14 Sugars, Sweeteners, and Confections

Introduction

Sugars are simple carbohydrates classified as *monosaccharides* or *disaccharides* (see Chap. 3). The common granulated or table sugar is the disaccharide sucrose, made of glucose and fructose. This chapter on sugars, sweeteners, and confections examines the sources, roles, and properties of sugars, the various types of nutritive sweeteners, and sugar substitutes added to foods. As well, confections and factors influencing candy types are addressed. Sugar should be used sparingly in the diet, and depending on serum glucose and lipid goals, nutritive and nonnutritive sweetener intake should be individualized by consumers.

Sources of Sugar

Table sugar comes from *two* sources. It naturally exists as syrup in the *sugar cane* or in *sugar beet*, both of which are *identical* in chemical composition. Sugar cane has been used for centuries. It is washed, shredded, pressed, and heated, and the extracted juice is centrifuged to create raw sugar with its slightly brown color. As the juice is centrifuged, molasses separates from the crystals and become a by-product of sugarcane sugar production. The crystals are then further refined for uses in various forms.

Roots of the beet are less frequently used to produce sugar and were first extracted in the 1790s. They too are washed, shredded, and so forth. Then, roots are treated with lime to remove impurities and further refined to yield usable sugar.

Roles of Sugar in Food Systems

The roles of sugars are diverse (some are listed below). Sugar may be utilized in *trace* amounts or it may be the *primary* ingredient of a formulation. Sugar imparts sweetness, tenderness, and browning, is hygroscopic (water retaining), and functions in various other ways in food systems, as may be seen in the following examples of sugar function.

Sweetness

Sugar provides flavor appeal to foods and is therefore incorporated into many foods. It is a significant ingredient of candy, many baked goods and frostings as well as some beverages, and may be used in a less significant manner or not at all in other foods. Around the world, there is an *innate* desire for sweetness. Some individuals consume fruit "picked off of a tree," as a piece of fruit, while others consume snacks they "pick out from the office vending machine"!

V.A. Vaclavik and E.W. Christian, *Essentials of Food Science, 4th Edition*, Food Science Text Series,
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Tenderness

A batter/dough formula *with* sugar is *more* tender than one *without* sugar, because sugar binds with each of the two proteins gliadin and glutenin and absorbs water so they do *not* form gluten.

Browning

Browning in some varieties of *fruits and vegetables* is due to *enzymatic*, *oxidative browning*. Yet it is *sugar* that browns and imparts color to foods by two types of *nonenzymatic* browning including (1) the low-temperature Maillard browning reaction and (2) high-temperature caramelization.

Maillard browning involves the reaction of the carbonyl group of a reducing sugar with the amine group of an amino acid and occurs with *low*-temperature heat, a high pH, and low moisture. Maillard browning is responsible for the color changes that occur in many baked breads, cakes, and pie crusts, canned milks, meats, as well as caramel candies (which, although the name is used, is *not* caramelization).

Caramelization is a *nonenzymatic* browning process that occurs in sugars heated to *high* temperatures. As sugar is heated to temperatures above its melting point [338 °F (170 °C)], it dehydrates and decomposes. The sugar ring (either pyranose or furanose) opens and loses water. The sugar becomes brown, more concentrated, and develops a caramel flavor as it continues to increase in temperature. The dessert flan is an example.

CULINARY ALERT! Caramelization in culinary terms refers to any sugar in food that is broken down to produce enhanced color and flavor upon reaching a high temperature. Most notable is caramelized, dark brown, onions.

Additional roles of sugar in food systems (not all inclusive!):

- Functions as a *separating agent* to prevent lump formation in starch-thickened sauces (Chap. 4)
- *Reduces starch gelatinization* (Chap. 4)
- *Dehydrates* pectin and permits gel formation in jelly-making (Chap. 5)
- Stabilizes *egg white foams* (Chap. 10)
- *Raises the coagulation temperature* of protein mixtures (Chap. 10)
- Adds *bulk* and body to foods such as yogurt (Chap. 11)
- Helps *aerate* batters and dough (Chap. 15)
- Reduces gluten structure by competing with gliadin and glutenin (Chap. 15) for water, thus increasing *tenderness* (Chap. 15)
- Acts as the substrate that *ferments* to yield CO_2 and alcohol (Chap. 15)
- Adds *moisture retention* properties to baked products (Chap. 15)
- Slows/prevents crystallization in candies if invert sugar is used (Chap. 14)

Types of Sugars and Sugar Syrups

Types of sugars "-ose," those used in food preparation, and syrups are discussed below. Sugar substitutes will be discussed later in this chapter.

Sucrose. Sucrose is a *disaccharide* consisting of the monosaccharides glucose and fructose. It is commonly referred to as "sugar," "white sugar," or "granulated sugar."

Fructose. Fructose is a *monosaccharide* that combines with glucose to form the *disaccharide* sucrose. It is known as fruit sugar, since it is contained in many fruits. Fructose is 1.2–1.8 times as sweet as sucrose.

Glucose. Glucose is a *monosaccharide* that combines with fructose to form sucrose, with galactose to form lactose, and with another glucose to form the *disaccharide* maltose.

Galactose. Galactose is a *monosaccharide* that combines with glucose to form the disaccharide lactose.

Lactose. Lactose is a *disaccharide* (a glucose and galactose molecule) known as milk sugar. It is less sweet than sucrose.

Maltose. Maltose is a *disaccharide* (two glucose molecules) formed by the hydrolysis of starch.

*All monosaccharides contain a free carbonyl group and are reducing sugars, as is the disaccharide maltose.

Specific recipe preparation may require use of the following sugars (the use of artificial sweeteners and sugar alcohols will be discussed in a later section of this chapter):

Brown sugar. Brown sugar has a molasses film on the sugar crystals, which imparts the brown color and characteristic flavor of this sugar. It contains approximately 2 % moisture and requires storage protection against moisture loss.

Confectioners' sugar. Confectioners' sugar (confectionery sugar) is also known as *powdered sugar* and is derived from either sugar cane or the sugar beet. Sugar grains are pulverized by machine to change the sugar grain to a powdered substance and form such sugars as "6× sugar" (pulverized 6 times to create "very fine"), "10× sugar" (pulverized 10 times to form "ultrafine"), and so on. Confectioners' sugar typically contains 3 % cornstarch to prevent caking.

Invert sugar. Invert sugar is created when *sucrose* is treated by acid or enzyme to form an equal amount of *fructose and glucose*. It is more soluble and sweeter than sucrose and is commonly used in confections, including that which will become the liquid center of chocolate-covered cherries.

Raw sugar. Raw sugar has a larger grain than ordinary granulated sugar. It is 97–98 % sucrose. It is *not* approved by the FDA for sale in the United States since impurities and contaminants remain in the granule. (It is not the same as "Sugar In The Raw®.")

Turbinado sugar. Turbinado sugar is raw sugar with 99 % of the impurities and most of the by-product of sugar crystal formation (molasses) removed.

Syrups (Liquids)

The conversion of starch yields dextrose (glucose). Syrups are then measured as dextrose equivalents (D.E.). Syrups may have a D.E. of 36–55. More pure glucose yield is 96–99 D.E.

Corn syrup: Corn syrup is a mixture of carbohydrates (glucose, maltose, and other oligosaccharides) formed from the hydrolysis of cornstarch by the use of acid or enzymes (HCl, or α and β amylases). Following hydrolysis, it is subsequently refined and concentrated. The sugar solution contains approximately 25 % water and is viscous.

$$\text{Starch} + \text{Water} \xrightarrow[\text{enzymes}]{\text{acid+heat}} \text{Dextrins} + \text{Maltose} + \text{Glucose}$$

Corn syrup, due to its high glucose content, more readily participates in Maillard reactions. As a reducing sugar, corn syrup (its glucose) is a major browning enhancer. Adding just 1 tablespoon (15 mL) of corn syrup to otherwise paler cookie dough significantly increases browning.

Read more from cooking pro Shirley Corriher at http://www.tipsonhomeandstyle.com/food/the-cure-for-common-cookie-problems#ixzz2IqVGlh2o

High-fructose corn syrup (HFCS): HFCS is a specialty syrup prepared by the same three steps as corn syrups—it is hydrolyzed, refined, and concentrated. In addition, isomerization occurs whereby the principle sugar, glucose, is made into a more soluble fructose by the enzyme action of another enzyme, isomerase.

The HFCS contains approximately 42 % fructose and may undergo a fractionation process to further remove glucose and create syrup that is 55 or 90 % fructose. HFCS containing 42 and 55 % fructose are *generally recognized as safe* (GRAS). Many beverages contain HFCS, and although sugar consumption in the United States may show a downward trend, HFCS is increasingly ingested.

See *What the Science Says about HFCS* at www.sweetsurprise.com/what science-says-about-hfcs (SweetSurprise.com).

Honey: Honey is made from the nectar of various flowers and therefore differs in color, flavor, and composition. It contains approximately 20 % water and a mixture that is glucose and fructose (predominantly the latter), with no more than 8 % sucrose. Due to the hygroscopic property of fructose, the addition of honey to a formulation favorably increases its level of moisture.

Darker colored honey is *more* acidic and *more* strongly flavored than light colored honey. The strains of alfalfa and clover honey, commonly sold in the United States, are mild-flavored honey. "Strained honey" is honey from a crushed honeycomb that is strained.

Maple syrup: Maple syrup is obtained from the sap of the maple trees. The sap is boiled and evaporated, and the final product contains no more than 35 % water (40 parts sap = 1 part maple syrup).

Molasses: Molasses is the syrup (plant juice) separated from raw sugar beet or sugar cane during its processing into sucrose, and it is thus a by-product of sugar making. The predominant sugar is sucrose, which becomes more invert sugar with further processing. Molasses provides very low levels of the minerals, calcium, and iron, although blackstrap molasses is the product of further sugar crystallization and contains a *slightly* higher mineral content.

The Sugar Association states that almost 60 % of sweetener intake is from corn sweeteners, especially those used in sodas and sweetened drinks. The other 40 % is from table sugar or sucrose (The Sugar Association, Washington, DC).

Properties of Sucrose

Properties of sucrose, in addition to supplying sweetness, are important in food systems, such as confections. These are discussed in the following subsections.

Solubility

Solubility of sugars varies with sugar type. For example, sucrose is more soluble than glucose and less soluble than fructose. This influences candy type and product success (see later chapter section on Formation of Invert Sugar).

In its dried, granular form, sugar becomes *increasingly* soluble in water with an increase in temperature. At *room temperature*, water is capable of dissolving sucrose in a ratio of 2:1 (67 % sucrose and 33 % water). If that same water is *heated*, more sugar is dissolved, and as the sugar–water is further heated and brought to a boil, water evaporates and the sugar syrup becomes increasingly concentrated. This is seen in the amount of sugar held by equal amounts of iced tea and hot tea beverages. Hot tea holds more dissolved sugar.

Sugar may precipitate from solution, forming an undesirable grainy, crystalline product. Therefore, to increase the solubility of sucrose and reduce possible undesirable crystallization, sucrose may be treated by inversion to become *invert sugar*.

Types of Solutions

Solutions are the homogeneous mixtures of ***solute***, dissolved in ***solvent***. Depending on the amount of dissolved solute that the water is holding at any specific temperature (see Sugar Concentration),

Table 14.1 Boiling point of sucrose–water syrups of different concentrations[a]

Percent of sucrose in syrup	Percent water	Boiling point in °F (°C)
0 (All water, no sugar)	100	212 (100)
20	80	213.1 (100.6)
40	60	214.7 (101.5)
60	40	217.4 (103)
80	20	233.6 (112)
90	10	253.1 (123)
95	5	284 (140)
99.5	0.5	330.8 (166)

[a]At sea level

solutions may be dilute (unsaturated), saturated, or supersaturated.

Elevation of Boiling Point

The boiling point of sugar *elevates* with *increasing concentrations of sucrose* in solution as shown in Table 14.1. The boiling point also rises as the liquid evaporates from a boiling solution and causes there to be a greater concentration. This more concentrated solution now has a reduced vapor pressure that elevates boiling point because more heat is needed to raise the reduced vapor pressure found in a more concentrated sugar solution.

The addition of sugars other than sucrose, as well as the addition of interfering agents (see Interfering Agents), may also *elevate the boiling point*. At sea level, water boils at 212 F (100 °C). For every gram molecular weight of *sucrose* that is dissolved in water, there is a 0.94 °F (0.52 °C) increase in boiling point. This is why sugar solutions reach a very high temperature and cause more severe burns than boiling water.

CULINARY ALERT! High elevation lowers the point at which water boils. For each 500 ft in elevation above sea level, there is progressively less atmospheric pressure and the boiling point *decreases* 1 °F. [Therefore, at an elevation of 5,000 ft, the boiling point is *lowered* by 10 °F, to 202 °F (94 °C)]. Also, the boiling point is *lowered* above sea level.

Formation of Invert Sugar

Another property of sugar is that *invert sugar* is formed by sucrose hydrolysis in the process of ***inversion***. The inversion process yields equal amounts of the monosaccharides *glucose* and *fructose*, and the latter is more soluble than sucrose (solubility of fructose > sucrose > glucose).

CULINARY ALERT! Due to its increased solubility, the use of invert sugar in confections is desirable in candies. It is used to slow crystallization and help keep crystals small. Invert sugar is combined in a ratio of 1:1 with sucrose in many product formulations.

As seen in the formula, sucrose may be hydrolyzed into invert sugar by either *weak acids*, such as in cream of tartar (the acid salt of weak tartaric acid), or by *enzymes* such as invertase. Each is described below.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[enzyme]{acid+\ heat} C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose Water Glucose Fructose

Concerning *acid hydrolysis*, it is both (1) the amount of acid and (2) the rate and length of heating that determine the quantity of invert sugar that forms. This is addressed below:

- **Amount of acid**:
  Too much acid, such as cream of tartar, may cause *too much* hydrolysis, which forms a soft or runny sugar product.
- **Rate and length of heating**:
  A *slow* rate and slow attainment (long length of heating) of the boiling point increases inversion opportunity, whereas a *rapid* rate provides less inversion opportunity.

In *enzyme hydrolysis*, sucrose is treated with the enzyme invertase (also known as sucrase) to form glucose and fructose.

CULINARY ALERT! Enzyme hydrolysis may take several days, as is the case with invert sugar that is responsible for forming the liquid in chocolate-covered cherries.

The *glucose* that forms from inversion is *less* sweet than sucrose, and the *fructose more* sweet, with the overall reaction producing a sweeter, more soluble sugar than sucrose. Invert sugar is combined in a ratio of 1:1 with untreated sucrose in many formulations to control crystal formation and achieve small crystals.

Hygroscopicity

Hygroscopicity, or the ability to readily absorb water, is a property of *sucrose*. However, other sugars that are high in *fructose*, such as *invert sugar*, *HFCS*, *honey*, *or molasses*, are *more* hygroscopic than sucrose. It is therefore important to control the degree of inversion that these more hygroscopic sugars undergo, or they may exhibit *runny* characteristics in storage. Sugar alcohols such as mannitol are nonhygroscopic.

Sugar that is stored in a *humid storeroom* location and candy that is prepared on a *humid day* are *both* situations that demonstrate this property of hygroscopicity in that the sugar becomes lumpy and the finished candy is soft. (This hygroscopicity property of sugar carried caution for the preparation of meringues in the Egg chapter.)

Due to this hygroscopic property of sucrose, product developers may *encapsulate* or coat sugars so that sugars are time released.

Fermentable

One more property of sugar is that it is fermentable. It undergoes ***fermentation*** by the biological process in which bacteria, mold, yeast, and enzymes anaerobically convert complex organic substances, such as sucrose, glucose, fructose, or maltose, into *carbon dioxide* and *alcohol*.

The next discussion encompasses substances with very different properties than the aforementioned organic substances.

Sugar Substitutes

Sugar substitutes include two categories: (1) *artificial* (*or high-intensity*) *sweeteners* (noncaloric, nonnutritive) and (2) *sugar alcohols* (caloric, nutritive). Each of these sugar substitutes may be utilized with varying degrees of success in food products including cereals, cakes, pies, ice cream, soda, and candies. Americans regularly consume low- or no-calorie or sugar-free sugar substitutes in order to cut back on calories or sugars.

Artificial or High-Intensity Sweeteners

[You may prefer to differentiate between artificial sweeteners and high-intensity sweeteners because natural high-intensity ones are being discovered/developed such as steviosides and Reb A (covered on in this chapter).]

Artificial sweeteners or high-intensity sweeteners are one category of sugar substitute. They are noncaloric, nonnutritive, intense sugar substitutes, whose use has grown in response to increased consumer demand. They must be FDA approved before use. As with foods discussed throughout other book chapters, an individual aversion, medically or otherwise, may exist.

Various examples of artificial sweeteners are included as follows.

Acesulfame K. *Acesulfame potassium* is a noncaloric, synthetic derivative of acetoacetic acid. It received FDA approval in 1988. Acesulfame K is an organic salt consisting of carbon, hydrogen, nitrogen, oxygen, potassium, and sulfur and is *not* metabolized by the body; however, it is rather excreted *unchanged*. It is 200 times (thus high intensity) sweeter than sucrose and is heat stable, able to successfully be used for baking and cooking purposes in addition to use as a tabletop sweetener.

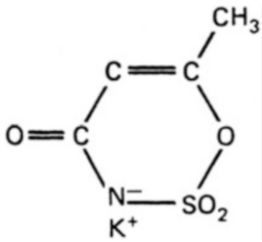

Fig. 14.1 Chemical structure of acesulfame K

Acesulfame K has no bitter aftertaste and may be used *alone or in combination* with the other sweeteners saccharin or aspartame (Fig. 14.1). Some brand name examples of acesulfame K are Sunett®, Sweet One®, Swiss Sweet®, and Nutra Taste®.

CULINARY ALERT! *Sweet One® 12 packets = 1 cup sugar.*

Advantame—developed by Ajinomoto—is made from aspartame and vanillin and is 20,000 times as sweet as sugar and 100 times as sweet as aspartame.

Aspartame. *Aspartame* is a *nutritive* sweetener that contains the *same* number of calories per gram as sugar (4 cal/g). However, due to the fact that it is much sweeter and used in minute amounts, it is *not* a significant source of either calories or carbohydrates and is often put in the category of *nonnutritive*, *noncaloric* sweeteners. Aspartame is a methyl ester comprising two amino acids: aspartic acid and phenylalanine. Thus, because of the latter, phenylalanine, it should *not* be consumed by those with the genetic disease phenylketonuria (PKU) because the phenylalanine is *not* metabolized (Fig. 14.2).

Aspartame is one of the most thoroughly tested and studied food additive the FDA has ever approved (FDA). It gained FDA approval in 1981 and is 180–200 times sweeter than sucrose. It is marketed under the trade names NutraSweet® and Equal®. (Equal® is the tabletop low-calorie sweetener with NutraSweet®.) Aspartame was *not* originally intended for use in heated products; however, it may be encapsulated in hydrogenated cottonseed oil with a time–temperature release, which makes its inclusion in baked products acceptable.

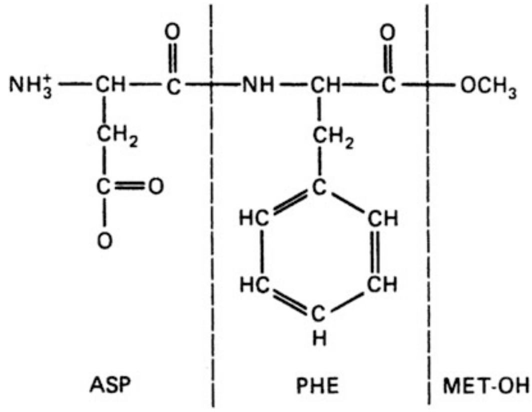

Fig. 14.2 Chemical structure of aspartame. *ASP* aspartic acid, *PHE* phenylalanine, *MET-OH* methyl alcohol. ASP ¼ aspartic acid; PHE ¼ phenylalanine; MET-OH ¼ methyl alcohol

CULINARY ALERT! *Equal® 24 packets = 1 cup sugar.*

Commonly, aspartame and acesulfame K are used together at a ratio of 50:50 or so, “Their synergy together covers the entire sweetness curve” (Hazen 2012a).

Neotame. Neotame is chemically similar to the artificial sweetener aspartame. It is between 7,000 and 13,000 times as sweet as sucrose. It was granted FDA approval in 2002.

Saccharin. *Saccharin* is a noncaloric substance produced from methyl anthranilate, a substance naturally found in grapes. It has been used as a noncaloric sweetener since 1901 in the United States and is 300–700 times sweeter than sucrose.

The use of saccharin was periodically reviewed as specified by US Congress in the *Saccharin Study and Labeling Act*. The ruling required that foods containing saccharin must be labeled to read as follows: “Use of this product may be hazardous to your health. This product contains saccharin which has been determined to cause cancer in *laboratory animals*.”

However, following a moratorium on banning saccharin, which was extended by Congress several times, pending further safety studies, it was shown that saccharin has *not* demonstrated any carcinogenicity applicable to *humans*. Therefore, after several decades the safety of saccharin has been shown, and the use of a warning label is *no* longer required. The use of saccharin has been reported to be acceptable by the American Medical Association, the American Cancer Society, and the Association of Nutrition and Dietetics (formerly American Dietetic Association).

In December 2000, Congress passed H.R. 5668—the **S**accharin **W**arning **E**limination via **E**nvironmental **T**esting **E**mploying **S**cience and **T**echnology (**SWEETEST**) Act. It is approved for use in more than 100 countries.

Calcium or sodium saccharin, combined with dextrose (nutritive, glucose) and an anticaking agent, may be used in tabletop sweeteners. Saccharin may also be used in combination with aspartame. Brand name examples include Sweet'N Low®, Sugar Twin®, Necta Sweet®, and Sweet-10®.

CULINARY ALERT! *Sweet'N Low® 12 packets = 1 cup sugar.*

Sucralose. *Sucralose* gained FDA approval in 1998 for use in 15 specific food and beverage categories, including baked goods and baking mixes; beverages and beverage mixes; chewing gum; coffee and tea; confections and frostings; dairy product analogs; fats and oils (salad dressings); frozen dairy desserts and mixes; fruit and water ices; gelatins, puddings, and fillings; jams and jellies; milk products; processed from it and fruit juices; sweet sauces, toppings, and syrups; and sugar substitutes.

Sucralose is a *noncaloric* trichloro derivative of sucrose [three hydroxyl (hydrogen–oxygen) groups on a sugar molecule are selectively replaced by three atoms of chlorine], plus maltodextrin, which gives it bulk and allows it to be measured cup for cup, like table sugar. It is 400–800 times sweeter than sucrose.

Several advantages to its approval are that (1) it is the only *noncaloric* sweetener made from sugar; (2) it is *stable* under a wide range of pH, processing, and temperature scenarios, for example, it is water- and ethanol-soluble and heat stable in baking and cooking; and (3) it carries *no health warnings*. Splenda® is the brand name under which sucralose is marketed (Fig. 14.3).

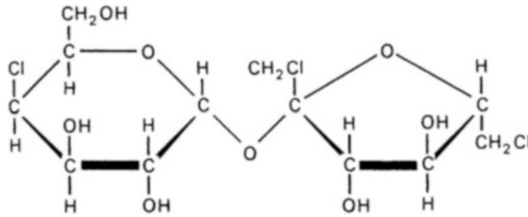

Fig. 14.3 Chemical structure of sucralose

Cyclamate. Cyclamate does not have FDA approval although it is still used as a sweetener in many parts of the world, including Europe. It was discovered "accidently" in a US university research lab in 1937 and was used through the 1960s, although banned in the United States in 1970 and suspect for bladder cancer, liver damage, and other health issues. Currently, the FDA is considering a petition for reapproval, as evidence of its connection with bladder cancer is not verified. It is noncaloric and 30 times sweeter than sucrose.

Cyclamate: Calorie Control Council

Substantial scientific evidence supports cyclamate's safe use by the millions of consumers who seek to control their intake of carbohydrate-based sweeteners and calories…

No low-calorie sweetener is perfect for all uses. However, with several low-calorie sweeteners available, each can be used in the applications for which it is best suited. Also, when used in combination (as would most often be the case with cyclamate), the strengths of one sweetener can compensate for the limitations of another, providing for increased stability, improved taste, lower production costs and more product choices for the consumer. (The Calorie Control Council, Atlanta, GA)

Sugar Alcohols (Polyols)

A category of sugar substitute with a *distinct* classification from *artificial sweeteners* is *sugar alcohol*. Sugar alcohols are *caloric*, chemically reduced carbohydrates (slightly less calories than sugar) that provide sweetness to foods. Examples of sugar alcohols include erythritol, HSH, isomalt, mannitol, sorbitol, xylitol as well as lactitol, and maltitol. **Polyols** is another term for the sugar alcohols which, although they are carbohydrates, are neither sugars nor alcohols.

Q and A: What Other Names Are Used for Polyols?

Since "polyols" is not a consumer friendly term, many nutritionists and health educators refer to polyols as "sugar replacers" when communicating with consumers. Scientists call them sugar alcohols because part of their structure chemically resembles sugar and part is similar to alcohols. However, these sugar-free sweeteners are neither sugars nor alcohols, as these words are commonly used. Other terms used primarily by scientists are polyhydric alcohols and polyalcohols. (The Sugar Association, Washington, DC)

The sugar alcohols are similar in chemical structure to glucose, yet with an *alcohol* group that replaces the aldehyde group of glucose. The sugar alcohol classification includes:

Erythritol. NECTRESSE® is 150 times sweeter than sucrose. A monk fruit extract is blended with other natural sweeteners to create NECTRESSE™ Sweetener. The result is 0 cal per serving and the sweet taste of sugar.

The monk fruit extract is combined with small amounts of sugar, molasses, and erythritol. Erythritol is a sugar alcohol that is found in many fruits and vegetables. According to McNeil Nutritionals (McNeil Nutritionals Fort Washington, PA) in 2012:

"Erythritol is an all-natural, sugar alcohol that is naturally fermented from sugars and is found in many vegetables and fruits. Erythritol contributes zero calories per serving of NECTRESSE™ Sweetener. Consuming erythritol from NECTRESSE™ Sweetener is not expected to result in laxative or other gastrointestinal effects that are known to sometimes occur with other sugar alcohols.

Monk Fruit Extract is about 150× sweeter than sugar and contributes zero calories per serving to NECTRESSE™ Natural No Calorie Sweetener. Like other no-calorie sweeteners, NECTRESSE™ Sweetener contains a small amount of carbohydrate (1–2 g per serving) from other food ingredients to provide needed volume and texture. These food ingredients, which include small amounts of erythritol, sugar, and molasses, contribute so few calories per serving that NECTRESSE™ Natural No Calorie Sweetener Products meet the FDA's criteria for no-calorie foods (<5 cal/serving) (McNeil Nutritionals Fort Washington, PA)."

CULINARY ALERT! One packet of NECTRESSE™ is equal to 2 teaspoons of sugar.

Hydrogenated starch hydrolysate (HSH) and hydrogenated glucose syrup (HGS) are other sugar alcohols. According to the Calorie Control Council, polyols that do not contain a specific polyol as the majority component continue to be referred to by the general term "hydrogenated starch hydrolysate" (The Calorie Control Council, Atlanta, GA).

Isomalt. Isomalt is 45–65 % as sweet as sucrose; 2 cal/g is in HSH and HGS has 3 cal/g. Isomalt is a disaccharide comprised of two glucose molecules sharing a 1–6 link

Mannitol provides half the sweetness of sucrose and provides 1.6 cal/g. Mannitol has a low glycemic index and therefore does not stimulate an increase in blood glucose; thus, it may be used as a sweetener for people with diabetes and in chewing gums.

Mannitol and sorbitol sugar alcohols provide half the sweetness of sucrose and may be used in various foods. They are isomers. Mannitol is in a wide variety of natural products, including almost all plants, including seaweed.

Sorbitol is commercially produced from glucose and contains 2.6 cal/g.

It provides half the sweetness of sucrose. In *combination* with aspartame and saccharin, it provides the volume, texture, and thick consistency of sugar. It is also used as a bulking agent.

Xylitol. Xylitol is approximately as sweet as sucrose with 33 % fewer calories.

Sugar alcohols may be *sugar-free*; however, they are *not calorie-free*! The body does not metabolize sugar alcohols, so persons with diabetes may use them without a rise in their blood sugar. Large amounts of sugar alcohols may cause intestinal diarrhea; therefore, they are not recommended for use in significant amounts.

Novel Sweeteners

"A few sweeteners are considered novel sweeteners because of their chemical structure" (Mayo Foundation for Medical Education and Research (MFMER)).

Stevia—Stevia is from the leaves of the stevia plant with 300× the sweetness of sugar and 0 cal. The FDA once labeled stevia as an "unsafe food additive" and restricted its import. The FDA's stated reason was "toxicological information on stevia is inadequate to demonstrate its safety." Further studies have shown it to be safe, and it began to be used in the United States in 2008.

CULINARY ALERT! *24 packets = 1 cup of sugar.*

Stevia is, according to Webster's definition:

1. Any of a genus (*Stevia*) of composite herbs and shrubs of tropical and subtropical America; *especially*: a white-flowered tender perennial (*S.rebaudiana*) native to Paraguay
2. A white powder composed of one or more intensely sweet glycosides derived from the leaves of a stevia (*S. rebaudiana*) and used as noncaloric sweetener

Its first known use was in 1806. The many types of stevias on the market are listed in the general "stevia" category.

"Extracts from the stevia plant glycosides or steviosides vary in sweetness and flavor profiles. The combinations and percentages of these glycosides differ from manufacturer to manufacturer."

> They don't all taste the same, so it is important for food scientists to try out the different types that are available. If one doesn't work for their needs there are plenty of others to choose from. Stevia extracts also come in a variety of percentages (e.g. 95%) but the numbers don't really say anything about the taste profile. It's still very much a formulator's world where art meets science. (Hazen 2012b)

Three newer sweeteners are becoming more frequently publicized as sugar replacers. These are fructo-oligosaccharide, tagatose and trehalose. Each is made from different carbohydrate sources, and each bestows slightly different functional properties. (These are categorized by the FDA as GRAS substances.)

What is a fructo-oligosaccharide?

Like many of the starch-based sugar replacers, the term "fructo-oligosaccharide" represents a family of ingredients, not a single product. Fructo-oligosaccharides (FOS) are manufactured by fragmenting a large molecule. In the case of FOS, that molecule (polysaccharide) is inulin. Inulin is a polysaccharide in which a single glucose unit ends a chain of up to sixty fructose units linked together.

Inulin occurs naturally in chicory, Jerusalem artichokes, wheat, onions, and bananas. Chicory and Jerusalem artichoke are the commercial sources of FOS products. Since commercial FOS products can have various numbers of fructose units linked to the ending glucose unit, the Food and Drug Administration has ruled that "fructooligosaccharide" is the term approved for an ingredient list.

FDA has agreed with manufacturers' conclusions that FOS products are safe food ingredients. FOS may be used in hard and soft candies, baked goods like biscuits, cakes, cookies and crackers, frozen dairy desserts, cereals, jams and jellies, flavored and unflavored milks, and soups. Additionally, FOS has been approved for use a binder and stabilizer in a variety of meat and poultry products.

What is tagatose?

Tagatose occurs naturally in dairy products, but the commercial product is manufactured from lactose (milk sugar) by a patented process. It is very similar to fructose in structure.

Tagatose has the bulk of sugar, and is almost as sweet. However, it has only 1.5 cal per gram since less than 20 % of ingested tagatose is absorbed in the small intestine. Although tagatose is digested the same as fructose, its limited absorption means that it is metabolized mainly in the large intestine. The short chain fatty acids promote the growth of the two bacteria recognized to improve colon health. Consequently, the prebiotic potential of tagatose is often stressed for the foods using this sugar replacer.

Tagatose was launched in the U.S. in 2003 after the Food and Drug Administration issued a letter agreeing with the manufacturer's determination that it is a safe food ingredient. Tagatose may be used in foods like soft and hard candies, frozen dairy desserts, cereals, frostings and fillings, and chewing gum.

What is trehalose?

Trehalose is found naturally in such diverse foods as honey, mushrooms, shrimp and lobster, and in foods produced with baker's or brewer's yeast. It is found naturally in such diverse foods as honey, mushrooms, shrimp and lobster, and in foods produced with baker's or brewer's yeast.

Commercially, trehalose is manufactured from cornstarch. Although trehalose is a disaccharide of two glucose units, its molecular bonding makes it different than maltose, the other glucose disaccharide made from cornstarch. Trehalose has four calories per gram—same as sugar—but is only half as sweet (The Sugar Association, Washington, DC).

Confections

The word *confections* has several uses and meanings. For example, chocolates may be known as *chocolate confectionery*, cakes and pastries may be referred to as *flour confectionery*, and the term *sugar confectionery* may signify any sugar-based products. Sweet food products may utilize the terms "confections" or candy. However, in the United States, both chocolates and the various sugar-based confections are simply referred to as "candy."

CULINARY ALERT! In the manufacture of confectionery products, sugar syrups achieve a very high temperature and can cause severe skin burns.

Candy-making is primarily dependent on the *concentration* of sugar in boiled sugar syrups and *controlling or preventing crystal formation*. Various ingredients, such as gelatin, fruit, nuts, milk, and acids, in addition to sugar, may be added to sugars to produce specific candies.

Sugar substitutes are not generally used for candy-making although there exist "chocolates" and other confections for consumption by those with diabetes mellitus. Since they are used in small quantities, and cannot add bulk to candy formulation/recipes, and due to the fact that they do not crystallize, sugar substitutes do *not* produce satisfactory results in all candies. Real sugar may be necessary as a major recipe ingredient in successful candy-making.

During the preparation of candies, the sugar solution must be ***saturated***—holding the *maximum* amount of dissolved sugar it is capable of holding at the given temperature needed for the specific candy type. Upon cooling, the solution becomes ***supersaturated***—holding *more* dissolved sugar that it can theoretically hold at a given temperature.

CULINARY ALERT! Sugar is hygroscopic. Therefore, high humidity during candy preparation results in excess moisture retention of the sugar and less than desirable results.

Major Candy Types: Crystalline and Amorphous Candies

Two major types of candies are *crystalline* and *amorphous* candies. Each will be discussed in this chapter section. ***Crystalline*** candies are formed in the process of ***crystallization*** as heat is given off—***heat of crystallization***. This type of candy has crystals suspended in a saturated sugar solution. Crystals may be *large and glasslike*, as in rock candy, or they may be *small and smooth textured*, breaking easily in the mouth, as in fondant or fudge candies.

Crystalline candies have a highly structured crystalline pattern of molecules that forms around a nuclei or seed, and therefore, it is required that the sugar mixture for crystalline candies must be left undisturbed (more later) to cool. Again, examples of crystalline candies include:

- Rock candy
- Fondant
- Fudge candies

Amorphous or noncrystalline candies are those without a crystalline pattern and include several types as follows:

- Caramel and taffies are chewy amorphous candies.
- Brittles are hard amorphous candies.
- Marshmallows and gumdrops are aerated, gummy amorphous candies.

In general, amorphous candies contain a:
- *High* sucrose concentration (Table 14.2)
- Large amount of agents that interfere with (see Interfering Agents) or prevent crystal formation
- Low moisture level (the molecular ring opened and water is lost)
- More viscous as syrup than crystalline candies

Factors Influencing Degree of Crystallization and Candy Type

Crystals are closely packed molecules that form definite patterns around ***nuclei*** as a sugar solution is heated and subsequently cooled. Crystal development (crystalline candies) or lack of it (amorphous candies) is dependent on factors discussed in the following text. Such factors include the *temperature*, *type and concentration of sugar*, *cooling method*, and *use of added substances* that interfere with crystal development.

Crystalline formation in a sugar solution occurs due to ***seeding***. It is desirable. Yet seeding may occur prematurely. For example, stray sugar crystals remaining on the side of the pan after stirring may later fall into the mixture in the pan. To prevent this unwelcome addition, use of a *pan lid* is recommended for initial cooking so that all crystals dissolve.

CULINARY ALERT! It is recommended that the pan lid remain on the sugar mix for a few minutes initially so that steam can dissolve stray sugars and prevent seeding.

Within this upcoming chapter section, various factors that influence the degree of crystallization and, consequently, candy type are presented.

Temperature. *Temperature* of a sucrose solution is an indication of its concentration. Specific temperature requirements must be met for cooking each type of candy (Table 14.2). If the designated temperature has been *exceeded*, water may be added to the sugar solution in order to *dilute* its concentration and *lower* the temperature. This helpful addition of water is possible

Table 14.2 Major candy types

Candy type	Final temperature in °F (°C)	Percent sucrose
Crystalline		
Fudge	234 (112)	80
Fondant	237 (114)	81
Amorphous		
Caramel	248 (118)	83
Taffy	265 (127)	89
Peanut brittle	289 (143)	93

only as long as the sugar solution has not yet reached the caramelization stage.

A *slow rate* of achieving the boiling point of a sucrose and water solution is desirable. A slow rate increases the time available for inversion of sucrose, allows increases in the solubility of the sugars, and produces a softer final product compared to *rapid* heating.

CULINARY ALERT! Candy-making temperatures exceed the boiling point of water, and as water evaporates, the sugar syrup becomes viscous, causing more severe burns than boiling water if it contacts the skin.

Sugar Type. *Sucrose* molecules are able to align and form large lattice arrangements of crystals. Other sugars, such as the monosaccharides *glucose and fructose* (or invert sugar), possess different shapes that interfere with aggregation and crystal development (thus, a candy with too much invert sugar will fail to harden and is deemed unsatisfactory). HFCS, *honey*, *and invert sugar* are examples of sugars that are added to syrup in candy-making in order to *prevent* the formation of large crystals.

Sugar Concentration. As previously mentioned, candy-making is dependent upon the sugar *concentration*. A sugar solution is *dilute* (unsaturated) if the concentration of a solute is less than maximum at a given temperature. Initially, this is true in candy-making. Then, as the sugar solution boils, water evaporates, and the solution becomes *saturated*. When the saturated solution is cooled, it becomes *supersaturated* and easily precipitates sugar.

Amorphous candies have a *higher* sugar concentration (Table 14.2) than crystalline candy because more sugar is incorporated and more water has evaporated at the higher temperature. The candy mixture is so viscous that crystals *cannot* form.

Cooling Method and Timing of Agitation/Beating. The cooling method and timing of agitation determine adequacy of crystalline candy. *Crystalline* candy must *not* be disturbed by *premature* agitation/beating during cooling. *Crystalline* candy is best formed by *slowly* cooling the sugar solution to approximately 100–104 °F (38–40 °C) *before* stirring or beating. (In reading temperature, stray crystals/seeds are prevented from entering the mixture if the thermometer is free from sugar residue.)

Once cooled to the desirable cooling temperature, the timing is correct and agitation becomes necessary because timely agitation produces/keeps *many small* ***nuclei*** in the supersaturated solution. Then, with agitation, excess sugar molecules in the solution are prevented from attaching to already developed crystals. The crystal size remains small.

Amorphous candy is formed from a very supersaturated solution (Table 14.2), and an undisturbed cooling method is *not* crucial for success. The solution is too viscous to allow aggregation of solute molecules and crystal formation.

Interfering Agents. These influence the degree of crystallization and, consequently, candy type. There are two types of interfering agents—chemical and mechanical:

*Chemica*l interfering agents include *corn syrup or cream of tartar*. Both reduce the quantity of excess sucrose (the solute) available for formation of the crystalline lattice (see Sugar Type, above). Corn syrup contains *glucose*, and the acid cream of tartar inverts sucrose to glucose and fructose. These *non-sucrose* molecules (*glucose and fructose*) do not fit properly (are not able to join) onto existing sucrose lattice structures, thereby keeping crystals *small*. Both *small crystals* and the resultant smooth-textured candy are produced by the addition of cream of tartar or corn syrup to the solution.

Mechanical interfering agents used in candy-making *adsorb* to the crystal surface and physically *prevent* additional sucrose from attaching to the crystalline mass; thus, crystals are many and small. Some examples of mechanical interfering agents are *fat*, the *fat in milk or cream*, and the *proteins* in milk and egg whites.

In crystalline products, ***interfering agents*** *reduce the speed of crystallization* and help to *prevent* undesirable growth of crystal structures that result in the formation of large, crystalline, gritty candies.

Again, examples of crystalline candies include:

- Rock candy
- Fondant
- Fudge candies

In *amorphous* products, interfering agents *prevent crystallization* and add flavor.

To repeat from *Major Candy Types* above, amorphous or noncrystalline candies are those without a crystalline pattern and include several types as follows:

- Caramel and taffies are chewy amorphous candies.
- Brittles are hard amorphous candies.
- Marshmallows and gumdrops are aerated, gummy amorphous candies.

Factors Affecting Candy Hardness. Candies vary in their moisture content. Moisture in the air and other added ingredients affect candy hardness or softness. A hard candy has 2 % moisture, while gummy candy, such as gumdrops, contains 15–22 % moisture.

Ripening

Crystalline candies must ripen in order to produce an acceptable candy. Ripening occurs in the initial period of *storage*, *following* the cooking, cooling, and crystallization of a sugar solution, as the moisture level (sugar is hygroscopic) increases, and small crystals are redissolved in the syrup, preventing unwanted crystallization. Smoothness of the finished candy is desired.

Nutritive Value of Sugars and Sweeteners

Sucrose is a carbohydrate that contains 4 cal/g. It supplies *energy*, although *no* nutrients to the body. Use of nutritive sweeteners should be based on a patient's eating habits along with serum glucose levels and lipid goals. For example, the diabetic must manage *blood serum glucose* levels, and others watch their levels of *serum lipids* that are adversely affected by large amounts of fructose. "There is nothing unusual about craving sweets ... Humans have an appetite for sugary things. But in excess, sugary foods can take a toll. Large quantities add up to surplus calories, which can contribute to weight gain" (FDA).

Sugar substitutes, including (1) the nonnutritive, artificial sweeteners and (2) caloric sugar alcohols, may pose adverse health effects for some individuals. If that is the case, intake of that product should be limited or eliminated from the diet. For example, aspartame contains phenylalanine, a substance phenylketonurics are unable to properly rid from their bodies, and excessive levels of sugar alcohols may cause diarrhea.

A healthful diet uses sugars sparingly, as high consumption equates to a diet with low nutrient density. "Sugars" that appear on the Nutrition Facts label include (1) the total sugars found *naturally* in foods and (2) *added sugars*. Labeling criteria require that *all monosaccharides* and *disaccharides* be listed as "sugars" on the

Nutrition Facts label, regardless of whether they are a natural part of the food or added to the product.

Clarification of natural and added sugars may be determined by reading the foods' *ingredients* list.

HFCS has been receiving much attention. See more at *Myth* vs. *Facts* (above in HFCS) or in reference (SweetSurprise.com).

CULINARY ALERT! An example of "sugars" on labels is seen in orange juice which reports "sugars" on the label although it may not contain added sugar.

Sugars have a recommended intake of 10 % of calories, yet no % Daily Value. "Sample dietary patterns recommend limiting total added sweeteners, on a carbohydrate-content basis to no more than 6 tsp/day at 1,600 kcal, 12 tsp/day at 2,200 kcal, and 18 tsp/day at 2,800 kcal . . . 6–10 % of energy" (USDA). Reducing added sugar is often recommended (Hazen 2012b).

The designation "sugar-free" signifies that there is less than 0.5 g of sugar per serving. "Reduced sugar" indicates that the food contains 25 % less sugar per serving than the regular product. "No added sugar" signifies that the product has no sugar added. Product labels may state that the product is a *reduced-* or *low-calorie* food, if the food meets the necessary requirements of those definitions.

The Academy of Nutrition and Dietetics Position Statement with regard to sweeteners is as follows:

> . . . consumers can safely enjoy a range of nutritive and non-nutritive sweeteners when consumed in moderation and within the context of a diet consistent with the Dietary Guidelines for Americans.

Peruse more http://www.livestrong.com/article/319513-the-calories-in-sugar-alcohol/#ixzz2PJuR6xie.

> There are eight commonly used sugar alcohols and each provides a different amount of calories. Per gram each sugar alcohol contains the following amounts of calories: erythritol provides 0.2, polyglycols have up to 3, isomalt has 2, lactitol provides 2, maltitol has 2.1, mannitol contains 1.6, sorbitol offers 2.6, and xylitol gives you 2.4 cal per gram.

In February 2013 the FDA released standards (proposed) to limit individual vending machine foods to 200 cal. High intensity sweeteners may be called on to come to the rescue for ingredient innovation! (Decker 2013).

Safety

Safety of foods is always important. Although *foodborne illness* could certainly occur in sugary products, bacterial contamination and multiplication in sugary products is deterred by competition for life-sustaining water between many microbes and sugar. There *is* a safety and health concern for persons with illnesses such as *diabetes mellitus* though, because sugars may not be properly utilized.

Adverse personal health effects for some individuals may be the result of either consuming too many calories and therefore gaining weight or using *sugar substitutes* including (1) the non-nutritive, artificial sweeteners and (2) caloric sugar alcohols. In either case, intake of too much food or various "diet" products should be limited or eliminated from the diet.

A healthful diet uses sugars sparingly, due to the fact that high sugar consumption equates to a diet with low nutrient density. For some individuals though, *no* sugar consumption is their way of life. In general, wise intake of sugar is recommended to be 10 % or less of the total daily calories.

Conclusion

Sugar comes from sugar cane or sugar beets, both of which have the same chemical structure. The roles of sugar are many and include providing flavor, color, and tenderness. Real sugars elevate boiling point and are soluble in water, hygroscopic, and fermentable. A variety of sweeteners, including sugar substitutes, and syrups are incorporated into food systems to provide sweetness at a lesser amount of calories.

In order to control the rate of crystallization and the formation of small crystals and to ensure a smooth texture, interfering agents are incorporated into a sugar formulation. Chemical interfering agents produce invert sugar (glucose and fructose), thereby slowing crystallization and increasing the solubility of solute. Mechanical interfering agents such as fat and protein help to keep crystals small by preventing the adherence of additional sugar crystals onto the nuclei. According to the USDA, a healthful diet uses sugars sparingly.

Notes

CULINARY ALERT!

Glossary

Amorphous Noncrystalline candies without a crystalline pattern; may be hard candies and brittles, chewy caramel and taffies, gummy **marshmallows**, and gumdrops.

Artificial sweetener Noncaloric, nonnutritive sugar substitute; examples are acesulfame K, aspartame, and saccharin.

Caramelization Sucrose dehydrates and decomposes when the temperature exceeds the melting point; it becomes brown and develops a caramel flavor, nonenzymatic browning.

Crystalline A repeating crystal structure; solute forms a highly structured pattern of molecules around a nuclei or seed; includes large crystal, glasslike rock candy, or small crystal fondant and fudge.

Crystallization Process whereby a solute comes out of solution and forms a definite lattice or crystalline structure.

Fermentation The anaerobic conversion of carbohydrates (complex organic substances), such as sucrose, glucose, fructose, or maltose, to carbon dioxide and alcohol by bacteria, mold, yeast, or enzymes.

Heat of crystallization The heat given off by a sugar solution during crystallization.

Hygroscopicity The ability of sugar to readily absorb water; sugars high in fructose such as invert sugar, HFCS, honey, or molasses retain moisture more than sucrose.

Interfering agent Used in crystalline products to reduce the speed of crystallization and help prevent undesirable growth of large crystal structures; interference is by mechanical or chemical means.

Inversion The formation of equal amounts of glucose and fructose from sucrose, by acid and heat or enzymes; invert sugar is more soluble than sucrose.

Maillard browning Browning is a result of reaction between the amino group of an amino acid and a reducing sugar.

Nuclei An atomic arrangement of a seed needed for crystalline formation; fat is a barrier to seeding of the nuclei.

Saturated A sugar solution holding the maximum amount of dissolved sugar it is capable of holding at the given temperature.

Seeding To precipitate sugar from a supersaturated solution by adding new sugar crystals (the seed may originate from sugar adhering to the sides of the cooking utensil).

Solute That which is dissolved in solution; the amount of solute held in solution depends on its solubility and the temperature.

Solution Homogeneous mixture of solute and solvent; it may be dilute, saturated, or supersaturated.

Solvent Medium for dissolving solute; i.e., water dissolves sugar.

Sugar alcohol Caloric sugar substitute; chemically reduced carbohydrates that provide sweetening; examples are mannitol and sorbitol.

Supersaturated Solution contains more solute than a solution can hold at a specified temperature; formed by heating and slow, undisturbed cooling.

References

Decker KJ (2013) Finding the sweet spot: confections for a slimmer society. Food Product Design:39–48

Hazen C (2012) Optimizing flavors and sweeteners. Food Product Design (November):30–42

Hazen C (2012) Reducing added sugars. Food Product Design (May):40–52

Bibliography

http://www.polyol.org/fap/fap_HSH.html

Pfizer Food Science Group, New York, NY