Chemistry and metabolism of carbohydrates pdf

1. Carbohydrates Compiled and Edited by Dr. Syed Ismail Associate Professor, SSAC College of Agriculture, VN MKV Parbhani 1 2. Carbohydrates Carbohydrates are broadly defined as polyhydroxy aldehydes or ketones and their derivatives or as substances that yields one of these compounds Composed of carbon, hydrogen, and oxygen Functional groups present include hydroxyl groups -ose indicates sugar 2 3. Carbohydrates are the most abundant of all the organic compounds in nature. In plants, energy from the Sun is used to convert carbon dioxide and water into the carbohydrate glucose. Many of the glucose molecules are made into long-chain polymers of starch that store energy. About 65% of the foods in our diet consist of carbohydrates. Each day we utilize carbohydrates in foods such as bread, pasta, potatoes, and rice. Other carbohydrates called disaccharides include sucrose (table sugar) and lactose in milk. During digestion and cellular metabolism, carbohydrates are converted into glucose, which is oxidized further in our cells to provide our bodies with energy and to provide the cells with carbon atoms for building molecules of protein, lipids, and nucleic acids. In plants, a polymer of glucose called cellulose builds the structural framework. Cellulose has other important uses, too. The wood in our furniture, the pages in your notebook, and the cotton in our clothing are made of cellulose. 4. Function of Carbohydrates in Cells Major source of energy for the cell Major structural component of plant cell Immediate energy in the form of GLUCOSE Reserve or stored energy in the form of GLYCOGEN Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani 4 5. Classification of Carbohydrates • Carbohydrates are classified according to the number of subunits that make them up 3 Types of Carbohydrates Monosaccharides Oligosaccharides Disaccharides Trisaccharides Tetrasaccharides Polysaccharides Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani 5 6. Monosaccharides are simple sugars, or the compounds which possess a free aldehyde (CHO) or ketone (C=O) group and two or more hydroxyl (OH) groups. They are the simplest sugars and cannot be hydrolysed further into smaller units. Monosaccharides contain a single carbon chain and are classified on the basis of number of carbon atoms they possess, and as aldoses or ketoses depending upon their groups. 6 7. Monosaccharides Classification by Carbon Atoms Sugar Structure formula Aldoses Ketoses 1. Triose C3H6O3 Glyceraldehydes Dehydroxy acetone 2. Tetroses C4H8O4 Erythrose, Threose Erthrulose 3. Pentoses C5H10O5 Xylose Ribose Arabinose Ribulose 4. Hexoses C6H12O6 Glucose Galactose Mannose Fructose 7 8. Monosaccharides Glucose Hexoses • D-glucose “dextrose” Blood sugar Fructose: Seldom occurs freely in nature • The sweetest of all sugars – (1.5 X sweeter than Binds with glucose to form sugar sucrose) in milk: lactose. Once absorbed by the body, • Occurs naturally in fruits and galactose is converted to glucose honey “the fruit sugar” to provide energy. Galactose The essential energy source for all body functions. Other names: Dextrose and Blood Sugar. A component of each disaccharide. D-galactose Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani D-fructose “Levulose” Fruit sugar 8 9. Steriochemistry Optical isomers (= enantiomers) differ from each other in the disposition of the various atoms or groups of atoms in space around the asymmetric carbon atom. These are, in fact, the mirror image of each other. These may also be likened to left- and right-handed gloves. One form in which H atom at carbon 2 is projected to the left side and OH group to the right is designated as D-form and the other form where H atom is projected to the right side and OH group to the left is called as L-form (note the use of small capital letters D and L) For example, the glyceraldehyde has only one asymmetric carbon atom (numbered as 2) and it can, therefore, exist in 2 isomeric forms : 9 Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani 10. D-Aldoses containing three , four , five and six atoms 10 11. Properties of monosaccharides 1. Mutarotation : when a monosaccharide is dissolved in water, the optical rotatory power of the solution gradually changes until it reaches a constant value. For ex : when Dglucose is dissolved in water, a specific rotation of +112.2o is obtained, but this slowly changes , so that at 24h the value has become +52.7o. This gradual change in specific rotation is known as mutarotation. This phenomenon is shown by number of pentoses, hexoses and reducing disaccharides. 2. Glucoside formation : when D-glucose solution is treated with methanol and HCl, two compounds are formed, these are α – and β-D- glucosides. Thus, formed glucosides are not reducing sugar and also doesnot show phenomenon of mutarotation 3. Reducing power : Sugars having free or potentially free aldehyde or ketone group have an ability to reduce the cupric copper to cuprous Reducing sugar + 2 Cu++ (cupric) oxidized + 2Cu+ sugar (cuprous) 4. Oxidation / Reduction: The alcoholic OH, aldehyde (COH) or keto (C=O) group are oxidized to carboxyl group with certain oxidizing agents. The oxidation may be brought under mild or with vigorous oxidizing condition i. With mild oxidant like BrH2O : In this group only aldehyde is oxidized to produce gluconic acid (monocarbonic). Ketoses do not respond to this reaction. Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani 11 12. ii. With strong Oxidizing agent like Conc HNO3 : Both aldehyde or ketone groups are oxidized to yield dicarboxylic acids iii. Oxidation with metal hydroxides: Metal hydroxides like Cu(OH)2, Ag OH oxidize free aldehyde or ketone group of mutarotating sugar and reduce themselves to lower oxides of free metals Reduction: The aldehyde or ketone group present can be reduced to its respective alcohol with sodium amalgum. For ex: Fructose and glucose give the hexahydric alcohol i.e. Sorbitol and Mannitol Dehydration : The monosaccharides when treated with Conc H2SO4, it get dehydrated to from 5 – hydroxyl – methyl furfural derivative Methylation or Esterification : The glucosidic and alcoholic OH group of mono saccharides and reducing disaccharides react with acetylating agent like acetic anhydride in pyridine to from acetate derivatives called esters. 12 13. Carbohydrates with free carbonyl groups or in hemiacetal form give positive tests to Benedict’s and Fehling’s reagents without having been hydrolyzed are referred as ‘reducing’ sugars ; others (i.e., the acetal types) are then ‘non-reducing’ sugars 14. Oligosaccharides These are compound sugars that yield 2 to 10 molecules of the same or different monosaccharides on hydrolysis. Accordingly, an oligosaccharide yielding 2 molecules of monosaccharide on hydrolysis is designated as a disaccharide, and the one yielding 3 molecules of monosaccharide as a trisaccharide and so on. Disaccharides – Sucrose, Lactose, Maltose, Cellobiose, Trehalose, Gentiobiose, Melibiose Trisaccharides – Rhamninose, Gentianose, Raffinose (= Melitose), Rabinose, Melezitose Tetrasaccharides – Stachyose, Scorodose Pentasaccharide – Verbascose The molecular composition of the 3 legume oligosaccharides (viz., raffinose, stachyose and verbascose) is shown below : α-Galactose (1–6) α-Glucose (1–2) β-Fructose Raffinose α-Galactose (1–6) α-Galactose (1–6) α-Glucose (1–2) β-Fructose Stachyose α-Galactose (1–6) α-Galactose (1–6) α-Galactose (1–6) α-Glucose (1–2) β-Fructose Verbascose 15. Disaccharides – Composed of 2 monosaccharides – cells can make disaccharides by joining two monosaccharides by biosynthesis. Glucose + fructose = sucrose Table sugar Found naturally in plants: sugar cane, sugar beets, honey, maple syrup Sucrose may be purified from plant sources into Brown, White and Powdered Sugars. Glucose + galactose = lactose • • The primary sugar in milk and milk products. Many people have problems digesting large amounts of lactose (lactose intolerance) Glucose + glucose = Maltose • • Produced when starch breaks down. Used naturally in fermentation reactions of alcohol and beer manufacturing. 15 16. Trisaccharides: Composed of three monosaccharide ex: Raffinose (Formed by one mole of each i.e. glu, fruc, galac) Tetrasaccharides : ex: Stachyose (composed of two moles of galactose one mole of glu & one mole of fruct) 16 17. Polysaccharides Containing 10 or more monosaccharide units attached together • Examples 1. Starch- digestible 2. Glycogen- digestible 3. Fiber- indigestible Long chains of glucose units form these polysaccharides • Cellulose gives structure to plants, fiber to our diet • Glycogen is an energy storage sugar produced by animals • Liver cells synthesize glycogen after a meal to maintain blood glucose levels Compiled and Edited by Dr.Syed Ismail,MAU, Parbhani 17 18. A great majority of carbohydrates of nature occur as polysaccharides Chemically, the polysaccharides may be distinguished into homopolysaccharides, which yield, on hydrolysis, a single monosaccharide and heteropolysaccharides ,which produce a mixture of monosaccharides on hydrolysis. Based on their functional aspect, the polysaccharides may be grouped under two heads : (a) Nutrient (or digestible) polysaccharides. These act as metabolic reserve of monosaccharides in plants and animals, e.g., starch, glycogen and inulin. (b) Structural (or indigestible) polysaccharides. These serve as rigid mechanical structures in plants and animals, e.g.,cellulose, pectin and chitin and also hyaluronic acid and chondroitin. 19. Types of Polysaccharides 1. Starch – – – – The major digestible polysaccharide in our diet. The storage form of carbohydrate in plants. Sources: Wheat, rice, corn, rye, barley, potatoes, tubers, yams, etc. Two types of plant starch: 1. Amylose 2. Amylopectin 19 20. Amylose: is in the form of straight chain linked together with α- 1-4, linkages indicating 300 – 5,500 glucose units per molecules, molecular wt range from 105 to 106. Generally it is water soluble and gives blue colour with iodine. Amylopectins: It contain beside straight chain several branched chains, which are arranged in α—1-4 and β-1-6 linkage units, one molecule of amylopectin contains 50,000 to 5,00,000 glucose molecules, molecular wt. range from 107 to 108, it is insoluble in water and gives purple colour with iodine . 20 21. Types of Polysaccharides 2. Cellulose - form cell walls in plant cells - also called fiber or ruffage - indigestible by humans Compiled and Edited by Dr.Syed Ismail, MAU, Parbhani 21 22. Types of Polysaccharides 3. Glycogen The storage form of glucose in the body. Stored in the liver and muscles. Found in tiny amounts in meat sources. Not found in plants. Not a significant food source of carbohydrate. 22 23. Some clinical concepts • • • • • • • • • • Glucose is the most important energy source of carbohydrates to the mammals (except ruminants). The bulk of dietary carbohydrate (starch) is digested and finally absorbed as glucose into the body. Dextrose (glucose in solution in dextrorotatory form) is frequently used in medical practice. Fructose is abundantly found in the semen which is utilized by the sperms for energy. Several diseases are associated with carbohydrate's e.g., diabetes mellitus, glycogen storage diseases galactosemia. Accumulation of sorbitol and dulcitol in the tissues may cause certain pathological conditions e.g. cataract, nephropathy. The non-digestible carbohydrate cellulose plays a significant role in human nutrition. These include decreasing the intestinal absorption of glucose and cholesterol, and increasing bulk of feces to avoid constipation. The mucopolysaccharide hyaluronic acid serves as lubricant and shock absorbent in joints. The mucopolysaccharide heparin is an anticoagulant(prevents blood clotting). The survival of Antarctic fish below -2oC is attributed to the antifreeze glycoproteins. streptomycin is a glycoside employed in the treatment of tuberculosis 24. Further readings Jain, J.L. (2005) Fundamentals of Biochemistry, S. Chand & Company Ltd. Ram nagar, New Delhi, India Karen C. Timberlake (2012) Chemistry : An Introduction to General, Organic, and Biological Chemistry -11th ed. Publishing as Prentice Hall in the United States of America. Satyanarayana, U. (2007) Biochemistry , Books and Allied (P) Ltd, Kolkata, India Compiled and Edited by Dr.. Syed Ismail, VNMKV, Parbhani 25. Thank You!

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