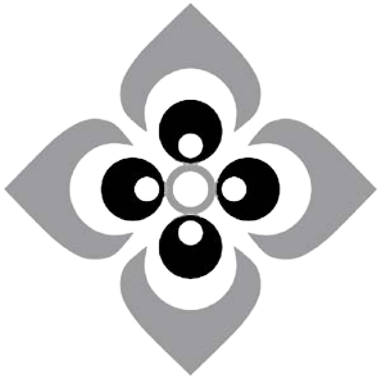

Consortium for Educational Communication

Module
on
Manufacture And Health Effects Of Sugars

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TEXT

Introduction

Sugars are polyhydroxy aldehydes or ketones, commonly classified into monosaccharides*, disaccharides, oligosaccharides and polysaccharides. Monosaccharides* are single unit sugars with 'mono' meaning 'one' and 'saccharide' meaning sugar molecule. Monosaccharides commonly found in food are glucose, fructose and galactose. *Disaccharides* consist of two monosaccharides joined together. Disaccharides commonly found in food are sucrose (glucose + fructose), lactose (glucose + galactose) and maltose (glucose + glucose). *Oligo - and polysaccharides* contain more than two monosaccharides joined together. The simple sugars, or monosaccharides, are the building blocks of carbohydrate chemistry. Sugars with five, six, seven, or eight carbon atoms are classified appropriately as pentoses, hexoses, heptoses, or octoses, respectively. They can be designated by more specific names, such as aldohexose or ketohexose**,** to denote the kind of carbonyl compound they represent. Raw sugar is the name applied to sugar crystals from the juice of sugar cane or sugar beet plants. Apart from sucrose, raw sugar contains reducing sugars (glucose and fructose), inorganic ash (mainly calcium and potassium salts) and other organic matter which includes gums, amino acids and colour components, essentially from the cane. These impurities must be removed from the sucrose during refining as follows: a) *affination* - dissolving off some surface impurities, b) *carbonation* - removing further impurities that precipitate from solution with calcium carbonate, c) *char filtration* - removing further impurities with activated carbon, and d) *crystallisation* - using a vacuum process. Sugars play an important role in different foodstuffs. As well as bringing sweetness, they also have important biological, sensory, physical and chemical properties. Sugars help provide the taste, texture and colour of foods, extend their shelf-life, which preserves the safety and quality of the food. Recent evaluations commissioned by the WHO have concluded that limiting the amount of sugar added to foods and decreasing the intake of sugar sweetened beverages (which are a major source of added sugars) would be beneficial in promoting public health, particularly with regard to reducing the risk of dental caries, type 2 diabetes and cardiovascular disease. Consequently, the WHO released a new guideline in March 2015 which recommends that "adults and children should reduce their daily intake of free sugars to less than 10% of their total energy intake. A further reduction to below 5% or roughly 25 g (6 teaspoons) per day would provide additional health benefits".

Production of sugar

Sugar is a valuable agricultural commodity. About 80 per cent of the world's sugar comes from sugar cane and about 20 per cent comes from sugar beet. Most of the sugar marketed in the EU comes from sugar beets grown and harvested in the EU (at least 80 to 85 percent). Sugar beet resembles root-crops such as parsnip. Sugar cane *(Saccharum officinarum)* is similar to bamboo, having a shiny outer coating and sweet, woody inner fibre. Sugar cane grows in the tropical and subtropical regions, while sugar beet grows in colder more temperate regions. In 2013, the world's largest producers of cane sugar were Brazil, India, China, Thailand and Mexico. The EU is the world's largest sugar beet producer with France, Germany, Poland and the UK producing the most.

Sugar beets are perishable and progressively lose sugar content from the moment they are harvested. Therefore, beet sugar factories are located close to sugar beet fields, mostly in rural areas. Sugar beets are washed, sliced into small pieces (known as cossettes) and mixed with hot water. Lime and carbon dioxide are applied to clean the juice. The brown liquid is filtered and boiled under a vacuum to produce thick syrup. This then begins to crystallize and the crystals are separated from the syrup using a centrifuge.

The processing of sugar cane is very similar. Sugar cane tends to be extracted in sugar mills in the country where it is grown through the following processes:

1. Cutting, shredding and crushing between heavy rollers.

2. Hot water spray and lime to clarify the juice.

3. Filtering of the brown juice produced.

4. Boiling of juice under vacuum to form thick syrup.

5. Separation of crystals (raw sugar) and syrup (molasses) in a centrifuge.

6. Brown raw sugar or crystals is then exported around the world for local refining.

The production of starch based sugars

Starch together with other co-products (mainly fibres and proteins) is extracted from cereal and tubers (in the EU, the main raw materials used to produce starch are maize, wheat and starch potatoes). The starch molecule is a long chain of glucose

units. Through hydrolysis these long chains can be broken up into smaller chains to produce, amongst other starch derivatives, glucose syrups and dextrose (pure glucose). In a process called isomerisation, some of the glucose units in glucose syrups can be converted to fructose to produce glucose fructose syrups.

Under EU food legislation, the word fructose is part of the syrup name when the syrup contains more than 5% fructose, as follows: glucose-fructose syrup up to 50% fructose and fructose-glucose syrup above 50% fructose. In Europe the most commonly produced of these syrups has a fructose content of 42%. In the US the most commonly produced such syrup contains 55% fructose. It is known there as high fructose corn syrup. The term isoglucose is used in EU legislation and applies to glucose-fructose syrups with fructose content exceeding 10%. This term appears in technical literature but cannot be used to replace the glucose fructose syrup and fructose-glucose syrup designations in food labelling.

Refining of sugars

Raw sugar is the name applied to sugar crystals produced from the juice of sugar cane or sugar beet. Apart from sucrose, raw sugar contains reducing sugars (glucose and fructose), inorganic ash (mainly calcium and potassium salts) and other organic matter which includes gums, amino acids and colour components, essentially from the cane. These impurities must be removed from the sucrose during refining.

Step 1 - Affination

The first step is called affination, a French word meaning refining. The process consists of mixing the sugar with a saturated syrup to soften the adhering film of molasses, then spinning and washing off as much of this adhering impure syrup as possible in centrifugal machines. The centrifugal machine utilizes the considerable gravitational force at the periphery of a basket spinning at high speed. This means minimum contact time between wash water and sugar, thus reducing the amount of sugar dissolved in this process. The impure syrup is recycled but an excess is produced. This material contains recoverable sugar and is processed separately in the boilout section of the refinery. Recovered boilout sugars are returned for remelting with the washed sugar. The impurities are concentrated into *molasses* which can be regarded as a final by-product. The “washed” or “affined” sugar is then dissolved, utilizing “sweet” water from parts of the refinery process. At this stage the melted liquor is temperature and density controlled. The liquor is screened to exclude fibrous material.

Step 2 - Carbonation

In carbonation, milk of lime (calcium hydroxide) is added to the heated liquor, and boiler flue gas, containing CO2, is bubbled through the mixture.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

The chemical reaction occurs under controlled conditions and as the calcium carbonate precipitate is formed it includes and occludes organic impurities such as the gums, amino acids and colour components mentioned earlier, removing them from the sugar syrup. The carbonation

process is carried out in two stages to obtain an optimum quality precipitate for filtration, i.e. a suitable size and distribution of precipitate particles. Measurement of the electrical resistance of the solution indicates the residual lime content. Eighty to ninety percent of precipitation is sought in the first stage. The second stage is controlled by the measurement of the pH of the solution which is important throughout the process and ensures complete precipitation of the lime.

pH control

The pH of factory liquors is of considerable importance. Below pH 7 sucrose is hydrolysed to the reducing sugars glucose and fructose, while above pH 9, alkali destruction of sugars occurs and coloured components are formed.

Filtration

The calcium carbonate precipitate, including the impurities, is now removed in a pressure filtration stage using polypropylene filter cloth as supporting media and utilising the calcium carbonate as a filter aid. The filter mud is later subjected to water washing to remove sucrose residue and this mud is a waste material. Sweet sugar recovered by washing the mud is used for melting in an earlier stage.

Step 3 - Char Filtration

The relatively pure honey coloured liquor from the filtration stage, “raw liquor”, is then subjected to final decolourisation by contact with bone charcoal. The bone char consists of active carbon on a calcium phosphate skeleton. It has a high surface area and the unique ability to absorb colour and inorganic ash impurities from the sugar. The bone char used at the Chelsea refinery is imported from Portugal or Scotland.

Following the decolourisation cycle the bone char is revivified first by water washing, to remove inorganic impurities, and then heating in the absence of air to 650°C to volatilise organic impurities. The decolourised 'fine liquor' is now ready for the final refining and recovery step, which is achieved by crystallisation in vacuum pans.

Step 4 - Crystallisation

Crystallisation is not only a means to convert the sucrose to a more usable form, but also an important refining step, since pure sucrose tends to crystallise out of the solution, leaving most of the impurities in the associated syrup. The process is carried out under a reduced pressure of 75 - 90 kPa to allow a reduced boiling temperature (60 - 70 °C), so avoiding the further formation of colour compounds. Vacuum is achieved by the use of an air pump and vapour contact condenser. These condensers utilise salt water for cooling. Fine liquor is concentrated until it is super-saturated then stage is shock-seeded by the addition of a small quantity of sucrose to give spontaneous nucleation of fine sucrose crystals. The crystals thus formed are grown under automatically controlled conditions until the desired final grain size is achieved. The pan contents, known as *massecuite*, are then discharged to receivers prior to separation on automatic centrifugal machines. The sugar thus recovered is then dried and graded prior to packing, the syrup being recycled for three further recovery boilings. The final syrup is used as the starting material for other sugar products, such as soft brown sugar, coffee crystals, golden syrup and treacle.

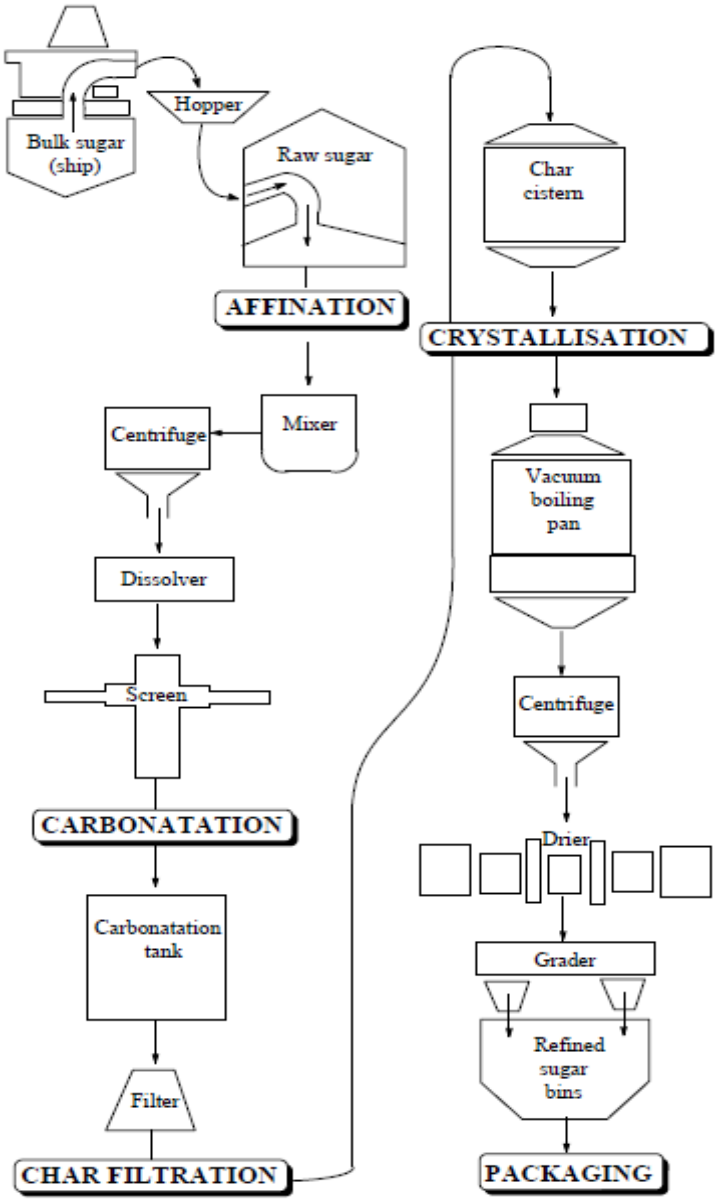

Fig. 6: Flow chart of the sugar refining process

Function of sugars in foods

Sugars play an important role in different foodstuffs and bring sweetness. They also have important biological, sensory, physical and chemical properties. For example, sugars help provide the taste, texture and colour of foods, extend their shelf-life, which preserves the safety and quality of the food. Sugars can in some cases be reduced/replaced, but no other single ingredient can replace all the functions of sugars.

• Taste - Sugars generate flavours by interacting with proteins when heating; a process known as the Maillard Reaction.

• Texture - Sugars contribute to the texture of foods, providing sensations of crispiness in biscuits, for example.

• Colour -Again through the actions of the Maillard Reaction, sugars interact with food proteins giving certain foods a 'golden colour' e.g. bread and pastries.

• Shelf-life - Sugars improve the shelf-life of foods by lowering the water activity. Sugars reduce the amount of available water that supports the growth of micro-organisms (bacteria, mould and yeast) so they cannot multiply and cause food spoilage. This preserves the safety and quality of the food.

SUGARS AND HEALTH

Sugars (disaccharides and oligosaccharides) are typically hydrolysed into individual monosaccharides in the small intestine, and subsequently absorbed and metabolised to yield dietary energy. For labelling purposes, most sugars are considered to provide 4 kcal/g. However, subtle variations in chemical structure between different sugar compounds influence the way in which they are digested, absorbed and metabolised. These variations are evident in the glycaemic index (GI) of individual sweet-tasting mono- and di-saccharides. Some of the traditional sweeteners, such as honey, agave and carob, have a lower glycaemic potency than refined sugars and may therefore appeal to those following a low glycaemic index (GI) diet. The low GI of these products may be attributed in part to their relatively high proportion of fructose, which has a particularly low GI of 19, compared with glucose (GI=100) and sucrose (GI=68). The main health concerns about sugars and sugar-rich products are their cariogenic properties upon their excessive intake. Therefore, sugars should be eaten in moderation within balanced diets and alongside active lifestyles that promote a healthy body weight.

Overweight and obesity

Excessive consumption of calories, regardless of their source, can lead to weight gain and obesity. It is unlikely that any one food group is responsible for this complicated metabolic state. However, sugar offers "empty" calories, devoid of other

nutritional benefits. By reducing the amount of sugar, and thus calories, in our diet, it is possible to lose weight without compromising intake of essential nutrients.

Additionally, eating foods with significant sugar content can create large swings in blood glucose, leading to subsequent overconsumption of food. Furthermore, multiple studies have examined the various pathways associated with sugar consumption, noting that sugar may be an addictive substance for some individuals. This may further contribute to overeating, leading to excessive weight gain.

Diabetes

Data from multiple studies suggests that the consumption of sugar-sweetened beverages may increase risk of developing diabetes. Approximately half of the US population consumes sugar sweetened beverages each day. Studies have observed an association between the consumption of high glycemic index foods, such as sugar, and the development of type 2 diabetes. Nonetheless, one of the biggest risk factors for type 2 diabetes is being overweight or obese. Reducing sugar consumption can aid in healthy weight loss, which can be very beneficial for individuals with prediabetes or diabetes. It is crucial to monitor sugar intake to successfully manage diabetes. Sustained elevated blood sugar can cause a myriad of health concerns, including the vision loss, kidney problems, neuropathy, and circulation issues. A balanced diet and regular physical activity can be very advantageous for the management of this condition.

Cancer

High sugar consumption is associated with an increased risk for certain cancers, including colorectal cancer, pancreatic cancer, and endometrial cancer. Additionally, excess sugar consumption is a risk factor for obesity. In cancer patients, obesity is linked to poorer treatment outcomes and increased mortality. Moreover, obesity is associated with increased risk for certain cancers, including postmenopausal breast cancer, pancreatic cancer, and cancer of the liver.

Heart Disease

Research has shown that high consumption of added sugar has been linked to higher risk for cardiovascular disease. It has consistently been linked to stroke, high blood pressure and elevated blood lipid levels. The American Heart Association recommends limiting added sugar consumption to 100 calories a day for women, and

150 calories for men. Decreasing sugar consumption can improve blood cholesterol and triglyceride levels, decreasing risk for heart disease.

Tooth Decay

Sugars and starches are major contributors to tooth decay. Risk for developing dental caries (cavities) increases with the frequency of consumption of foods with sugar and the longer they remain in the mouth without brushing the teeth. Sugars in the mouth are digested by bacteria on the tooth's surfaces. Acid produced by the bacteria causes the enamel to break down, leading to cavities and gum disease. Sugar that remains on the teeth is actually of more concern than amount of sugar consumed. The acid produced by the bacteria lasts for about 20 minutes each time carbohydrate is eaten. This is true regardless of which carbohydrate-containing food is eaten. Bacterial acid production is present whether the carbohydrate is glucose from concentrated sweets, starches, lactose from milk, or fructose from fruit. The stickiness of the sugar also supports bacterial growth. Oral health can be promoted by limiting between-meal snacks (especially those high in sugar or starch), brushing with fluoride toothpaste, and flossing regularly.

Consumption recommendations

Recent evaluations commissioned by the WHO have concluded that limiting the amount of sugar added to foods and decreasing the intake of sugar sweetened beverages (which are a major source of added sugars) would be beneficial in promoting public health, particularly with regard to reducing the risk of dental caries, type 2 diabetes and cardiovascular disease. Consequently, the WHO released a new guideline in March 2015 which recommends that "adults and children reduce their daily intake of free sugars to less than 10% of their total energy intake. A further reduction to below 5% or roughly 25 g (6 teaspoons) per day would provide additional health benefits". Overall, there seems to be a consensus among government agencies and regulatory bodies that sugars should be targeted as a potential means of reducing energy intakes and thereby curbing obesity rates. Indeed, the main sources of sugars consumed in the UK population are soft drinks and fruit juices, which together contribute on average 30% of sugars intake for those aged 4-64 years. The amount of sugars that is added to products during food processing has therefore come under particular scrutiny; hence, the food industry is now under pressure to reduce the sugar content of their processed products.