SUGAR BEARING CROPS

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Contents

Summary

Sugars and starch both belong to the carbohydrate group. Carbohydrates are the single most important source of food energy in the world. They may be classified according to their degree of polymerization and may be divided initially into three principal groups, namely sugars, oligosacharides, and polysaccharides. There are sugar crops, like sugar cane, sugar beet, sweet sorghum and Jerusalem Arthichoke that are cultivated for the production of sugar and some by-products such as alcohol, glyceria, citric acid etc. Of them sugar cane, sugar beet and sweet sorghum are multipurpose crops, because from the same piece of land food, fuel and fodder can be produced. Sugar cane alcohol, which is a biofuel, could become an important weapon against the greenhouse effect.

1. The present status of carbohydrate consumption

Carbohydrates are the single most improtant source of food energy intake, depending on locale, cultural considerations or economic status. The major source of carbohydrate in the human diet are: (1) cereals, (2) root crops, (3) sugar crops, (4) pulses, (5) vegetables, (6) fruit, and (7) milk products. Trends over the last 20-30 years indicate growth in world production of cereals, sugar cane, vegetables and fruit. Marked decreases have actually been seen in pulse production in some countries in Asia, and in root crop production in Europe.

This suggest a change in food preference away from roots and pulses and towards cereals (FAO/WHO, 1997). Populations continue to increase in most parts of the world and, overall food production would seem to be keeping pace with population growth. A major question is whether the amount of carbohydrate will be sufficient for the world's population in the future. Projections for future growth suggest problems ahead, particularly in Africa.

1.1. The role of carbohydrates in nutrition and feed

Carbohydrates provides the majority of energy in the diets of most people. In addition it provides easily available energy for oxidative metabolis, carbohyrate-containing foods are vehicles for important micronutrients and phytocemicals. Dietary carbohydrates is important to maintain glycemic homeostasis and for gastrointestinal integrity and function. An optimum diet should consist of at least 55 % of total energy coming from carbohydrate obtained from a variety of food sources (FAO/WHO, 1997).

1.2. Definition and classification of carbohydrates

The name carbohydrates is derived from the French *hydrate de carbone* and was originally applied to neutral chemical compounds containing the elements carbon, hydrogen and oxygen, with the last two elements present in the same proportions as in water. Many carbohydrates have the empirical formula $(CH_2O)_n$ where n is three or larger.

But some compounds with general properties of the carbohydrates contain phosphorus, nitrogen or sulphur in addition to the elements carbon, hydrogen and oxygen. Moreover some compounds, e.g. deoxyribose ($C_5H_{10}O_4$) do not have hydrogen and oxygen in the same ratio as that in water. Nowadays is spreading to define carbohydrates as polyhydroxy aldehydes or ketones, or as substances that yield one of these compounds on hydrolysis.

The carbohydrates are usually divided into two major groups, the **sugars** and the **non-sugars**. The **simplest sugars** are the MONOSACCHARIDES which are divided into sub-groups: *trioses* ($C_3H_6O_3$), *tetroses* ($C_4H_8O_4$), *pentoses* ($C_5H_{10}O_5$), *hexoses* ($C_6H_{12}O_6$) and *heptoses* ($C_7H_{14}O_7$) depending upon the number of carbon atoms present in the molecule.

The term 'sugar' is generally restricted to those carbohydrates containing less than ten monosaccharide residues, while the name oligosaccharides (oligo=few) is frequently used to include all sugars other than the monosaccharides.
Non-sugars are divided into two groups, the HOMOPOLYSACCHARIDES and the HETEROPOLYSACCHARIDES.

1.4. Properties and derivatives of sugars

Monosaccharides have reducing properties i.e. they are able to reduce certain metal ions, copper or silver, in alkaline solution. The aldehyde and ketone groups may also be reduced chemically, or enzymatically, to yield the corresponding sugar alcohols. The most important monosaccharide derivatives are: phosporic acid esters (α-D-Glucose 1-phosphate, α-D-Glucose 6-phosphate), amino sugars (D-glucosamine, D-galactosamine), deoxy sugars (deoxyribose, fucose, rhamnose), sugar acids (in the case of glucose: gluconic, glucaric and glucuronic acids), sugar alcohols (sorbitol, mannitol), glycosides (linamarin, vicianin, amygdalin)

Pentoses have the general formula $C_5H_{10}O_5$. The most important members of this group os simple sugars are the *aldoses* L-arabinose, D-xylose and D-ribose, and the *ketoses* D-xylulose and D-ribulose. The phosphate derivatives of D-xylulose and D-ribulose occur as intermediates in the pentose phosphate metabolic pathw

Glucose and fructose are the most important naturally occurring *hexose* sugars, while mannose and galactose occur in plants in a plymerised form as mannans and galactans.

D-*Glucose*, grape sugar or dextrose, occurs free in plants, fruits, honey, and is the sole or major component of many oligosaccharides, polysaccharides and glucosides.

D-*Fructose*, fruit sugar or laevulose, occurs free in green leaves, fruits and honey. It also occurs in the disaccharide sucrose and in fructans. Green leafy crops usually contain appreciable amounts of this sugar both free and in polymerised from.

D-*Mannose* and D-*Galactose* do not occur free in nature but the first one exists in polymerised form as mannam and also as a component of glycoproteins. The second one occurs as a component of the anthocyanin pigments, galactolipids.

Heptoses contain seven carbon atoms. D-*Sedoheptulose* occurs, as the phosphate, as an intermediate in the pentose phosphate metabolic pathway.

Dissacharides

Disacharides consist of two molecules of hexose sugars combined together with the loss of one molecule of water:

$$2C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O.$$

The most important disaccharide compounds are sucrose, maltose, lactose and cellobiose. *Sucrose*, cane sugar, beet sugar or saccharose is the familiar sugar of domestic use (Figure 1).

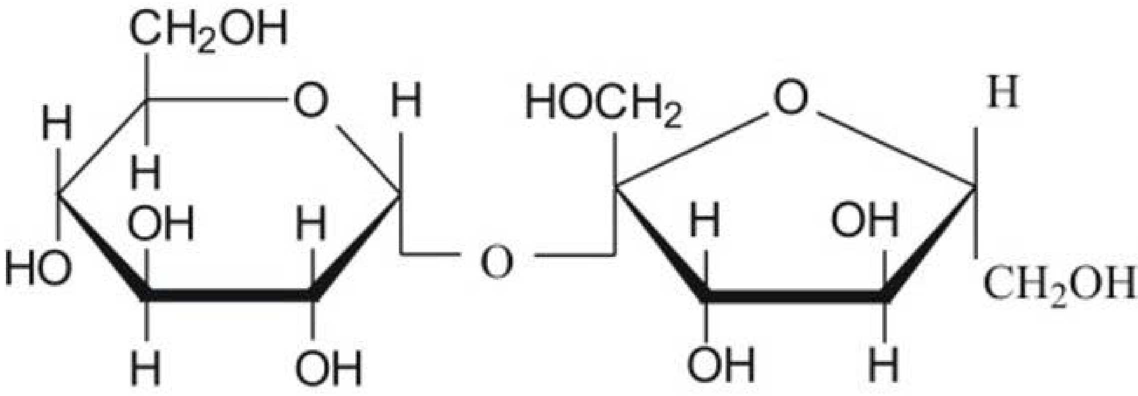

Figure 1. The structure of a succrose molecule. Succrose consists of one molecule of α-D-glucose and one molecule of β- D-fructose joined together through an oxygen bridge between their respective anometric carbon atoms.

It is widely distributed in nature and occurs in most plants. Sugar cane contains about 20% of sucrose and sugar beet 15 to 20%; it is also present in other roots such as mangolds and carrots. *Lactose* occurs only as a product of the mammary gland. *Maltose* is produced from starch during the germination of barley by the action of the enzyme amylase. *Cellobiose* is the basic repeating unit of cellusose. *Trehalose* is present in fungi and seaweeds.

Trisaccharides

Trisaccharides are formed by the union of four hexose residues:

$3C_6H_{12}O_6 \rightarrow C_{18}H_{32}O_{16} + 2H_2O.$

Raffinose is the most frequently occurring member of the group. It exists in small amounts in sugar beet and accumulates in molasses during the commercial preparation of sucrose. Cotton seed contains about 8% of raffinose.

Tetrasaccharides

Tetrasaccharides are produced by the union of four hexose residues:

$4C_6H_{12}O_6 \rightarrow C_{24}H_{42}O_{21} + 3\ H_2O.$

Stachyosis has been isolated from about forty different plant species. I occurs in the seeds of leguminous plants.

The sweetness of a sugar is due to the OH groups, which react with the receptors on our tongue. But the quantity of the OH groups is not decisive; rather it is the relative positions of these OH groups in three-dimensional space. Only certain orientations can fit onto the sweet receptors on the tongue.

Homopolysaccharides

These carbohydrates are very different from the sugars. They do not possess a sweet taste, and do not give the various sugar reactions characteristic of the aldoses and ketoses. Many of them occur in plants either as reserved food materials such as starch or as structural materials such as cellulose. Arabinans, xylans, glucans (glycogen, dextrins, cellulose), fructans, galactans, mannans, galacturonans and glucosaminans (chitin) are the most important members of this group.

Fructans (formerly called fructosans) occur as reserve material in roots, stems leaves and seeds of a variety of plants, but particularly in the *Compositae* and *Graminae.* These polysaccharides are soluble in cold water and are of a relatively low molecular weight. All known fructans contain ß-D-fructose residues joined by 2,6 or 2,1 linkages. They can be divided into three groups: (1) the levan group; (2) the inulin group; and (3) a group of highly branched fructans, found, for example, in couch grass (*Agropyron repens)* and in wheat endosperm. Most fructans, on hydrolysis, yield in addition to D-fructose a small amount of D-glucose. The structure of a typical grass fructan is depicted on Figure 2.

Heteropolysaccharides
Hemicelluloses (xylans, gluco- and galactogluco-mannans), complex acidic polysaccharides (exudate gums), lignin (acidic mucilages), sulphated polysaccharides (agar), and amino polysaccharides (hyaluronic acid, chondroitin, heparin) belong to the heteropolysaccharides.

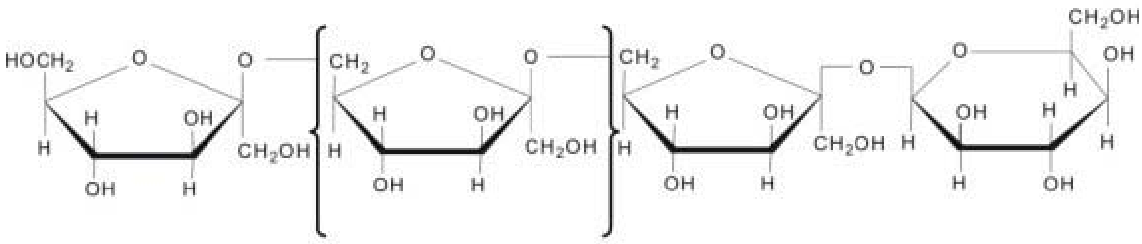

Figure 2. The structure of a typical grass fructan .

2. Sugar Crops

Sugar crops, like sugar cane, sugar beet, sweet sorghum and Jerusalem Arthichoke are cultivated for the production of sugar and some by-products such as alcohol, glyceria, citric acid etc. In the developing countries of the tropical belt of Asia, Africa and America, where the human diet is poor in protein, sugar is very important. Pure crystalline sugar is derived from two plants: the sugar cane (*Saccharum officinarum)* which is the basic sugar crop in the tropical zone (30º NL to 30º SL), and the sugar beet (*Beta vulgaris* L.) cultivated in the countries of the temperate belt (45 to 59º NL). Sugar cane is grown on 19 million hectares (FAO, 2000). Approximately 50% of the world area is found in North and South America. This crop is particularly widespread in Cuba (1.5 million hectares), Brazil (2 million hectares), and to a lesser extent in Argentina, the USA, and Peru. It is not widely raised in Africa.The average yields of commercial sugar cane stems are vary from continent to continent; 48 to 66 tonas/hectare in Asia, North and South America and 55 tons/hectare in Africa.

Sugar beets are grown on 6.5 million hectares. Their yields fluctuate from 28 (Asia) to 30 tons/hectare (Africa), and from 35 (Europe) to 43 tons/hectare (South America).

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Biographical Sketch

Dr. Márta Novák-Hajós was born on 21.06.1949. Kecskemét, Hungary
Marital status: married with one child

EDUCATION AND QUALIFICATION

1967-1972 Gödöllő Agricultural University, Faculty of Agricultural Sciences
1972 MSc Agricultural Sciences
1975 MSc Genetics and Plant Breeding
1976 University doctoral degree
Ph.D. biology
1998 Habilitation in plant breeding

WORK EXPERIENCE

1972-1980 Research worker at Department of Genetics and Plant Breeding
1981-1984 Ph.D. student at Department of Genetics of Eötvös Loránd University, Budapest, Hungary

Supervisor: Dr. Gábor Vida Ph.D., DSc., Memeber of Hungarian Academy of Sciences
1985-1987 Research worker at Gödöllő Agricultural University
1988-1989 Senior Lecturer in Classical Genetics and Plant Breeding
1990- Associate Professor - Lecturer in Plant Breeding

RESEARCH ACTIVITIES

1972-1978 National research program on 'Biological consequences of applying chemicals'. The genetic effect of applying chemicals and mineral nutritions with normal and high doses on corn and pea plants.

1978-1990 National research program on 'Development of crop production'. Developing corn inbred lines and hybrids, variety maintenance. Development of methods to produce breeding stock in corn. Isozymes studies on diploid and autotetraploid corn. Study on regulation of *Adh1* gene in corn.

1992- Molecular markers (isozymes, RFLPs and RAPDs) in tetraploid corn breeding. (This program is supported by the National Scientific Research Foundation).

1995- Breeding for earliness and seed quality in soybean by induced mutation. RCM on „Improvement of new and traditional industrial crops by induced mutations and related biotechnology"(supported by the FAO/IAEA Vienna, No. 312.D2.RC.578.3).

2002- Application of molecular markers in poppy and grape variety protection.