SUGARS

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1. INTRODUCTION

Sugars are simple carbohydrates. Carbohydrates may be roughly divided into three groups:

a) Simple carbohydrates or sugars: these may be monosaccharides, the simplest form of sugars, or disaccharides in which two monosaccharides are bound together.

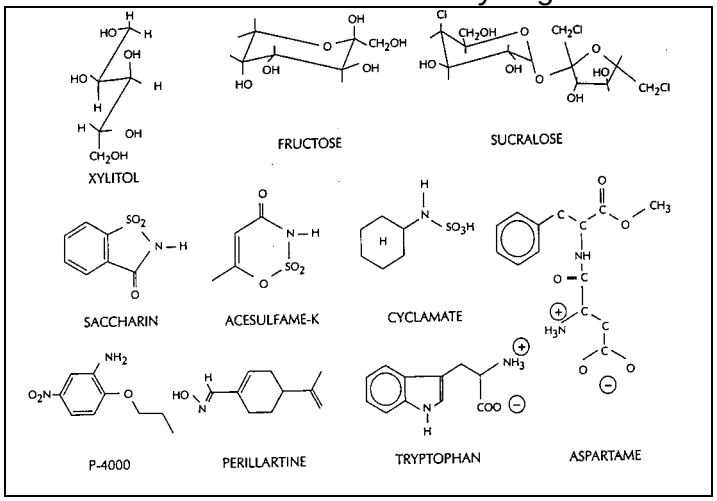
b) Oligosaccharides, in which three or more monosaccharides are bound together. Those oligosaccharides which comprise only a few monosaccharides and taste sweet, may also be regarded as sugars.

c) Polysaccharides or complex carbohydrates in which an indefinitely large number of monosaccharides are bound together. Unlike simple sugars or oligosaccharides, polysaccharides may or may not be digestible. The digestible ones are called "starches". The others form part of the group known collectively as "dietary fibre" or non starch polysaccharides.

All carbohydrates are compounds of carbon, hydrogen and oxygen in which the hydrogen and oxygen are present in the same proportion as in water.

Simple sugars are sweet, though not equally so. Oligosaccharides are less sweet, and polysaccharides are not sweet at all.

Figure 1
Structures of some dietary sugars



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The commonest sugar is sucrose (or "saccharose") and is popularly referred to simply as "sugar". In this report it will be referred to as "sucrose".

Some modified carbohydrates are also found in the diet and are used to replace sugars. The common ones are sorbitol, maltitol and xylitol. These are called sugar alcohols.

2. OCCURRENCE

Sugars are:

a) glucose, also known as dextrose, found in fruit, vegetables, honey, glucose syrup (also known as confectioners' glucose and corn syrup) and invert sugar syrup (a product manufactured from sucrose),

b) fructose, found in fruit, vegetables, honey and invert sugar syrup,

c) lactose, found only in milk and products made from milk,

d) maltose, found in malt and glucose syrup,

e) sucrose found in fruit and vegetables, made commercially from sugar-cane and sugar-beet.

Glucose and fructose are monosaccharides. The other three are disaccharides.

Oligosaccharides are found in small quantities in some fruits and vegetables, and honey; and as major components of glucose syrup. Glucose syrup is manufactured from starch by hydrolysis, using enzymes. There are several varieties, differing in sweetness and other properties according to the relative proportions of glucose and the various oligosaccharides. Starches are the major component of staple foods such as cereals, rice, cassava, and potatoes, and to a lesser extent in vegetables.

3. CONSUMPTION

The amount and type of carbohydrate consumed will depend on a number of factors such as geographical area, cultural differences and economic and development status of the country. In poor countries, where there is little variety in the diet, carbohydrates make up 70-80 % of total energy, mostly from starch. In richer developed countries carbohydrates may make up as little as 40-45 % of total energy of which up to 18 % may be from simple sugars.

There is a paucity of data about total sugars consumption across the world. The consumption of sucrose or saccharose is better documented, although the data collection and definitions used to define 'sugar consumption' may well be different in different countries. The F.O. Licht 'Sugar Year Book' reports sucrose (saccharose) consumption as set out in Table 2.

TABLE 1

Sugar Consumption per head of population in 1991 (kg raw value)

Country	Consumption kg/person/yr	Country	Consumption kg/person/yr
Belgium	48.0	CIS	44.2
Denmark	53.4	Hungary	54.1
France	37.0	Poland	42.3
Germany	37.2	Canada	42.8
Greece	34.7	USA	31.8
Ireland	47.8	Argentina	33.0
Italy	32.3	Brazil	47.5
Netherlands	57.9	South Africa	38.3
Portugal	33.0	China	6.3
Spain	31.7	Hong Kong	27.8
UK	43.7	India	13.3
Austria	55.1	Japan	23.0
Finland	42.7	Saudi Arabia	30.7
Norway	42.0	Australia	48.9
Sweden	45.0	New Zealand	48.2

The data for consumption are not all collected in the same way, so comparison between countries is not precise. Other and quite different values for consumption have been claimed so the figures here must be treated with caution.

There is a tendency for the more industrialised countries to consume their sugars in the form of sugars used as such by the housewife, caterer, or manufacturer, either in the preparation of food or as an optional addition to it. For example, in the USA, about two-thirds of the sugars consumed are in the form of sugars added as such.

4. SUGARS INTAKE

22% of the energy content of food in the USA, and 18% in the UK comes from sugars. Their contribution in most other countries is probably lower. (Belgium 15%, Denmark 8%, Germany 14%, Ireland 14%, Spain 8%.

5. THE NUTRITIONAL ROLE OF SUGARS

The primary nutritional role of carbohydrates, whether sugars or starches, is to provide energy. This energy is constantly needed by the body to maintain life.

Survival without carbohydrate is possible (as among primitive Eskimos) since fat and protein also provide energy. However, a diet containing only fat or protein, or both, as the source of energy would be unsatisfactory. It is generally accepted that the consumption of fat should be limited. The primary function of protein is in tissue building and maintenance and to consume it as a source of energy would be wasteful. It would even be harmful if consumption was too high. Carbohydrates, in the form of glucose, is needed by the brain as essential fuel for brain function.

Absorption of sugars.

After ingestion sugars (and starches) are converted into their constituent monosaccharides and absorbed into the blood stream by three processes: simple diffusion, facilitated diffusion and "active transport".

The constituent monosaccharides are:

a) glucose from starch, oligosaccharides, maltose, lactose and sucrose

b) fructose from sucrose

c) galactose from lactose

Sucrose digestion is influenced mainly by gastrointestinal factors such as the rate of gastric emptying. This is itself influenced by many factors in a mixed meal including, fat and energy content, viscosity and solid content of the meal and the quantity of dissolved solids. Monosaccharides, derived from hydrolysis of disaccharides by enzymes on the surface of the cells in the lining of the small intestine, may be absorbed into the blood more rapidly than free monosaccharides. This may be due to their being physically close to the carrier transporters needed for active transport across the cell.

Starch digestion is influenced by the nature of the starch, the food itself, its processing and the presence of dietary fibre. Most starchy foods are cooked before eating which not only makes them palatable but also renders them easily digestible. Some commercial methods of cooking, including high-pressure canning and extrusion cooking, make starch more available for digestion.

Although there are some differences in the digestion of starches and sugars, ultimately all are absorbed as their constituent monosaccharides.

Glucose is the predominant monosaccharide which is absorbed as it is the only one found in starch and makes up 50 % of sucrose. It circulates in the blood, passing via the liver where a proportion will be removed and stored as glycogen. The remainder is taken up elsewhere, especially by muscle, where it is used for energy production or stored as glycogen (see Diet and Exercise fact sheet for more information on the importance of glycogen stores in exercise preformance).

Fructose is also absorbed into the blood but is taken up by the liver, where it is converted to glucose, so little enters the general circulation even after the ingestion of large amounts of fructose or sucrose.

Although there are major differences of taste and physical properties between starches and sugars, and minor differences of sweetness and metabolic effects between individual sugars, the body utilises them all in essentially the same way. Nutritionally, they are all essentially equivalent to each other.

Energy Production From Carbohydrate.

Although fat is also an important energy source, glucose is more versatile as all cells can use it. The red blood cells (erythrocytes), brain and central nervous system needs a supply of glucose in order to function.

Most of the metabolic pathways leading to the production of energy are common to all dietary sugars (see Figure 3). The same enzymes and co-enzymes are involved irrespective of the original sugar. The metabolism of starch, after digestion and absorbtion, can be considered to be that of glucose.

6. OTHER ROLES OF SUGARS IN FOOD

These include:

a) Conferring palatability by virtue of their sweetness:

b) Preservation, by virtue of their effect on water activity (ie. by rendering the water in a food inaccessible to micro-organisms)

c) Providing characteristic textures by virtue of their special properties in solution, or in crystalline and amorphous forms;

d) Generating flavours and colours by their interaction with proteins when heated (the Maillard Reaction).

e) By making more foods available in a palatable form, sugar has an important role in increasing the nutritional value of the whole diet.

7. SUGARS AND HEALTH

7.1 *Blood Glucose Levels After Eating Sugars and other carbohydrates:*

Eating food containing carbohydrate raises the blood glucose (sugar) levels and this is termed the 'glycaemic response'.

The 'glycaemic index' (GI) is a measure of the glycaemic response of a carbohydrate containing food over 2-3 hour period after ingestion, expressed as a percentage of the response given by a standard such as glucose or white bread. Figure 4 shows the glycaemic index of some common foods. Glucose itself has a very high GI. White bread (a source of starch) has a higher GI than sucrose.

There is little difference between white and wholemeal bread or white and brown rice whereas rice variety, parboiling and grinding is important. The presence of fat in a food will slow gastric emptying thereby lowering the GI. Sucrose has a substantially lower GI than glucose or maltose. This is because of the low GI fructose component of sucrose.

Some of the factors affecting blood glucose levels are:

Chemical nature of carbohydrate
Physical form of carbohydrate
Presence of other food constituents
Whether carbohydrate is in solution or solid form
Amount of food consumed at one sitting
Whether food is raw, cooked or processed
Energy content and composition of habitual diet
Time period after which response is measured
Method of blood sugar analysis
Site of blood sampling - arterial or venous
Variation between individuals

When different sugars are given in equal amounts in solutions of equal concentrations they have differing effects on blood glucose levels. The response in descending order of magnitude is: glucose, sucrose, lactose, galactose, fructose. There is a common assumption that sugars in foods such as confectionery raise blood glucose (sugar) levels as much as do sugars in solution. However, there is good evidence that the presence of other components such as protein and fat reduces the glycaemic response of these foods.

The glycaemic response to high sucrose meals containing large amounts of different types of starches, such as those in rice, wheat and potatoes, has been studied widely in insulin-dependent and non-insulin-dependent diabetics, and to a more limited extent in normal subjects. A very clear pattern emerges from all these studies: blood glucose curves for high sucrose foods and meals are similar to, or sometimes less than, those for meals containing predominantly starchy foods.

Size of the glycaemic response is not, therefore, dependent on whether sugars or starches are the main carbohydrate constituent of the diet but on other ingredients present, i.e. fat, dietary fibre and protein, and the physical form in which they are ingested.

TABLE 2

Glycaemic index of foods (using white bread as standard)(from Wolever 1990).

	Glycaemic Index
Sugars	
Fructose	26
Glucose	138
Honey	126
Lactose	57
Maltose	152
Sucrose	83
Cereals	
Bread, white	100
Bread, wholemeal	100
Rice, polished	81
Rice, brown	81
Rice, parboiled	68
Spaghetti, white	67
Spaghetti, brown	61
Allbran	74
Cornflakes	121
Muesli	96
Shredded Wheat	97
Digestive biscuits	82
Vegetables	
Potatoes, mashed	98
Potatoes, instant	120
Baked beans, canned	70
Peas	65
Kidney beans, canned	74
Lentils	38
Soya beans, canned	22
Fruit	
Apple	52
Apple juice	45
Banana	84
Orange	59
Orange juice	71
Raisins	93

Snack foods	
Ice cream	69
Mars bar	94
Corn chips	99
Potato crisps	77
Peanuts	15

7.2 *Sugars and other metabolic diseases*

Many diseases have been claimed to be associated with a high sugar intake including coronary heart disease, diabetes, dental caries, and obesity. The findings on various issues by the FASEB Report on Sugar (1977) prepared by a committee known as the Select Committee on GRAS Substances, the WHO/FAO Expert Committee on Carbohydrates (1980), and the more recent US FEDA Sugars and Corn Sweeteners Task Force (1986), the British Nutrition Foundation Sugars and Syrups Task Force (1987) and the UK's COMA Report on Dietary Sugars in Human Disease (1989) are the following:

7.2.1 *Obesity:*

All foods can contribute to an excess calorie intake which will result in weight gain. Sugars and starches are equal in this respect as weight for weight they provide the same number of calories. The importance of fat, which provides more than double the calories (9kcal per gramme) of carbohydrate, in the development of obesity has long been recognised. Interestingly, all food consumption surveys show an inverse relationship between sucrose and fat consumption. An inverse relationship between BMI and sugars and/or sucrose has also been consistently reported.

7.2.2 *Coronary Heart Disease:*

The hypothesis put forward in the 1960's, that sucrose raises blood cholesterol and triglyceride levels and is therefore linked to the development of heart disease, has not been supported by subsequent clinical, epidemiological or experimental research.

There is in fact no evidence for a direct adverse effect in most people on blood levels of cholesterol, triglycerides, glucose or insulin when sucrose is substituted isocalorically for starch up to about 150g per day or 25 % of total food energy (DoH, 1989).

7.2.3 *Diabetes. See above section on blood glucose.*

7.2.4 *Hypoglycaemia:*

Many of the reports of adverse reactions following ingestion of meals high in carbohydrates and sugars have been attributed to hypoglycaemia either by unqualified individuals or by the affected person themselves. It is rarely supported by the demonstration of low blood glucose concentrations, which if measured at all, are usually within the normal range.

7.2.5 *Dental caries:*

All fermentable carbohydrates (whether cooked starches or sugars) have the potential to become the dietary component of the caries process. However, it is the frequency of consumption and not the amount or type consumed which is the main dietary factor associated with the potential caries incidence (see Dental Caries fact sheet).

7.2.6 *Hyperactivity:*

Hyperactivity and other behavioral problems in children have also been linked with dietary sucrose and attributed to a number of causes including a rapid rise in blood glucose after ingestion, reactive hypoglycaemia several hours after ingestion and an allergic response. Most reports are subjective and controlled studies have not found consistent effects. A recently published study (Wolraich et.al., 1994) showed that even when sucrose intakes exceeded typical dietary levels, it did not affect children's behavioral or cognitive function.

7.2.7 *Sweet Preference or 'Sweet Tooth':*

Infants like sweet things and this can be demonstrated in newborn infants. The liking for sweet foods continues into childhood and adult life probably because of our preference for familiar foods and flavours. This is not a disorder, but a genetic predisposition. It is important that health professionals do not seek to suppress it.

7.3 *Sugars intake and nutrient dilution:*

Because sugars supply only energy, they are often referred to as 'empty calories' and are thought to be fattening whereas non-sugar carbohydrates are reported to be 'non-fattening'. Such statements are contrary to basic thermodymanics.

Both sugars and starches provide only energy -4 (or 3.75) kcal/17kJ per gram. The fact that starch is often associated with fibre and other nutrients does not render the starch itself more valuable. The same is also true for sugars. Most sugars-containing foods contain valuable amounts of other nutritients.

Sugars and starches provide 17 Kjoule per gram of energy and in the case of sugars it is often argued that their presence at high levels in the diet leads to micronutrient dilution.This is not the case as has been shown from analysis of the UK survey of food and nutrient intakes of British School Children. Nutrient intakes were not significantly lower in the higher sugar consumers and were often higher in the group with the highest per cent energy from sugars.

8. IOCCC POSITION.

Based on the large body of scientific evidence and dietary recommendations, the IOCCC concludes the only health risk associated with sugars is dental caries, and then only when they are eaten too frequently. Sugars however are not unique in this respect, as all digestible carbohydrates including cooked starch are implicated. There is therefore a logical place for foods containing sugars in a balanced and nutritionally adequate diet.

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