



Sucrose: From Field to Table

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The term “**sugar**” is used to describe sucrose (or table sugar) as it is the most common of all sugars in nature. For thousands of years, sugar has enhanced the pleasure of eating and drinking. Sweetness is a basic taste with recognition and enjoyment qualities that are considered innate. The function of sugar, however, extends well beyond its sweetness by playing a vital role in many sensory and food safety aspects of food. Without sugar, many foods, either natural or processed, would not exist.

SUGAR PRODUCTION IN ALL GREEN PLANTS

Sucrose is present naturally in all fruits and vegetables. Plants use sucrose for energy to live and grow. The chlorophyll (green pigment) in the plant’s leaves captures the energy from the sun which allows carbon dioxide (taken up through the pores of the plant leaves) and water (absorbed through the roots in the soil) to combine and form sucrose; a process referred to as photosynthesis (Figure 1). Sucrose is the first carbohydrate formed by photosynthesis, and is the source of the glucose, fructose and other sugars found in plants as well as the starches distributed throughout the green plant kingdom.

Sucrose is a 12-carbon disaccharide composed of single units of glucose and fructose (monosaccharides), which are linked together by a glycosidic bond (Figure 2). Sucrose, glucose, and fructose are distributed extensively in fruits and some vegetables, sap, honey, and molasses, either individually or linked together. Fructose, glucose and sucrose exist frequently in combination in many foods (Figure 3). The highest concentration of pure sucrose is found in sugar cane and sugar beets. Regardless of the source of sucrose, whether from fruits, vegetables, sugar cane or sugar beets, the molecular structure and nutritional value (4 Calories per gram) are the same.

Figure 1: Photosynthesis: How plants make sugar (sucrose)

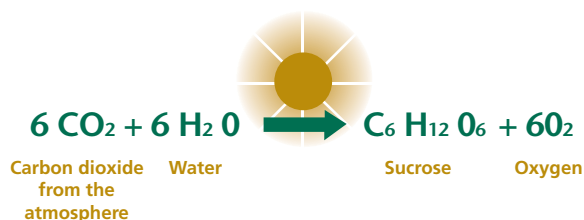
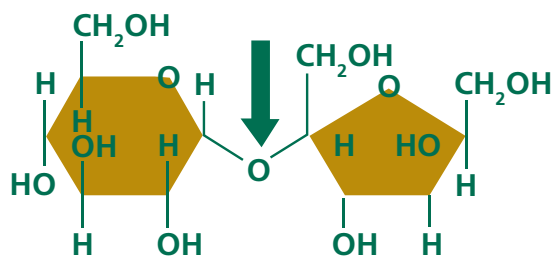


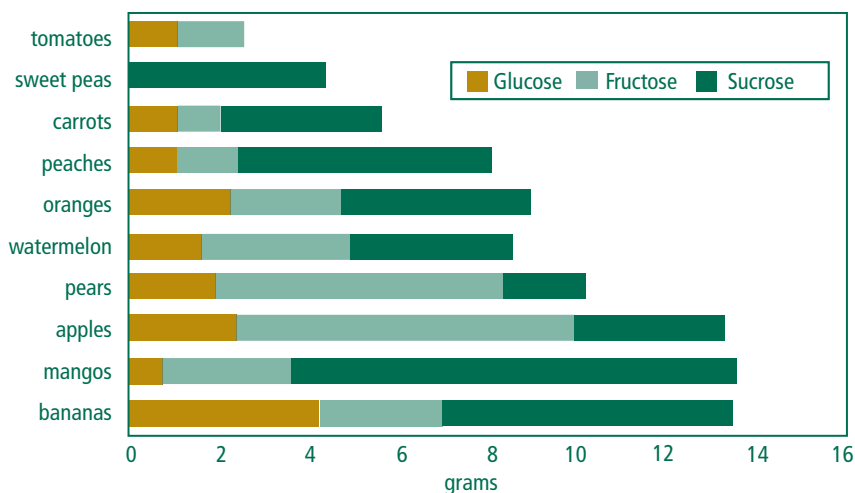
Figure 2: Sucrose molecule. Glucose molecule (left) is linked together to fructose molecule (right) by a glycosidic bond (arrow).



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Figure 3: Sugars content of fruits and vegetables per 100 gram of edible portion. Values from USDA Nutrient Laboratory, Sugar Content of Selected Foods, 1987.



DID YOU KNOW?

The production and processing of sugar in Canada is linked to Canada's economic history and once measured the wealth of our nation. Historically, sugar was a rare, valuable and sought-after commodity as it elicited the purest intensity of sweetness compared to other sweeteners. However, technological advances for its efficient extraction were lacking. Consequently, the cost of one teaspoon of sugar in the 1600s was equivalent to five dollars today; and four pounds of sugar would purchase a calf. In the 1800s, the consumption of sugar and tea per inhabitant were considered the best measure of our nation's prosperity. The first Canadian sugar refinery was established in 1854 in Montreal, boasting favourable economic development. Today, sugar purification in Canada remains an important part of our economy.

SUGAR CANE AND SUGAR BEET CROPS AS A SOURCE OF SUPPLY

Sucrose was first separated from sugar cane plants (*Saccharum robustum*) more than 12,000 years ago in Papua New Guinea. Sugar cane is a tall grass grown and harvested worldwide in tropical and sub-tropical regions, such as South and Central America, South and South East Asia, Africa, and Australia. After harvest, the sugar cane is transported to nearby mills where the sugar cane is cut up into small pieces, crushed and mixed with hot water to begin the separation of sucrose from its surrounding plant fibres and remaining soil. The watery juice is boiled down to thick syrup and tiny sugar crystals are added to start the crystallization process. The raw sugar crystals are separated from the syrup in centrifugals (like large washing machines) then dried and stored. By-products of sugar cane production are molasses and the fibrous residue known as *bagasse*. Bagasse is not wasted, but is recycled as a fuel for the raw sugar mill. After milling, the raw sugar crystals are refined locally or shipped in bulk by sea to distant refineries for the final purification process. In Canada, refineries are located in Montreal, Toronto and Vancouver.

Sugar beet plants (*Beta vulgaris*) are a bulbous root crop found in the temperate zones of the North, such as the Canadian Prairies, the US Midwest, Europe and Russia. Unlike sugar cane, sugar beets are both harvested and purified locally. In Canada sugar beets are grown in southern Alberta and processed at the sugar beet factory in Taber. Crops are rotated (successive planting of different crops on the same land) every four years to optimize yields and reduce diseases and unwanted pests. After harvesting, sugar beets are first sliced into thin strips called *cossettes* which are heated to disintegrate the cell wall, thus facilitating the recovery of sugar. The sugar in the cossettes,

along with some non-sugar impurities, is extracted using hot water, resulting in a watery juice that must be further concentrated and purified, similar to the final purification process for raw cane sugar. The by-product of sugar beet production (pulp) is not wasted, but is used as nutritious cattle feed. Sugar, whether from sugar beets or sugar cane, is identical.

SUGAR PURIFICATION PROCESS

To meet Canadian food standards, sugar must have a minimum purity of at least 99.8% sucrose. This means that raw sugar must undergo further purification before the sugar is ready for human consumption. The final purification processes for cane and beet sugar are similar. First, the thin coat of molasses surrounding the sugar crystals is removed. Sugar crystals are dissolved in water and filtered to produce a clear golden coloured syrup. The syrup is boiled to evaporate excess water, and tiny sucrose crystals are added to the thickening syrup to facilitate the formation of large sugar crystals. The liquor is then spun in a centrifuge to separate the pure white sugar crystals from the syrup. As sugar is naturally white, no bleaching is required. The pure sugar crystals are dried and packaged. The refining process does not alter the natural sucrose in any way, but simply separates pure white sugar crystals from the surrounding plant materials.

To meet Canadian food standards, sugar must have a minimum purity of at least 99.8% sucrose. Refining is a purification process to separate pure white sugar crystals from surrounding plant materials.

BEYOND SWEETNESS - THE ART AND SCIENCE OF SUCROSE IN FOODS

FUNCTIONAL PROPERTIES AND PHYSICAL ATTRIBUTES IN FOOD

Sugar is not added solely for sweetness. Sugar has many important functional properties that improve both the sensory and safety aspects of food.

SWEETNESS

An obvious function of sugar is the provision of sweet taste. Since sugar provides energy, it is a nutritive sweetener. Taste receptors are located on the tongue and throughout the mouth. Sweetness is perceived when a chemical compound, such as sucrose, stimulates the taste receptors, sending signals acting like messages to the brain. Sugar must first be dissolved in a watery solution like saliva, in order to bind to the taste receptor. Factors such as sugar concentration, temperature, pH, the presence of other flavours in the mouth as well as individual sensitivity to sweet taste affect our ability to detect and thus recognize sweetness. Nutritional status is also important for optimal taste function; zinc and other micronutrient deficiencies have been suggested to cause taste impairment. In healthy individuals, taste receptors rejuvenate every 10 days. As we age, the rejuvenation process slows, causing a loss of taste which can potentially diminish the taste of sweet foods. Humans are born with a preference for sweet taste and the majority of us react and interpret sweetness in a positive way.

FLAVOUR AND APPEARANCE

Flavour is the combined sense of taste and aroma experienced during the consumption of food. Even though flavour is often referred to as "taste", the flavour of foods is mostly (60-70%) attributed to aroma. Sugar plays an important and unique role in contributing to the flavour of foods by interacting with other ingredients to enhance or lessen certain flavours. For example, small amounts of sugar added to cooked vegetables and meat enhance the food's natural flavours, without making them taste sweet. Sugar can also depress the unpleasant sensations of bitter or sour, making foods, such as chocolate and lemonade more palatable. Sugar also has its own subtle flavour, which is mainly produced when it is heated, and is a result of the products derived from the Maillard and caramelization reactions.

The *Maillard* reaction occurs when sugars react with proteins, producing caramel-like aromas and dark coloured pigments. Early stages of the Maillard reaction are responsible for the pleasant smell during baking, while late stage reactions contribute to the colour of roasted coffee and baked bread. *Caramelization* occurs when sugars are degraded by heat in the absence of proteins, producing caramel

colouring and flavouring. Caramel colours and flavours are produced commercially to add brown colour to foods and pleasant characteristics to baked goods, candies, meats, breads, desserts and other food and beverage products.

TEXTURE

Sugar contributes to the texture of foods, commonly described as *mouthfeel*. Sugar produces the soft, smooth, and airy texture of frozen products like ice cream, by preventing lactose (milk sugar) crystallization and by lowering the freezing point to facilitate the production of smaller ice crystals. Sugar crystallization is minimized to create the soft texture of taffy candies and, in contrast, is maximized to create the desirable grainy texture of hard candies. The concentration of sugar also increases the boiling point of solutions, allowing more sugar to be dissolved, optimizing the final consistency of the candy. To form the crisp-like texture of baked goods, recrystallization of sugar occurs as water in the product is removed during the baking process. The slow crystallization of sugar prevents a grainy texture and retains the moisture of baked and packaged foods, keeping them soft and moist. The high solubility of sugar facilitates sweetness and viscosity characteristics that contribute to the desirable mouthfeel of beverages.

PRESERVATION

Sugar has several important physical properties in food processing, quality control and food safety applications that relate to influencing water function, such as hygroscopicity and osmotic pressure. *Hygroscopic* is defined as the ability to absorb water from the surrounding environment. The hygroscopic nature of sugar plays a key role in reducing water activity in food systems. *Water activity* is the ratio of free water versus bound water within a food system and is important in food preservation, since microorganisms require free (available) water to survive and multiply. Sugar reduces water activity in a food system (e.g. jam) by absorbing free water and increasing osmotic pressure, resulting in reduced microbial and mold growth as well as extending the storage life of foods. Finally, sugar can act to preserve the colour and texture of certain food products, such as frozen or cooked fruits, by inhibiting the loss of water and water-soluble colour pigments.



FERMENTATION

Fermentation occurs when yeasts metabolize sugar under anaerobic conditions, producing carbon dioxide, ethanol and water. This reaction is required for the creation of many food products, such as beer and wine as well as baked goods, such as bread. In bread making, sugar plays two important roles (in addition to taste) – sugar acts as a leavening agent through the formation of carbon dioxide and acts as a tenderizing agent due to its high affinity to bind to gluten (grain protein). When dough is kneaded, a gluten structure of high elasticity forms, enabling the dough to stretch under the expansion of gases without collapsing. However, if the gluten structure is too well formed, the dough becomes tough and rigid, resulting in a hard, flat bread. Sugar controls the activity of gluten, ensuring a soft and tender bread. A precise amount of sugar is added to a bread recipe to yield the optimum elasticity of gluten.

ANTIOXIDANT FUNCTION

The hygroscopic nature of sugar produces a weak antioxidant effect by decreasing the availability of water that is otherwise required to solubilise potential oxidants. The antioxidant effect of sugar reduces rancidity, discolouration and deterioration of certain food products (e.g. canned fruits and baked goods). Also many early stage products of the Maillard reaction (in which sugar is involved) have been shown to work synergistically with other natural antioxidants (e.g. vitamin E) to prevent oxidation of lipids and proteins, extending the shelf-life of foods.

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Sugar provides multiple functional qualities in both natural and formulated foods which are important for ensuring high quality and safety to the consumer. The variety and uniqueness of these functional qualities eliminates the need for numerous alternative food additives which would otherwise be required if sugar was not present in the food product. This simple fact makes sugar an invaluable and versatile natural ingredient and an important nutrient in our food.

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