleness of cartilage and tendon, is among this group of extracellular polysaccharides. Other heteropolysaccharides, sometimes in very large aggregates with proteins (proteoglycans), account for the high viscosity and lubricating properties of some extracellular secretions.

Unlike proteins, polysaccharides generally don't have definite molecular weights, due to consequence of the mechanisms of assembly of the 2 styles of polymers.

Proteins are synthesized on a template (messenger RNA) of defined sequence and length, by enzymes that copy the template exactly. For polysaccharide synthesis with no template; the program for polysaccharide synthesis is intrinsic to the enzymes that catalyze the polymerization of monomeric units. For every form of monosaccharide to be added to the growing polymer there is a separate enzyme, which acts only after the enzyme that inserts the preceding subunit has acted. The alternating action of several enzymes produce a polymer with a precise repeating sequence, but the precise length varies from molecule to molecule, within a general size class.

1. Homopolysaccharides:

A homopolysaccharide is formed of one quite mono-saccharide.

Starches, glycogens, and celluloses, which are made of only glucose residues, are example of homopolysaccharides.

i) Starch:

The starches occur widespread as reserve carbohydrate in tubers like potatoes, in many fruits, grains and seeds. Within the grains, the starch is arranged in the concentric layers. When Starch grains are treated with boiling water, the substance within the center passes into solution, but the greater part of the grain is not soluble.

This insoluble portion swells because it absorbs water and also the whole mass becomes starch paste. Both the soluble portion and the insoluble portion are heterogeneous mixtures.

The soluble fraction is observed as amylose, and the insoluble fraction as amylopectin. Most starches contain 80-90 per cent amylopectin and 10—20 per cent amylose. Amylose and amylopectin are often separated by taking advantage of the difference in solubility in water. Both amylose and amylopectin are polymers of glucose and upon hydrolysis with acid they furnish D-glucose like a product.

Structure of amylose: Amylose is an unbranched long chain polymer with in which the glucose residues are linked through α -1, 4- glycosidic linkages.

The amylose structure could be regarded as a repeated maltose structure with a free sugar group at one end.

This is also referred to as the reducing end, whereas, the alternating end (first residue) observed to as the non-reducing end. Any particular preparation of amylose usually consists of combination of populations of molecules, which differ widely in chain length.

Amylopectin structure:

Amylopectin additionally product of chains of glucose residues, but chains are highly branched. Glucose residue situated at the branching point is substituted not only on carbon 4 but also on carbon 6. Both amylose and amylo-pectin gives characteristic color reactions with iodine. Amylose produces a blue-black color, whereas, amylopectin gives a purple color.

- **Cellulose:**

Cellulose is the most abundant chemical compound in nature and it is the chief constituent of the fibrous parts of plants. The purest sort of cellulose is sometimes obtained from cotton. Cellulose could be a polymer made from glucose residues.

Upon hydrolysis, cellulose yields D- glucose as product. Cellulose preparations may contain trace amounts of arabinoxylans

Molecular structure: Cellulose is an insoluble molecule consisting of between 2000 - 14000 residues with some preparations being somewhat shorter.

It forms crystals (cellulose I α) where intra-molecular (O3-H O5' and O6 H-O2') and intra-strand (O6-H O3') hydrogen bonds holds the network flat allowing the more hydrophobic ribbon faces to stack.

Each residue is oriented 180° to the following. . Although individual strand of cellulose is intrinsically no less hydrophilic, or no more hydrophobic, than other soluble polysaccharides (amylose) this tendency to create crystals utilizing intra-and intermolecular hydrogen bonding makes it completely insoluble in normal aqueous solutions. It is thought that water molecules catalyze the formation of the natural cellulose crystals by helping to align the chains through hydrogen-bonded bridging. Part of a cellulose preparation amorphous between these crystalline sections.

The structure is of aggregated particles with extensive pores capable of holding relatively large amounts of water by capillarity. The natural crystal is formed up from metastable Cellulose I with all the cellulose strands parallel and no inter-sheet hydrogen bonding. This cellulose I (natural cellulose) contains 2 coexisting phases cellulose I α (triclinic) and cellulose I β in varying proportions passionate about its origin.

Function –it is that the structural component of the primary cell wall of green plants, (first plasma membrane) many styles of algae and the oomycetes.

- **Glycogen:**

Glycogen is that reserve carbohydrate in animals and it found in significant amounts in the liver and muscle. Glycogen is created of D-glucose residues. Upon hydrolysis, it yields D-glucose as product. Glycogen could be a highly branched chain polysaccharide and it resembles amylopectin in structure.

Thus, glucose residues linked together through α -1,4-glycosidic linkages at the branch points. The branch is linked to the main chain through α -1,6-glycosidic linkages.

Its very kind of like the structure of amylopectin.

- The average molecular weights of glycogen preparations vary from 270,000 to 100,000,000.
- A single preparation usually consists of a combination of populations of molecules that differ in molecular weight. In the structure of glycogen, O represents glucose residues. The arrows indicate the α -1 \rightarrow 6 glycosidic linkage. All the opposite glycosidic linkage is α -1,4. The asterisks indicate the non-reducing end groups. strands for reducing end group. In a big selection of organisms, excess glucose is stored not as monomer but converted to polymeric forms for storage—glycogen in vertebrates and plenty microorganisms, starch in plants.

With two minor differences, glycogen has almost the identical structure as amylopectin (a constituent of starch). The glycogen molecule is roughly twice large as amylopectin, and branching frequency—that also controls mobilization of stored polysaccharide.

Glycogen has roughly twice as many branches (branching occurs on a mean after every 8-12 residues unlike amylopectin where it's after every 24-30 residues).

- There's an advantage to branched polysaccharides like amylopectin. During times of shortage, enzymes attack one end of the polymer chain and top glucose molecules, one at a time.

More the branches, more the points at which the enzyme attacks polysaccharide. Thus, a highly branched polysaccharide is best suited to the rapid release of glucose than a linear polymer.

- **Chitin:**

Chitin could be a linear homo polysaccharide composed of N-acetyl-D-glucosamine residues β -linkage. The sole chemical difference from cellulose is that replacement of a hydroxyl group at C-2 with an acetylated amino. Chitin forms extended fibers kind of like those of cellulose, and structure of glycogen. Chitin like cellulose is indigestible by vertebrate animals.

It is the most important component of cell walls of fungi, exoskeletons of arthropods, such as crustaceans (like the crab, lobster and shrimp) and the

insects, including ants, beetles and butterflies, the radula of mollusks and the beaks of the cephalopods, including squid and octopuses. Chitin is probably the second most abundant polysaccharide next to cellulose, in nature.

2: Heteropolysaccharides:

A heteropolysaccharide is created of two or more different monosaccharides, or monosaccharide derivatives.

- **Agar:**

Agar could be a gelatinous substance. Chiefly used as a solid substrate to culture medium for microbiological work. It is an unbranched polysaccharide obtained from the cell membranes of species of red algae or seaweed. Agar could be a polymer made of subunits of the sugar galactose. Agar polysaccharides function the first structural support for the algae's cell walls. Agar is a heterogeneous mixture of two classes of polysaccharide:

agaropectin and agarose.

- **Agarose:**

Certain marine red algae, including number of seaweeds, have cell walls that contain agar, combination of sulfated heteropolysaccharides made of D-lactose and an L-galactose derivative ether-linked between C-3 and C-6. The 2 major components of agar are unbranched polymer agarose and branched component, agaropectin. The remarkable gel-forming property of agarose makes it useful in the biochemistry.

- **Xylan:**

Lignocelluloses in kingdom plantae are composed of cellulose, hemicellulose and lignin. 15-30% of the lignocellulose is hemicellulose, xylan is that the main component. They are almost as good as cellulose in plant-cell walls and contain predominantly beta-D xylose units linked as in cellulose. It could be a heteropolysaccharide found with in plant cell walls and some algae.

It's found in most parts of the plant, in the cell walls of some green algae, especially macro phytic siphonous genera, where it replaces cellulose.

It replaces the inner fibrillar cell-wall layer of cellulose in some red algae. Xylans are polysaccharides mainly having backbone of 1,4 beta-linked xylose. The backbone is branched with sugars like glucose, arabinose, acetylated sugars esters through alpha linkage. Xylans are of little commercial importance, but being related to cellulose, forms an element of sugar hydrolysis project to be converted to alcohol and other value added products.

Application:

Polysaccharides from renewable and sustainable sources, like food and agricultural wastes, can play good role within the emerging biobased economy, for example the new economy system shifting from fossil resources of energy and chemicals to renewable resources like biomass. Indeed, the wide range of structures and biological functions of polysaccharides that may be recovered from agro-wastes make them biotechnologically useful biopolymers that either are already exploited for several purposes or are under investigation for brand spanking new applications.

Health Benefits

- The health benefits of functional oligosaccharides are well known and much researching Starting from use in nutaceutical, pharmaceutical, prebiotics, cosmetics, animal feed and agriculture sector, oligosaccharides have benefits for everybody.
- As their ever-increasing demand oligosaccharides are subjected to an intensive and cutting-edge research during the last three decades. Potential markets for oligosaccharides in future are expected to trigger a significant boom across the world.
- Vegetable biomass is one among the foremost promising renewable sources of energy and chemicals. Its exploitation for biofuel and commodity chemicals is

indeed, the main focus of continuous researches since many years. Within the last few years the gradual shift toward the so-called biobased economy (an economy system supported exploitation of renewable resources like biomass) has determined a global increasing demand for goods derived mainly from polysaccharide components of vegetable biomass.