24 Sugar and Confectionery Products

1 Introduction

Sugar is the common name for sucrose, which is extracted and refined from sugar cane and sugar beet. There are many substances classified as sugars, and when these are referred to, they are always used with a qualifier such as in milk sugar (lactose), corn sugar (dextrose), and malt sugar (maltose). When the word sugar is used without a qualifier, it refers to the common sweetener (sucrose) or table sugar. Additional sources of sucrose include maple trees and some fruits. The aims of this chapter is to introduce the sugar and confectionery industry (Edwards 2003; Wolf 2016).

1.1 The Sugar and Confectionery Industry

The sugar and confectionery manufacturing industry (NAICS 3113) consists of companies that produce sugar from cane or sugar beet. For the Unites States (US), the sector covers non-chocolate confectionery, chocolate confectionery from cocoa beans and confectionery using purchased chocolate; the corn syrup industry (NAICS 311930) is also relevant (Table 24.1). The United Nations industry code ISIC 1073 applies to the manufacture of cocoa, chocolate and sugar confectionery. The range of products include, cocoa butter, cocoa fat, cocoa oil, chocolate and chocolate confectionery, sugar confectionery: caramels, cachous, nougats, fondant, white chocolate, chewing gum, preserving in sugar of fruit, nuts, fruit peels and other parts of plants, confectionery lozenges and pastilles.

The synthetic sweeteners industry is classed within basic organic chemical manufacturing (NAICS 325199) and manufacturing of so-called "miscellaneous chemical product and preparations (NAICS 325998) which are fascinating areas though outside of the scope of the current discussion.

1.2 Commercial Sugar Supplies

Currently, 80% of the world's sugar is obtained from sugar cane and 20% from sugar beet and other sources (Fig. 24.1). In 2014, the world total production for cane sugar was 175 million metric tons. The major producers of sugar include Brazil (33.8 million tons), India (27.2 million metric tons), EU (16.3 million metric tons), China (13.3 million metric tons), Thailand (10.2 million metric tons), US (7.6 million metric tons), Mexico (6.5 million metric tons) and Pakistan (4.7 million metric tons) (Table 24.4). The market for sugar was reported to be worth about US$40–70 billion dollars (USDA Foreign Agricultural Services 2014).

R. Owusu-Apenten, E. R. Vieira, *Elementary Food Science*, Food Science Text Series,
https://doi.org/10.1007/978-3-030-65433-7_24

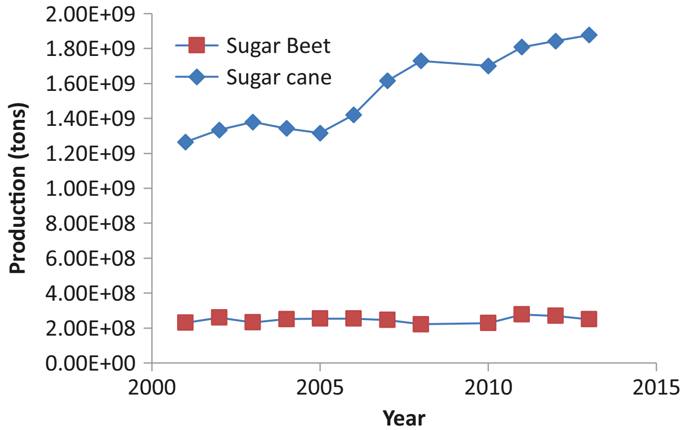


Fig. 24.1 World sugar cane and sugar beet production. (FOAOSTAT data, 2014)

1.3 Uses of Sugar

1.3.1 Technical uses

Chemically, and in every other way, cane sugar and beet sugar are the same. In addition to providing energy for the body and sweetness to foods, sugar performs numerous other roles in the food industry. Sugar is used in baked products where it contributes to the desirable texture of baked goods, and it stabilizes the foam of beaten egg whites. When it caramelizes, it imparts a unique, desirable color and flavor to surfaces of pastries and cakes. It is used in ice cream and other dairy products, in beverages, and in other types of food; it is used in the home, in institutions, and in restaurants for foods and beverages. Sugar is also used in some nonfood products such as pet food and other animal feeds and baits (Jeffery 1993).

One of the most obvious uses of sugar is as a sweetener but, not all sugars are equally sweet (see Table 24.2). Some forms of sugar (lactose) are only 16% as sweet as sucrose. Sugars may also be added for texture and appearance qualities (Table 24.3). Sugar interaction with water can contribute to viscosity, which is important in the consistency, body, and mouth feel of some foods (Table 24.3). Sugar interactions with water also underlie the role as preservative and antimicrobial agent. The availability of water to microorganisms is measured as water activity (Aw) and sugars, with their affinity for water, depress Aw in some foods such as jams and jellies, giving a preservative effect. Sugar also has a high refractive index and is responsible for the shiny appearance in high sugar products such as syrups, jellies, and dried fruits. Sugars may also possess some antioxidant value by virtue of their reducing properties or role as metal chelators though this role has yet to be characterized in more detail.

Table 24.1 Sugar and confectionery manufacturing

NAICS	Sector
31–33	Manufacturing
311	Food manufacturing
3113	Sugar and confectionery product manufacturing
31131	Sugar manufacturing
311313	Beet sugar manufacturing
311314	Cane sugar manufacturing
31134	Nonchocolate confectionery manufacturing
31135	Chocolate and chocolate confectionery manufacturing
311351	Chocolate and confectionery from cacao beans
311352	Confectionery manufacturing from purchased chocolate
325199	Synthetic sweeteners (i.e., sweetening agents) manufacturing
325998	Sugar substitutes (i.e., synthetic sweeteners blended with other ingredients)

Table 24.2 Degree of sweetness of sugars and other sweeteners

Sweetener	Degree of Sweetness
Sucrose	100
Fructose	173
Glucose	74
lactose	16
Maltose	32
Galactose	32
Saccharine	30,000-50,000
Sodium cyclamate	10,000
Neohesperidin dihydrochalcone	1,000,000

Table 24.3 Functional properties of sugars

Sensory function	Physical function
Sweetener	Solubility
Flavor	Freezing point depression
Texture and viscosity	Boiling point elevation
Tenderizer	Crystallization
Appearance	Glass formation
Bulking agent	Increases volume or weight

1.3.2 Consumption trends

The consumption of sugar is regarded as a public health issue, owing to the reported link with chronic illness such as diabetes. Current research indicates that the global sugar consumption rate will grow by about 1.4% per year for a decade (2017-2027). Alongside of nutrition transitions, the rise in sugar consumption is predicted to be higher for developing countries in Asia (China, Indonesia, and Pakistan) and Africa. By contrast, sugar consumption is expected to remain stagnant in those markets where purchases are already high. The per capita sugar consumption was highest for Brazil (67 kg) compared with the moderate sugar intake in countries such as the US (33 kg) to very low levels (<20 kg) in many low-income countries. There are calls to reduce sugar intake in many developed countries (Wolf 2016). Current per capita sugar consumption for some countries are shown Appendix 1 (OECD/ Food and Agricultural Organization 2018).

Table 24.4 World production of sugar (2014)

World Centrifugal Sugar						
	2010/11	2011/12	2012/13	2013/14	May 2014/15	Nov 2014/15
Production (x1000)						
Brazil	38,350	36,150	38,600	37,800	36,800	35,800
India	26,574	28,620	27,337	26,605	27,900	27,250
EU	15,939	18,320	16,655	16,010	16,300	16,300
China	11,199	12,341	14,001	14,263	13,700	13,300
Thailand	9663	10,235	10,024	11,333	11,000	10,200
US	7104	7700	8148	7672	7706	7677
Mexico	5495	5351	7393	6383	6890	6508
Pakistan	3920	4520	5000	5215	4860	4700
Australia	3700	3683	4250	4400	4400	4600
Russia	2996	5545	5000	4400	4400	4200
Guatemala	2048	2499	2778	2852	2850	2850
Indonesia	1770	1830	2300	2300	2500	2500
Philippines	2520	2400	2400	2450	2500	2500
Turkey	2274	2262	2130	2300	2300	2400
Colombia	2280	2270	1950	2300	2300	2300
South Africa	1985	1897	2020	2435	2500	2200
Argentina	2030	2150	2300	1780	2000	2050
Egypt	1830	1980	2000	2013	2050	2050
Cuba	1150	1400	1525	1600	1500	1650
Ukraine	1540	2300	2400	1300	1600	1600
Other	17,822	18,844	19,346	19,599	19,533	19,823
Total	162,189	172,297	177,557	175,010	175,589	172,458

Source: USDA Foreign Agricultural Services (2014). "Sugar: World Markets and Trade, November 20, 2014: World Production, Markets, and Trade Reports." Retrieved Dec 2014, from http://www.fas.usda.gov/data/sugar-world-markets-and-trade

2 Cane Sugar Manufacturing

As noted previously, most of the world's supply of white sugar is from the sugar cane or sugar beet plant. Globally the quantity of sugar cane produced in 2013 was 1887 million metric tons compared with a far smaller amount of 230 metric tons of sugar beet (Fig. 24.1).

2.1 Sugar Cane

The sugar cane plant is a species of giant grass belonging to the genus *Saccharum*. Although nearly all sugar canes are of the same species, differences in growing conditions affect the characteristics of the juices. For example, the sugar content of the juices from sugar cane grown in the tropics is higher than in sugar canes grown in cooler climates. In the US, sugar cane is grown primarily in Louisiana, and some is grown in Florida and Hawaii. Cuba, Puerto Rico, the Virgin Islands, the Philippines, and other countries also produce sugar cane.

Sugar cane is grown by planting cuttings from the stalk, each containing a bud. The length of time that the cane is allowed to grow before harvesting varies in different countries and may be from 7 months to 2 years. The yield of sugar from cane juice is about 14–17%. Sugar cane is harvested by cutting the stalks just above the ground. At this time, the tops of the stalks are cut off, because they contain high concentrations of an enzyme that hydrolyzes and greatly reduces the yield of cane sugar. Also at the time of harvesting, the leaves are stripped from the canes, although they may be burned off prior to harvesting. Parts of the sugar cane other than tops contain some of the enzyme that converts sucrose, so the cane must be processed shortly after harvesting in order to obtain maximum yields.

2.2 Processing Cane Sugar

At processing plants producing raw sugar the cane first passes through shredders and then through three to seven roller mills that press out the juice. After the first pressing, the bagasse (pressed cane) may be mixed with hot water or dilute hot cane juice and again pressed to extract more sugar. Following the final pressing, the bagasse is usually brought directly to the boilers, where it is used as fuel. The wet bagasse is reported to have about one-fourth the fuel value of ordinary fuel oil. However, bagasse is a wood-like fiber, and it is used to manufacture wallboard. It has been the object of study for use in other applications.

The juice, which is dark green in color, has a pH of about 5.2. After extraction, the cane juice is strained to remove pieces of stalk and other detritus, and a mixture of lime powder and water [source of calcium hydroxide, Ca (OH) 2] is added to raise the pH. The juice is heated to precipitate and remove impurities. The limed mixture is then held in tanks, where the lime-impurities mixture is allowed to settle out, and the clear juice is separated from the sediment (Fig. 24.2).

The clear juice is then heated (at temperatures below the boiling point of water) under vacuum to evaporate water and concentrate the sugar to the point where there is a mixture of sugar crystals and molasses. More syrup may be added to

Fig. 24.2 Production of raw sugar from sugar cane

Sugar Cane Shred
Press → Residue <Bagasse
Raise pH with Lime
Heat
Allow to Settle in Settling Tank
Bagasse< Usually Used as fuel
Crystallize Clear Juice! under Heat and Vacuum
Centrifuge and Wash → Supernatant
Brown Unpurified Sugar

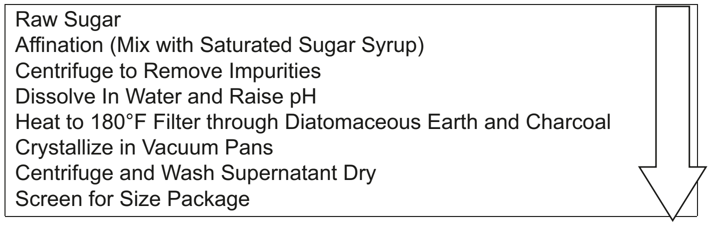


Fig. 24.3 Refining of sugar

the evaporation pans, as the syrup is concentrated. The mixture (called massecuite) is centrifuged to obtain the brown purified sugar. The liquid centrifuged from the sugar crystals still contains dissolved sugar and is returned to the evaporation pans. When the molasses from the centrifuge treatment reaches such a low concentration of sugar that removal of sucrose is uneconomical, it is called blackstrap. This is not discarded, but is not returned to the evaporation pans. Generally, blackstrap is sold to the fermentation industries for the production of rum. Sugar may be purified or refined at the plant that manufactures the raw sugar, but usually the raw sugar is packed in jute bags and shipped to sugar refineries. Higher grades of molasses for domestic use may be made from juice obtained from cane that is not pressurized sufficiently to extract all the liquid. The molasses is heated to 160 °F (71.1 °C) and canned or bottled hot. The containers are sealed, heated in water at 185 to 200 °F (85 to 93.3 °C) for 10 min, and immediately cooled.

2.3 Cane Sugar Refining

Raw sugar delivered to the refinery contains 97–98% sucrose. The first step in refining (Fig. 24.3) consists of mixing the raw sugar with hot saturated sugar syrup. This softens the film of impurities that envelop the sugar crystals. This mixture is then centrifuged, and during centrifugation, the sugar crystals are sprayed with water to remove some of the impurities. The washed sugar crystals are then dissolved in hot water, treated with lime to bring the pH to 7.3 to 7.6, and the temperature is raised to 180 °F (82.2 °C). The coarser colloidal impurities in the hot mixture are filtered out through diatomaceous earth or paper pulp. The coloring material in the sugar solution is removed by filtering the hot liquid through bone charcoal, after which the sugar is crystallized out in vacuum pans and centrifuged to separate it from the liquid. During centrifugation, the crystals are washed with water. They are then dried, screened for crystal size, and packaged.

The finished dried sugar, which has an indefinite shelf life, is made available in different grades. Large-grained sugar is used for the manufacture of candy and other prepared sweet products. Ordinary table sugar is made up of fine-sized grains. Ultrafine sugar grains (for confectioner's sugar) are produced by grinding the crystals in pulverizing hammer mills. To prevent caking in confectioner's sugar, about 3% cornstarch is used. There are other intermediate grades. Sugar is also prepared as cubes or tablets by forming a mixture of sugar crystals and white sugar syrup under pressure, followed by drying. A variety of "soft sugars" ranging in colors from white through various shades of brown, are produced. These sugars are allowed to retain some of the molasses, which provides their unique flavor.

Raw sugar may contain thermophilic bacteria (spore-forming bacteria that grow at high temperatures-as high as 170 °F (76.7 °C). If such bacteria are allowed to grow to high concentrations, they may serve as a source of contamination of such products as canned foods to which sugar is added. The spores of thermophilic bacteria are very difficult to destroy by heat, and canned foods can undergo some deterioration during heat processing. For this reason, during the various filtrations in which sugar solutions are held at high temperatures for comparatively long periods, they should be held at temperatures high enough to prevent the growth of thermophilic bacteria (about 185 °F [85 °C]).

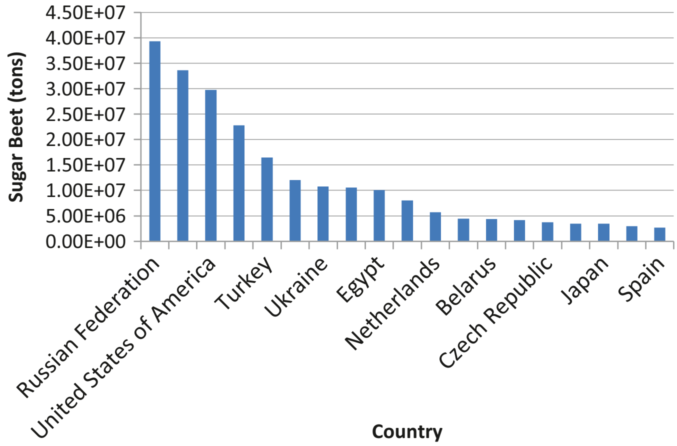


Fig. 24.4 World production of sugar beet in 2013. (FAOSTAT data)

3 Beet Sugar Manufacturing

3.1 Sugar Beet

The sugar beet (*Beta vulgaris)* stores its sugar in the root, unlike the sugar cane, which stores its sugar in the stalk. Another difference between cane sugar production and beet sugar production is that the latter is a continuous operation and does not produce the intermediate raw sugar. Whereas sugar beets contain 16–20% of sugar as sucrose, the yield of sugar per acre is considerably less than that obtained from sugar cane, owing to the quantity of beets or cane harvested per acre.

Sugar beets are planted as seed and require 70 days or more from planting to harvesting. Because the plants are subject to bacterial or mold infection and to infestation with aphids, maggots, and other insects, the plants may need spraying during the growing season. Worldwide the total production quantities for sugar beet did not change drastically from 2001 (230 metric tons) and 2013 (250 metric tons). The top producer nations for sugar beet are the Russian Federation, France and the US (Fig. 24.4). Within the US, beets for sugar are grown mainly in Colorado, California, Michigan, Utah, Idaho, Nebraska, and Montana. Sugar beets are harvested and topped mechanically and brought to the processing plant in bulk by freight cars or trucks. They may be stored outside the processing plant in large piles until treated to extract sugar.

3.2 Processing Beet Sugar

In extracting sugar from beets, the beets are first thoroughly washed to remove mud and stones, and then passed through mechanical slicers that slice them into thin shreds called cossettes. They are then covered with hot water to extract the sugar. Extraction is done even more quickly and effectively by a continuous countercurrent extraction with water. The juice from the extraction process is treated with lime or calcium hydroxide and then with carbon dioxide. The lime removes impurities as a precipitate, and the carbon dioxide is used to precipitate the calcium hydroxide as calcium carbonate ($CaC0_3$). The juice is then filtered and again treated with carbon dioxide to precipitate residual calcium hydroxide. After a second filtration, the extract is treated with sulfur dioxide to bleach out colored components in the liquid. The liquid extract is vacuum concentrated to 60–70% soluble solids and filtered through bone charcoal. Next, the filtered liquid is concentrated in vacuum pans to form crystalline sugar. The sugar is washed as it is centrifuged, dried, screened, and packaged, as in the case of cane sugar. In some manufacturing processes for beet sugar, the liquid from the third centrifugation is used for the manufacture of monosodium glutamate, a flavor enhancer used for many food preparations, including soups, gravies, Chinese foods, and meat dishes. Extracted beet pulp and the tops are dried and used as cattle feed.

Table 24.5 Classification of corn syrups by dextrose equivalent (DE)

Type	DE Value
Low conversion	28–38
Regular conversion	38–48
Intermediate conversion	48–58
High conversion	58–68
Extra high conversion	68–100

4 Other Sugar Sources

Sucrose can be obtained from the sap of a variety of palm trees, one of the most important being the date palm *(Phoenix sylvestris)*. Much of this sucrose is obtained in the Middle East by methods that involve boiling in open kettles, after which there is separation of crystals from molasses, or the unseparated mass may be allowed to set into a whole sugar.

4.1 Maple Syrup

In the northern part of North America, sucrose is obtained from the sap of the hard maple tree *(Acer saccharinum)*. Although the maple syrup sap is largely sucrose, it contains unique impurities that impart to it (when concentrated) a special delicate flavor that makes the natural maple syrup a valuable flavoring for certain preparations. Sucrose can also be produced from the cane of the sorghum plant, which is related to the sugar cane but resembles the corn plant.

4.2 Corn Syrup or Glucose Syrup

Although corn is not a source of sucrose, the value of corn sugar as a sweetener in the food industry makes it worthy of mention. It is noteworthy that the term corn syrup (North America) is often replaced with "glucose syrup" or simply "glucose" in other parts of the world, and chemical glucose is called dextrose in industry. The characteristics of corn syrup and its significance in the food industry have been recently discussed (Hull 2011).

Corn syrup is produced by heating starch in water acidified with hydrochloric acid. In general, the hydrolysis of starch is only partially completed so that the mixture contains some dextrose, maltose, and some longer chains of glucose (dextrin). The extent of starch hydrolysis for different glucose syrups is measured in terms of dextrose equivalents – or the extent to which syrup reacts with Fehling's regent for reducing sugars. A glucose syrup sample that reacts with Fehling's solution to the same extent as an equal weight of dextrose is designated as "dextrose equivalent value" DE equivalent to 100 (Table 24.5). Glucose syrup with DE of 48 is referred to as confectionery grade.

Corn syrups are divided into five commercial classes, depending on their DE value. By this classification scheme, pure dextrose is given a value of 100 DE. In addition to classification by their DE values, syrups are also classified by their solids contents.

A second method is also used for the manufacture of corn sugar is where the hydrolysis is carried out by first heating the starch with acid followed by treating it with an enzyme that hydrolyzes starch. The latter method produces syrup higher in maltose than does the straight-acid hydrolysis method. In this method, the use of amylolytic enzymes (alpha- and beta-amylases) is employed. Beta-amylase is specific in its action, attacking starch molecules at their non-reducing ends and causing progressive breaks in the molecule at 2-carbon intervals, with the resultant release of units of maltose (a 2-carbon sugar). Thus, by this conversion, the corn syrup will have high maltose content and be sweeter compared to the acid-only hydrolyzed corn sugar. Other enzymes, glucosidases, may also be used to supplement either of the two conversion processes. In this case, the syrup will contain significant amounts of glucose (Aiyer 2005) (Table 24.5).

After hydrolysis, the syrup is neutralized by addition of sodium carbonate, then filtered and concentrated to 60% solids, again filtered through bone charcoal, and finally passed through resins (ion exchange) that take out the salt (sodium chloride formed from the acid and sodium carbonate). The corn syrup may be spray or drum dried to about 3% moisture to obtain corn syrup solids. More completely hydrolyzed syrup, after purification, may be concentrated, seeded with fine corn sugar crystals, and crystallized to produce crude corn sugar. Dextrose or corn sugar can be produced in a similar manner from a completely hydrolyzed starch.

In another process, cornstarch is hydrolyzed to produce glucose, and then a percentage of the glucose molecules are converted into fructose. This high-fructose corn syrup (HFCS) has had a significant impact on the soft drink and confection industry. HFCS has been substituted either wholly or partially for sucrose in many formulas, allowing the manufacturers to meet their mammoth product demand with less dependence on the sugar cane industry. Corn syrup, corn sugar, and HFCS are used in bakery products, pharmaceuticals, carbonated beverages, confectioneries, ice cream, jams and jellies, meat products, and dessert powders.

Corn syrup and corn sugar are used largely in the food industry. They are used to supplement sucrose because they are less expensive, while at the same time nearly as effective as sucrose in sweetening characteristics. In addition, they inhibit crystallization of sucrose, especially when their maltose content is high. They are especially useful in the baking and brewing industries because of the quick and complete fermentability of dextrose. Their use in preserves minimizes oxidative discoloration, and other unique properties make them useful in many other applications. The vital role played by glucose syrup in the manufacturing of confectionery is outlined in the next section. Possible health concerns associated with increasing HFCS intake remain controversial (Parker et al. 2010).

4.3 Invert Sugar

Sucrose ($C_{12}H_{22}0_6$) is one of the most important of the naturally occurring disaccharides. It may be hydrolyzed, yielding glucose (dextrose) and fructose (levulose) which are both six-carbon sugars. The mixture of dextrose and levulose is called invert sugar. Invert sugar is made by treating sucrose with an enzyme (invertase) and some acid, whereupon it combines chemically with approximately 5.25% of its weight of water. The temperature must not be so high as to inactivate the enzyme invertase.

Dextrose is not as sweet as sucrose but the levulose is sweeter than sucrose with the result that the final syrup, invert sugar, is slightly sweeter than the syrups having the same concentration of sucrose. Invert sugar has special uses in the food industry. Mixtures of invert sugar and sugar are more soluble than sugar alone. In a proportion of 1:1, a mixture of invert sugar and sugar is more soluble than any other combination of their mixtures.

In candy making, invert sugar is produced directly by heating sugar syrup with acid added to the mix. Confectionery manufacturers prefer cream of tartar (tartaric acid) to promote hydrolysis of sucrose to invert sugar. More frequently, this technology is being replaced by the use of corn syrup. Other sugar products used in candy making include maple sugar, brown sugar (a less refined sugar from the cane sugar refining process), molasses (also from the cane sugar refining process), and honey.

5 Sugar Confectionery

5.1 Global Confectionery Sales

The confectionery sector may be divided into three major categories; (i) products with sugar as the main ingredient, (ii) or those based on chocolate and (iii) a flour based confectionery that are sweetened and baked (Edwards 2003; Hartel et al. 2017). Sugar confectionary products may be further divided into two sub-groups, i.e. those

Table 24.6 Classification of sugar confectionery

Non-crystalline groups	Sugar crystallized products
Boiled sweets	Creams and fudges
Gums and pastilles	Fondants
Jellies	Liquorice sweets.
Marshmallows.	Lozenges
Nougats (the chewy types)	Marshmallow (grained)
Toffees and caramels	Marzipan
	Nougats (short)
	Pralines

Adapted from (Anonymous 1982)

Table 24.7 Global confectionery sales ($bn)

Confectionery types	Sales (US$ billion)
Gum (chewing)	23.0
Chocolate confectionery	88.3
Sugar confectionery	59.0
Caramels and toffees	12.7
Candy (hard boiled sweets)	12.3
Gums and jellies	11.5
Medicated confectionery	8.7
Regular mints	5.9
Other	5.9
Power mints	5.5

Source: Adapted from (Business Insights 2011)

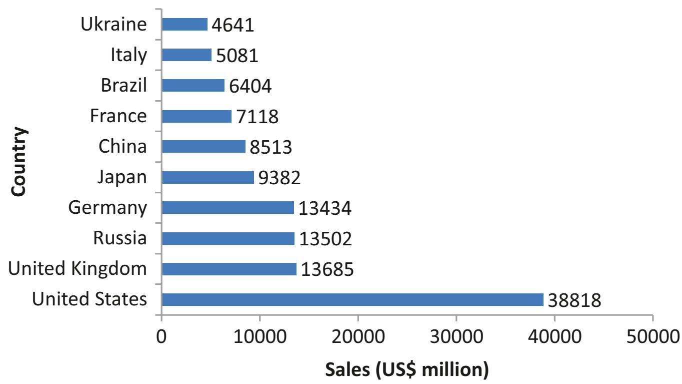


Fig. 24.5 Top 10 Global Market for confectionery 2014

containing crystalline sugar and those in which sugar is not in the crystalline state (Jackson 2000) (Table 24.6).

For 2014 the global sales of confectionery products were estimated at US$200 billion with an annual growth rate average of 2% (Euromonitor International 2014). This figure is slightly higher than predicted 3 years earlier by another market research organization that anticipated the 2014 sales figures US$171 billion (Business Insights 2011). The main confectionery sales categories were chocolate (51%), sugar confectionery (35%), and chewing gums (13.5%). Flour confectioneries are prominent in India and other parts of Asia, but sales of these products are not often captured by current economic metrics.

The US is the largest confectionery market accounting for 19% of global sales. The top-10 nations for confectionary sales account for 67% of market share. The most rapidly growing markets are thought to the BRIC countries (Brazil, Russia, India and China). Some of the largest food corporations are involved in the confectionery sector including; Mars Inc., Cadbury Plc (purchased by Kraft), Nestle' SA, Hershey Co., Kraft Food Plc., Ferrero group, Lotte Group etc. There is a clearly a great deal of economic interest in the confectionery sector (Table 24.7 and Fig. 24.5).

The word candy appears to be "olde" English (circa fifteenth century) apparently derived from *Khandy (Sanskrit)* pointing to the Indian or South Asian origins of the sugar confectionery derived from sugar cane as opposed to honey based sweets of Asia minor. Elsewhere across the world, a variety of acronyms for Candy appear, including terms like sweets, lollies, treats and "toffi".

5.2 Confectionery Art and Science

In the introduction to his well-received book titled "the science of sugar confectionery" the author argues that confectionery manufacturing *was not* (traditionally) a science based industry. However, confectionery was linked historically to pharmaceuticals (Edwards 2000).

In the middle ages, confectionery products were found in the apothecary alongside other medicines, and then later sugar was considered a luxury food items available only for wealthy citizens. Sugar and other ingredients were expensive and exotic items, shipped from faraway places. In renaissance Europe, early confectioners were said to be held in utmost regard and their trade considered "art" in the manner we still talk of culinary art when wishing to emphasize the creative aspects of such professions (Day 2004).

The industrialization of confectionery making in the early nineteenth century is rather well documented and illustrated in the book "Chicago's Sweet Candy History" (Goddard 2012). The confectionery industry is now securely grounded in food manufacturing. Nicholas Appert who developed canning was, initially, a confectioner by profession.

Candy making grew from origins in artisanship–as can be said for many areas of food manufacturing. The modern confectionary industry requires food science and technology competencies. A listing of some important food science and technology concepts for confectionery industry is shown in Table 24.8.

A systematic understanding of confectionery science and technology is a pre-requisite for product innovation, to lower costs, and to enable industry to meet "consumer needs". In line with the focus on carbohydrates in this Chapter, we will have reason to consider the behavior of highly concentrated solutions of sugar in detail later (Ergun et al. 2010).

The behavior of sugar solutions is affected the numbers of dissolved compounds and so appreciation of colligative properties is important. Some candy formulations contain fat, water, sugar and other ingredients so effective mixing, and emulsification may be appropriate (Ergun et al. 2010).

Table 24.8 Some candy science concepts

Water and moisture
Water activity, relative humidity, dew point, Colligative properties, moisture migration
Acidity and pH, buffer action
Emulsions science, Colloids, Surfactants
Material and polymer science
Nucleation and crystallization
Sugar glasses, transition temperatures and their control, Amorphous solids
Colors, dyes and lakes
Food process engineering
Food chemistry, Maillard reaction, Fat deterioration and rancidification
Sugars, fats, additives, general ingredients
High intensity sweeteners
Analytical chemistry and instrumental methods, Polarimetry, Refractometer
Densitometry, Infrared and NMR spectrometry

Adapted from (Edwards 2000; Hartel et al. 2017)

Food dyes and colors are a frequently employed in candy making and some appreciation of the behavior of such substances is essential.

Hard-boiled sweets are described as sugar glasses, which are thermodynamically metastable, super-cooled, solids. The molecules within a glass are trapped by an exceeding high viscosity from the optimum positions required to form a crystalline solid. Glasses are frozen liquids wherein the melting point is above room temperature. The instability of glasses means that they will eventually revert to the more stable crystalline solid on long time-scales. When heated, solid glasses undergo softening (called a glass-to-rubbery state) transition at a characteristic glass transition temperature (Tg).

A glassy material shows large and sudden deviations in physical properties (heat capacity, free volume, viscosity, elasticity et) when the surrounding temperature is raised above the Tg. A common method measuring Tg is using an instrument called a by differential scanning calorimeter (DSC) which detects changes to heat capacity (Cp) or amount of heat needed to raise the temperature of a substance by one degree (Cp; J/°K/g) (Kasapis 2008). The Tg of glassy materials can vary by tens of degrees above or below room temperature depending on moisture content.

Sucrose has a tendency to form crystalline solids. When glucose or fructose is added to sucrose the Tg value declines. Adding monosaccharides to sucrose decreases the crystallizing efficiency of sucrose because differently sized molecules arrange less perfectly within a single crystal matrix (Jeong-Ah et al. 2006). The change in sucrose crystallization behaviour is exploited when glucose syrups is added to sugar ingredient during candy making. As noted above, it is possible also to form invert sugar directly from sucrose by heating in the presence of cream of tartar. Addition or removal of water to sucrose will decrease or increase the Tg value for sucrose, respectively. The value of Tg has been found to provide information related to brittleness, tendency for powders to collapse, stickiness of products, microbiological stability of foods etc. (Ergun et al. 2010).

5.3 Candy Making

Candy making involves manipulating sugar crystals to achieve desired textural effects. This is done by controlling the crystallization of sugar and also sugar/moisture ratio. Examples of sugar-type candies include nougats, fondants, caramels, taffies, and jellies. The ingredient list used in candy making is virtually endless and includes, milk products, egg white, food acids, gums, starches, fats, emulsifiers, flavors, nuts, colors, and more.

The sugar in candies may be crystalline or noncrystalline. The crystals may be large or small and the noncrystalline structure may be glass-like or amorphous. Achieving the desired level of control during the manufacturing process usually means keeping a close eye on the boiling temperature of candy syrup. Softness is another textural quality and soft and hard candies can be made from both crystalline and noncrystalline structures. To achieve softness, higher levels of moisture can be maintained, air can be whipped in, or other ingredients can achieve this textural attribute. Table 24.9 shows the main types of sugar-based candies divided into crystalline and non-crystalline products.

Table 24.9 Some major types of sugar based candies and confectionery

Sugar confectionary	Texture
Type	Creamy or crystalline,
Rock Candy	Large crystals
Fondant, Fudge	Small crystals
Type	Non-crystalline, glassy
Sour Balls, Butterscotch	Hard candies
Peanut Brittles	Brittles
Caramel, Taffy	Chewy candies
Marshmallow, Jellies, Gumdrops	Soft or hard gels, gummy candies

The major sugars used in candy making are sucrose, invert sugar, corn syrups, and HFCS. Starting with a given syrup composition the concentration of sucrose will tend increase "automatically" with cooking time due to moisture loss from the sample. The evaporative loss of water means that syrup shows a continual rise in sugar concentration and this in turn leads to further rise in boiling point (Table 24.10).

In line with colligative properties (see below) the boiling point of a syrup is closely linked with the total solids content (sugar+ glucose syrup etc.) compared to the moisture present. Therefore, it is possible to produce a variety of candy types and textures, ranging from highly crystalline masses to amorphous glasses, if the boiling temperature is monitored and controlled within certain limits (Table 24.10).

To explain why boiling temperature is a good indicator for syrup composition we will borrow from the theory of colligative properties. This useful bit of high-school chemistry, states that the physical properties of liquid water changes predictably, according to the number (not the type) of particles dissolved. The list of colligative properties includes freezing point, boiling point, vapour pressure, relative humidity, osmotic pressure, etc. From common experience, salt depresses the freezing point of water. The theory of colligative properties is demonstrated when salt is added to the driveway or sidewalk in winter.

Interestingly, the boiling point of water increases when sucrose is added. The theory of colligative properties predicts that the boiling point of water will increase with increasing amounts of added

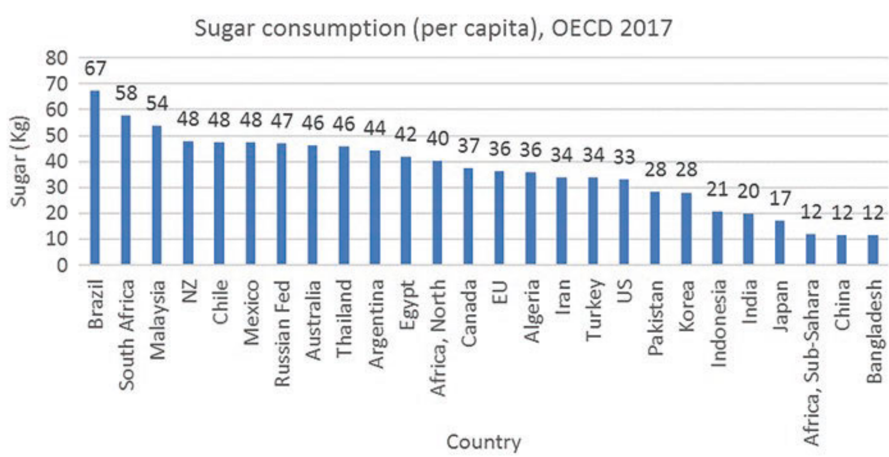
Table 24.10 The boiling point of sugar syrups at sea level relates to composition and candy types

Temperature	Sugar Solids (%)	Candy
Water boils at Sea Level; 212 ° F	0%	Water, Simple sugar syrups
Thread Stage; 215 ° F–234 ° F 101 ° C–112 ° C	80%	Sugar syrup, fruit liqueur and some icings
Soft-Ball Stage; 234 ° F–240 ° F /112 ° C–115 ° C	85%	Fudge, Fondant, pralines, peppermint creams and classic buttercreams
Firm-Ball Stage; 242 ° F–248 ° F /116 ° C–120 ° C	87%	Caramel candies
Hard-Ball Stage; 250 ° F–268 ° F /121 ° C–131 ° C;	92%	Nougat, marshmallows, toffee, gummies, divinity, and rock candy
Soft-Crack Stage; 270 ° F–290 ° F /132 ° C–143 ° C;	95%	Taffy, Butterscotch, Candy apples
Hard-Crack Stage; 300 ° F–310 °F/ 148 ° C–154 ° C;	99%	Brittles, hard candy (lollipops)
320 ° F + / 160 ° C + Sugar (sucrose) melt around 320 ° F and caramelize around 340 ° F.		Caramelizing sugar Thermal Decomposition

Source: Adapted from CraftyBaking, LLC (with permission) http://www.craftybaking.com/howto/candy-sugar-syrup-temperature-chart

sugar. The relation between total solids content and the boiling point of sugar syrup remains true – even as the mixture is heated and moisture is lost from the heated sugar syrup by evaporation. Such background shows why monitoring the boiling point of sugar syrups is such an important activity, and key to producing different types of confectionery.

Appendix 1



References

Anonymous (1982) General classification of sugar confectionery. Confection Prod 48(5):191–192

Aiyer PV (2005) Amylases and their applications. Afr J Biotechnol 4(13):1525–1529

Business Insights (2011) Future directions in confectionery. Retrieved from http://www.som.cranfield.ac.uk/som/dinamic-content/ki/Businessinsights/BI00049-001/MainDeliverable.pdf

Day I (2004) The art of confectionery. Retrieved from http://www.historicfood.com/The%20Art%20of%20Confectionery.pdf

Edwards WP (2000) The science of sugar confectionery. Retrieved from http://pubs.rsc.org/en/content/ebook/978-1-84755-216-7

Edwards WP (2003) Sweets and candies: sugar confectionery. Encyclopedia of Food Sciences and Nutrition (2nd edn, Caballero B, eds). Academic Press, Oxford, pp 5703–5710. https://doi.org/5710.1016/B5700-5712-227055-X/201173-227051

Ergun R, Lietha R, Hartel RW (2010) Moisture and shelf life in sugar confections. Crit Rev Food Sci Nutr 50(2):162–192. https://doi.org/10.1080/10408390802248833

Euromonitor International (2014) Global confectionery overview: key categories, countries and trends to 2019. Retrieved from http://www.euromonitor.com/Global-confectionery-overview-key-categories-countries-and-trends-to-2019/report

Goddard L (2012) Chicago's sweet candy history. Retrieved from https://books.google.co.uk/books?id=yekGvpKoLWwC

Hartel RW, von Elbe JH, Hofberger R (2017) Confectionery science and technology. Springer, 536pp. https://books.google.com.gh/books?id=QjE5DwAAQBAJ

Hull P (2011) Glucose syrups: technology and applications. Wiley. 392 pp

Jackson EB (1995) Sugar confectionery manufacture. Springer, 400pp. https://books.google.com.gh/books?id=GFw8HEqnLvIC

Jackson B (2000) Fundamentals of sugar confectionery. Manufact Confect 80(8):35–41

Jeffery MS (1993) Key functional properties of sucrose in chocolate and sugar confectionery. Food Technol 47(1):141–144

Jeong-Ah S, Kim SJ, Hyun-Joung K, Yang YS, Hyung Kook K, Yoon-Hwae H (2006) The glass transition temperatures of sugar mixtures. Carbohydr Res 341(15):2516–2520. https://doi.org/10.1016/j.carres.2006.08.014

Kasapis S (2008) Recent advances and future challenges in the explanation and exploitation of the network glass transition of high sugar/biopolymer mixtures. Crit Rev Food Sci Nutr 48(2):185–203. https://doi.org/10.1080/10408390701286025

OECD/Food and Agricultural Organization (2018) OECD-FAO agricultural outlook 2018–2027. Retrieved from, Sugar. https://doi.org/10.1787/agr_outlook-2018-en

Parker K, Salas M, Nwosu VC (2010) High fructose corn syrup: production, uses and public health concerns. Biotechnol Mol Biol Rev 5(5):71–78

Science Direct (2021) Sugar confectionery. From https://www.sciencedirect.com/topics/food-science/sugar-confectionery

USDA Foreign Agricultural Services (2014) Sugar: World markets and trade, November 20, 2014: World production, markets, and trade reports. Retrieved from http://www.fas.usda.gov/data/sugar-world-markets-and-trade

Wolf B (2016) Confectionery and sugar-based foods. Reference module in food science. Elsevier, New York, 4pp. https://doi.org/10.1016/B978-0-08-100596-5.03452-1