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[Agrawal, 6(6): June 2019] ISSN 2348 – 8034
IDSTM-2019 Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

CARBOHYDRATES

Bandana Agrawal
Assistant Professor , Department: Applied Science And Humanities Ganga Technical Campus, Bahadurgarh

ABSTRACT

Carbohydrates are the major source of metabolic energy, both for animals and plants that depend on food. Carbohydrates intake can take place in different forms like sugar, starch, fibres, etc. and the oxidation of carbohydrates is the central energy yielding pathway in most non photosynthetic organisms. Carbohydrates are present in DNA and RNA. In this review article, monosaccharides, disaccharides, trisacharides, raffinose, sucrose, maltose, lactose, starch, agar and previous study on carbohydrates has been given along with diagrams including

Keywords: *Monosaccharides, disaccharides, trisaccharides, polysaccharides, research study,*

I. INTRODUCTION

The carbohydrates are a major source of metabolic energy, both for plants and for animals that depend on plants for food. Carbohydrates are linked with amino acid polymers (proteins) forming glycoproteins and with lipids as glycolipids. Carbohydrates are present in DNA and RNA, Carbohydrates are polyhydroxylated aldehydes or ketones and their derivatives. Carbohydrate includes polymers and other compounds synthesized from polyhydroxylated aldehydes and ketones. They can be synthesized in the laboratory or in living cells. Simple carbohydrates or the entire carbohydrate family may also be called saccharides. of living organisms. Carbohydrates also serve as a structural material (cellulose), a component of the energy transport compound ATP, recognition sites on cell surfaces, and one of three essential components of DNA and RNA. Carbohydrates are classified as monosaccharides, disaccharides, trisaccharides, polysaccharides. Monosaccharides cannot be hydrolysed further into simpler form. Disaccharides give two monosaccharides on hydrolysis. Polysaccharides may be homopolysaccharides and heteropolysaccharides.

1. Monosaccharides:

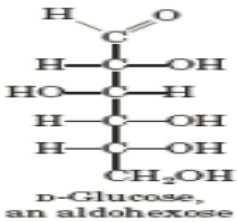
Monossaccharides cannot be hydrolysed further into simpler form of carbohydrates and are easily absorbed in intestine. Monosaccharides are either aldehydes or ketones, with one or more hydroxyl groups. The most important carbohydrate in human body is glucose which is found in blood.

Monosaccharides	Aldo form	Keto form
Trioses	Glyceraldehydes	Dihydroxyacetone
Tetroses	Erythrose and Threose	Erythrulose
Pentoses	Arabinose, Lyxose, Ribose and Xylose	Ribulose and Xylulose
Hexoses	Allose, Altrose, Galactose, Glucose, Gulose, Idose, Mannose and Talose	Fructose, Psicose, Sorbose and Tagatose
Heptoses	NA	Mannoheptulose, Sedoheptulose
Octoses	NA	2-Keto-3-deoxy-manno-octonate
Nonoses	NA	Sialose

a. **Glucose**:

Systemic name: D-Glucose

Molecular formula: $C_6H_{12}O_6$

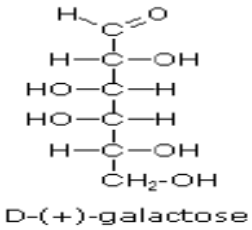


Glucose, a monosaccharide is a source of energy and metabolic intermediate and main products of photosynthesis and starts cellular respiration in both prokaryotes and eukaryotes.

b. Galactose

Systemic name: D-Galactose

Molecular formula: $C_6H_{12}O_6$

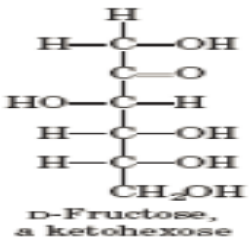


Galactose is less sweet than glucose and not very water-soluble. Galactose is commonly found in lactose, peas. Galactose is classified as an aldose, a hexose, and is a reducing sugar. It is considered a nutritive sweetener because it has food energy. A genetic defect of not being able to utilize galactose is called Galactosemia. Galactose builds up in the blood and urine. Undiagnosed it may lead to mental retardation, failure to grow, formation of cataracts, and death by liver damage.

c. Fructose:

Systemic name: D-Fructose

Molecular formula: $C_6H_{12}O_6$



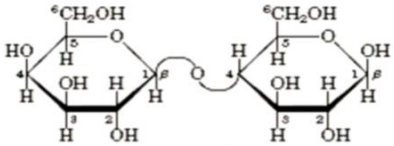
Fructose is a simple reducing sugar found in many foods. Honey, tree fruits, berries, beetroots, sweet potatoes, contains fructose. It is also derived from the digestion of sucrose. It a disaccharide consisting of glucose and fructose that is broken down by glycoside hydrolase enzymes. Fructose is the sweetest naturally occurring sugar. Fructose is consumed by people with diabetes mellitus or hyperglycemia, as it has a very low glycemic index relative to cane sugar due to the unique and lengthy metabolic pathway of fructose.

Hemiacetal:
Aldehyde reacts with an alcohol to form a hemiacetal.

Hemiketal:
A ketone reacts with an alcohol to form a hemiketal.

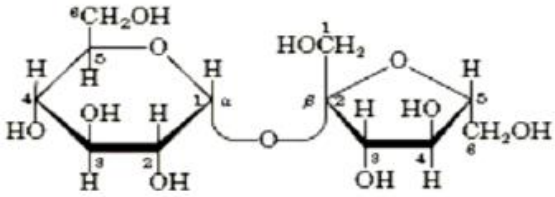
2. Disaccharides
Disaccharides consists of 2 monosaccharides that are linked by 0-glycosidic linkage which is formed by a condensation reactions that takes place between two sugar units with loss of hydrogen atom. Three abundant disaccharides are lactose, sucrose, and maltose.

a. Lactose:
Systematic name: 4-O- β-D-galactopyranosyl-D-glucose
Molecular formula: $C_{12}H_{22}O_{11}$



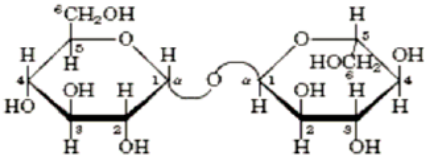
Lactose is also called milk sugar. It consists of β-D-galactose and β-D-glucose fragments bonded through a β(1↔4) glycosidic linkage. Children with lactose intolerance can be assisted clinically by dietary lactose elimination, use of lactase treated dairy products, and limitation of lactose containing food products.

b. Sucrose:
Systematic name: D-glucopyranosyl-(1↔2)-β-D-fructofuranoside
Molecular formula: $C_{12}H_{22}O_{11}$



Sucrose consists of glucose and fructose. It is easily assimilated macronutrient that provides energy to the body with rapid rise in blood glucose upon ingestion. High percentage of sucrose increase risks for chronic disease like defect in glucose metabolism or diabetes mellitus. A study was done on rats in which rats were fed diet containing two third of sucrose, initially triglyceride level was increased and later on insulin resistance was developed. In another study rats were fed sucrose rich diets that developed hypertriglyceridemia, hyperglycaemia and insulin.

c. Trehalose:
Systemic name: α-D-glucopyranosyl- α-D-glucopyranoside
Molecular formula: $C_{12}H_{22}O_{11}$

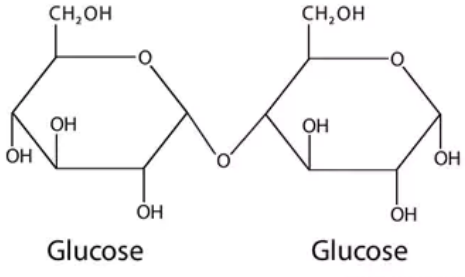


Trehalose is also called mycose synthesized by fungi, plants and animals. It is formed by α, α-1, 1-glucoside bond between two α-glucose units. It can be synthesised by fungi, plants and invertebrates animals. It is metabolised by no. of bacteria. Enzyme trehalose, a glycoside hydrolase, breaks trehalose into two glucose molecules which can then be readily absorbed in the gut. Trehalose is used by insects for flight for rapid energy requirement of flight.

d. Maltose :

Systemic name: 4-O-α -D-glucopyranosyl-D-glucose

Molecular formula: $C_{12}H_{22}O_{11}$



Maltose is also called malt sugar formed from two units of glucose joined with α(1→4) linkage. Maltase is hydrolysed by maltase in intestine. It occurs in body as an intermediate product of starch digestion.

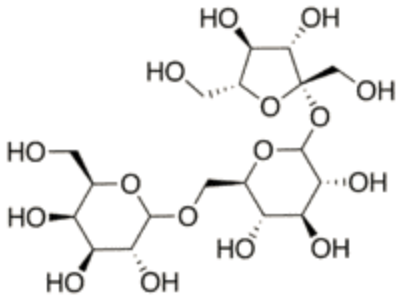
3. Trisaccharides:

Trisaccharides consists of three monosaccharides that are linked by 0-glycosidic linkage which is formed by a condensation reactions that takes place between three sugar units with loss of hydrogen atom.

a. Raffinose:

Systemic name: β-D-Fructofuranosyl-O-α-D-galactopyrnosyl-(1→6)- α-D- glucopyranoside

Molecular formula: $C_{18}H_{32}O_{11}$

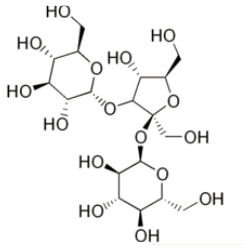


Raffinose consists of galactose, fructose, and glucose. It is found in beans, cabbage, Brussels, broccoli. It is used as base substance for sucralose.

b. Melezitose:

Systemic name: O- α -D-glucopyranosyl-(1→3)- β-D- fructofuranosyl- α-D-glucopyranoside

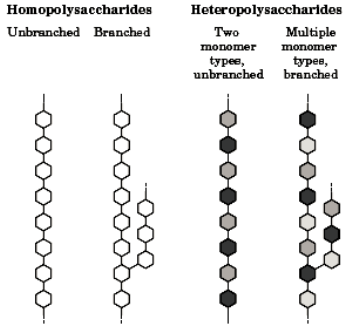
Molecular formula: $C_{18}H_{32}O_{16}$



Melezitose is produced from lice Cinara pilicornis by an enzyme reaction. It can be partially hydrolysed to glucose and turanose.

4. Polysaccharides

Carbohydrates composed of ten or more monosaccharides units joined by glycosidic linkage. They are also called glycans. Some typical polysaccharides are starch, glycogen, cellulose, agar, etc. They do not have sweet taste.



a. Starch:

Starch is storage form of glucose in body. It contains of amylase (10-20%) and amylopectin (80-90%). It gives blue colour with iodine solution. In starch linkage between glucose residues 1-4 and at branch point linkage is of 1-6.

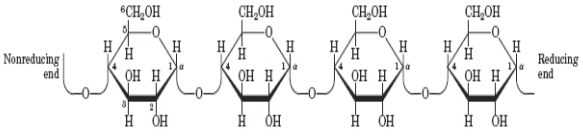


fig: AMYLOSE

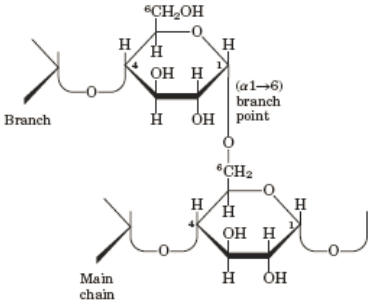
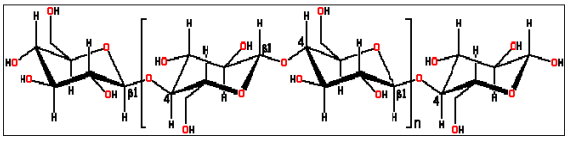


fig: AMYLOPECTIN

b. Cellulose:

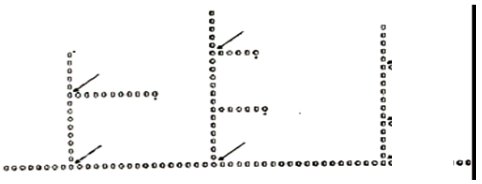
Cellulose is polymer made up of glucose residues. Cellulose is a linear polymer of β-(14)-D-glucopyranose units in $^4C_1$ conformation. These molecules are not branched but consist of long chain with glucose residues linked in

repeating sequence of cellobiose structures. It is structural component of primary cell wall of green plants many forms of algae and oomycetes.



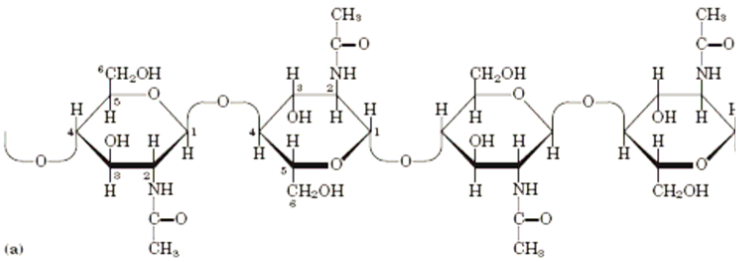
c. Glycogen:

Glycogen is made up of D-glucose residue, resembles amylopectin in structure. These residues are linked through except at branch points. The main difference between amylopectin and glycogen is that glycogen has more and shorter branches resulting in more compact, bush like molecule with less viscosity and greater solubility.



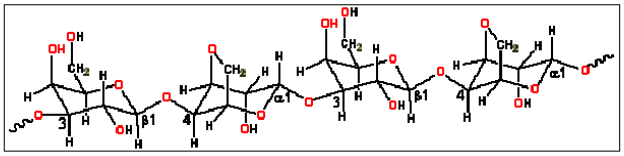
d. Chitin:

Chitin is a linear homopolysaccharide composed of N-acetyl- D-glucosamine residues in β-linkage. The difference between chitin and cellulose is replacement of hydroxyl group a C-2 with acetylated amino group. It is used in water purification additive to thicken and stabilise foods and pharmaceuticals also acts as a binder in dyes, fabrics and adhesives.



e. Agar:

Agar is gelatinous substance that is unbranched polysaccharide obtained from cell membrane of some species of red algae or sea weed. Agarose is composed of agarobiose repeating disaccharide units alternating with 1, 3-linked-β-D-galactopyranose and 1, 4-linked-3, 6-anhydro-α-L-galactopyranose.



II. DISCUSSION

Carbohydrates are commonly classified as monosaccharides, disaccharides, oligosaccharides, trisaccharides and polysaccharides. In animals, carbohydrates are quickly accessible reservoir of energy. Plants produce carbohydrates by photosynthesis. The main function of carbohydrates is to provide energy as well and important role in structure and function of body organs and nerve cells.

Why do cancers have high aerobic glycolysis?

The process of breakdown of glucose by enzymes, releasing energy and pyruvic acid is called glycolysis.If carcinogenesis occurs by somatic evaluation, then common components of the cancer phenotype result from active selection and confer a significant growth advantage. A near universal property of primary and metastatic cancers is up-regulation of glycolysis, resulting in increased glucose consumption, which can be observed with clinical tumour imaging. It has been evaluated that persistent metabolism of glucose to lactate even in aerobic conditions is an adaption to intermittent hypoxia in pre-malignant lesions. However, up-regulation of glycolysis leads to micro-environmental acidosis requiring evolution to phenotypes resistant to acid-induced cell toxicity. Subsequent cell populations with up-regulated glycolysis and acid resistance have a powerful growth advantage, which promoted unconstrained proliferation and invasion.

Glycolysis links p53 function with NF-κB signalling: Impact on cancer and aging process

In 1930, Otto Warburg observed the cancer cells produce an increased amount of their energy through aerobic glycolysis and subsequently, this was called the Warburg effect. During ageing, the capacity for mitochondrial respiration clearly declines and aerobic glycolysis appears to compensate for the deficiency in oxidative metabolism. This shift in energy production, both in aging and cancer, could protect from the toxic effects of oxygen free radicals whereas increased glycolysis can have adverse effects. It was recently demonstrated that the glycolysis-linked protein glycosylation can potentiate the catalytic activity of IKKβ and subsequently trigger NF-κB signalling. It seems that tumor suppressor oncogene p53 has an important role in the regulation of protein O-glycosylation since p53 is a potent inhibitor of glycolysis protein expression. Aging is known to repress the function of p53 and this could enhance glycolysis and NF-κB signalling.

Roles of p53, Myc and HIF-1 in Regulating Glycolysis— the Seventh Hallmark of Cancer

Despite diversity in genetic events in oncogenesis, cancer cells exhibit a common set of functional characteristics. Otto Warburg discovered that cancer cells have consistently higher rates of glycolysis than normal cells. The underlying mechanisms include mitochondrial changes, upregulation of rate-limiting enzymes/proteins in glycolysis and intracellular pH regulation, hypoxiainduced switch to anaerobic metabolism, and metabolic reprogramming after loss of p53 function. The regulation of energy metabolism can be traced to a "triad" of transcription factors: c-MYC, HIF-1 and p53. Glycolysis in cancer cells has clinical implications in cancer diagnosis, treatment and interaction with diabetes mellitus. Many drugs targeting energy metabolism are in development.

Evolution of the coordinate regulation of glycolytic enzyme genes by hypoxia

Two billion years of aerobic evolution have resulted in mammalian cells and tissues that are extremely oxygen dependent. Exposure to oxygen tensions outside the relatively narrow physiological range results in cellular stress and toxicity. Consequently, hypoxia features prominently in many human diseases, particularly those associated with blood and vascular disorders, including all forms of anaemia and ischemia. Bioenergetic enzymes have evolved both acute and chronic oxygen sensing

Mechanisms to buffer changes of oxygen tension; at normal PO oxidative phosphorylation is the principal energy supply for eukaryotic cells, but when the PO falls below a critical mark metabolic switches turn off mitochondrial electron transport and activate anaerobic glycolysis. Without this switch cells would suffer an immediate energy deficit and death at low PO. An intriguing feature of the switching is that the same conditions that regulate energy metabolism also regulate bioenergetic genes, so that enzyme activity and transcription are regulated simultaneously, albeit with different time courses and signaling pathways (Keith, 2003)

Glycolysis and Proteases as Targets for the Design of New Anti- Trypanosome Drugs

Glycolysis is considered as a promising target for new drugs against parasitic trypanosomatid protozoa as this pathway plays an essential role in their ATP supply. Structure- and catalytic mechanism-based approaches are applied to design compounds that inhibit the glycolytic enzymes of the parasites without affecting the corresponding proteins of the human host. For some trypanosomatid enzymes, potent and selective inhibitors have already been developed that affect only the growth of cultured trypanosomatids, and not mammalian cells. Concerning cysteine protease inhibitor development, a great number of irreversible alkylating agents have shown their efficacy towards

the active site cysteine of parasite proteases. This includes fluoromethylketones, epoxides, diazomethylketones, and vinylsulfones to mention a few. These functional groups are activated electrophiles that react with the nucleophilic cysteine of the active site and are generally quite selective for cysteine versus serine and thiols. This potentially hampering property seems not to be detrimental for two reasons: first a recent report has shown that cysteine protease inhibitors containing a vinylsulfone electrophile are uncreative towards thiols such as glutathione and can be considered to be inert in the absence of catalytic machinery. Secondly, irreversible inhibitors are shown to be less toxic than presumed in the parasite treatment, owing to some bioselectivity displayed by the parasite itself.

Phylogenetic Analysis of Glycolytic Enzyme Expression

Phylogenetic analysis of the expression of the glycolytic enzymes among 15 taxa of a North American fish genus (Fundulus) indicated that most variation in enzyme concentration is due to evolutionary distance and may be no adaptive. Additionally, two pairs of enzymes ovary, indicating coevolution. Thus, metabolic flux may be modulated by many different enzymes rather than by a single rate-limiting enzyme.

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Mulk Memorial Hospital, Hamdard University, Karachi, Pakistan. 3University College of Pharmacy, Punjab University, Lahore.