Maple Sugar Troubleshooting

Catherine Belisle, Ph.D., 2023

Overview

Maple sugar is a versatile product with distinct maple flavor. It is produced by boiling syrup to a set temperature followed by stirring the heated solution until it crystalizes into a granulated or brown sugar consistency. Multiple factors influence the quality of maple sugar. This bulletin provides guidelines for addressing issues commonly encountered during and after the production of maple sugar, including moisture content, granulation size, and flavor formation. For maple sugar production details, please refer to the Crystallization and Granulated Maple Sugar chapters in the New York State Maple Confections Notebook, available on the Cornell Maple Program website.

Background

Maple syrup contains 66 – 68.9% sugars, the majority of which is sucrose, an easily crystallizable sugar. When sucrose is exposed to microorganisms (yeast and bacteria), heat, acids (e.g. tartaric or citric), or the invertase enzyme, it hydrolyzes or splits into the invert sugars, glucose and fructose (Fig. 1).

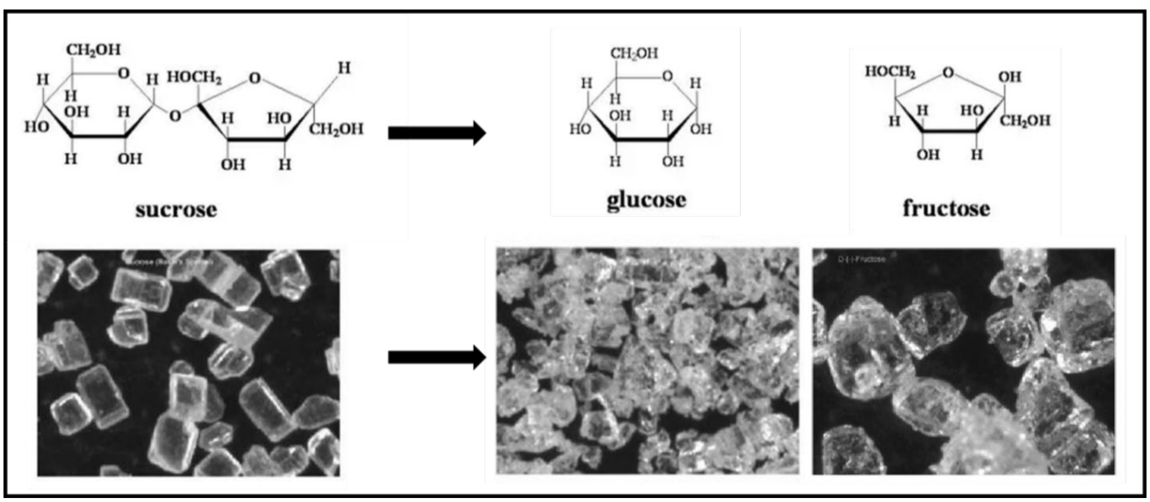

Figure 1. Molecular structures and crystalline images of sucrose, glucose, and fructose (Kweon et al., 2009).

Invert sugars act as crystal inhibitors and help retain moisture in food products. Glucose inhibits crystallization by physically preventing sucrose molecules from associating. Meanwhile, fructose is highly hygroscopic; it absorbs moisture more quickly and to a greater extent than glucose or sucrose (Bhandari and Hartel, 2002). When invert sugars are present, a slowed or inhibited crystallization should be expected. It is recommended to use syrup with <0.5% invert sugars for granulated sugar consistency or <4% invert sugars for brown sugar consistency. Invert sugar levels can be measured using a glucose meter. Guidelines are available in the New York State Maple Confections Notebook and in the video: "How to Test Invert Sugar Levels in Maple Syrup" on the Cornell Maple Program YouTube channel.

For reference, granulated sugar contains 99% sucrose, 0.015% invert sugars, 0.02% moisture, and 0.01% inorganic compounds. Meanwhile, light and dark brown sugars contain less sucrose (89 and 87.9%), and higher levels of invert sugars (4.2 and 4.6%), moisture (2.7 and 2.8%), and inorganic matter (1.4 and 1.7%), respectively (Hartel et al., 2018).

Amorphous or **glass sugars** are sugars that are immobilized and unable to crystalize due to limited water (<15%) in the sugar solution (Hartel et al., 2011). Hard candies and lollipops are commercially produced amorphous sugars. Amorphous sugars appear in granulated sugar production as sugar clumps formed in response to rapid cooling or slow agitation. They are unstable and dissolve more readily than a sugar crystal. However, the chemical nature of these sugars allows flavors to be dispersed throughout the confection, compared to crystalized sugars where the flavor is only on the surface.

Moisture in Sugar

Moisture or water content is influenced by the production environment, invert sugar levels, and finishing temperature (the highest temperature syrup is boiled to). To reduce excess moisture in the final product, produce sugar in a 20 – 65% relative humidity (RH) environment, use maple syrup with <2% invert sugar, and select a finishing temperature of 50 – 55 °F above the boiling point of water (ABPW).

Relative humidity. It is expressed as the percent of moisture in the air relative to the total amount of moisture the air can hold at its current temperature. Maple sugar production requires moisture removal from the syrup during boiling followed by a release of moisture in the form of steam during stirring. If sugar is produced in a high RH environment, the moisture removal is slowed. High moisture in the air hinders the release of the moisture in sugars during stirring. Maintain a RH of 20 – 65% during production. Fans and dehumidifiers can aid in moisture removal.

Invert sugar levels. Sugars produced from syrups with high invert levels (>2%) will absorb more moisture than those produced with lower invert sugar levels (<2%). Invert sugars, particularly fructose, will hold and continue to draw in moisture during storage.

Finishing temperature. The higher the finishing temperature, the lower the water content. A finishing temperature of 50 – 55 °F ABPW is recommended for producing a sugar with <3% moisture. Lower finishing temperatures are used for confections with more moisture. For instance, the maple candy finishing temperatures range from 28 – 34 °F ABPW and result in an estimated 11 – 14% moisture (Belisle, 2022; Childs, 2007).

Boiling to a higher finishing temperature can result in increased levels of amorphous sugars and scorch flavors.

Consistency in Granulation Size

Granulation size is dependent on production conditions, invert sugar levels, seeding, and stirring temperature, speed, and duration. To reduce clumps in the final product, produce sugar in a 20 – 65% RH environment, use maple syrup with <2% invert sugars, seed the sugar solution, and allow the sugar solution to cool before stirring.

Relative humidity. High moisture in the air slows the conversion of sugar to its crystalline form, which can lead to larger granules of sugar. As noted in the previous section, maintain a RH of 20 – 65% during sugar production. Use fans and dehumidifiers as needed.

Invert sugar levels. As invert sugar level increases, stirring time increases (Bhandari and Hartel, 2002). When stirring the sugar solution, sugar crystals are physically arranging into a crystal lattice. Invert sugars prevent sucrose molecules from forming a lattice. To form sugar crystals with high invert sugar syrup, the solution will need to be stirred longer (Bhandari and Hartel, 2002) and increased clumping may occur.

Seeding. Seeding is the process of adding sugar crystals of an ideal size to an un-crystalized solution. Stir the sugar crystal "seeds" into the solution to initiate crystallization. To accomplish this, add maple sugar with the desired crystallization size to the heated sugar solution immediately before or at the start of stirring. Approximately 1 – 2 tablespoons per gallon of syrup used is sufficient. This is crucial when producing sugar from higher invert sugar syrup (2 – 4%), but can be helpful in all sugar batches.

Stirring temperature. For consistently small sugar crystals, quickly cool the sugar solution to 180 – 200 °F. This is the optimal temperature range for crystallization when syrups are heated to 50 – 55 °F ABPW, according to the phase/state diagram (Hartel et al., 2011). This temperature range is cool enough to allow sugars to come out of the sugar solution and warm enough to allow the sugars to physically interact and crystalize. When the sugar solution is <140 °F, amorphous sugar will form. Inversely, when the sugar solution is >200 °F, a small number of sugar crystals form; these sugar crystals continue to grow as the sugar solution cools, resulting in large sugar granules.

Stirring speed and duration. When stirring, sugar crystals form and moisture is released in the form of steam (Fig. 2). To optimize this process, stir the sugar solution at a medium to high speed. Stirring too slowly can reduce moisture release and result in a higher volume of sugar clumps. Stir the sugar solution for 10 – 15 minutes for a 2-gallon batch, or until the sugar is no longer releasing heat.

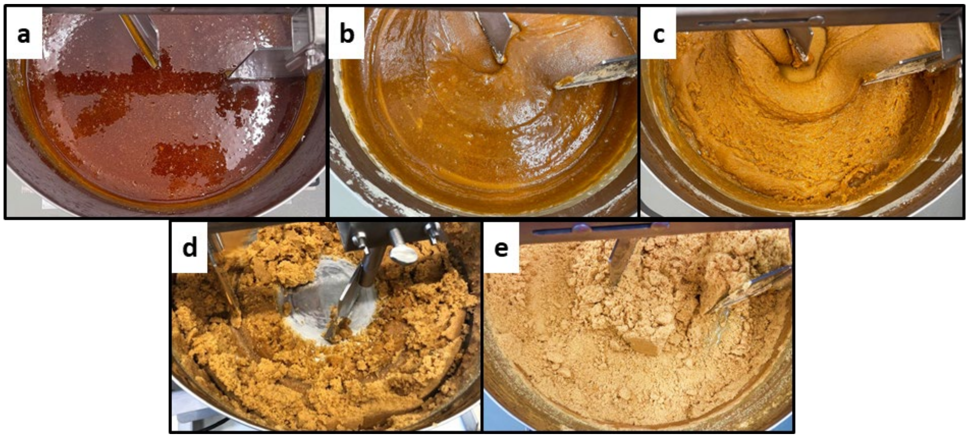

Figure 2. Crystallization of maple syrup into sugar during agitation (a to e).

Flavor Formation

Flavor of maple sugar is determined by the initial syrup quality and the production process. To increase flavor of maple sugar, use a darker grade of syrup with up to 4% invert sugar levels, or heat the syrup solution slowly to allow sucrose inversion to occur.

Equipment. Maple syrup is prone to excessive boiling at approximately 219 – 245 °F. Use 1/8 teaspoon of defoamer to prevent boiling over. To reduce hot spots, evenly distribute heat, and slow sucrose inversion, boil syrup on an induction stove top, in a copper pot, aluminum pot, steam kettle, or in a vacuum chamber. To avoid further inversion and degradation of the invert sugars into various flavor compounds, boil the sugar solution quickly.

Invert sugars. During boiling, caramelization and Maillard reactions occur. Caramelization is the degradation of sugars in response to heat, while the Maillard reaction is a process in which amino acids and reducing sugars (fructose and glucose) react and undergo multiple steps to produce flavor compounds. In both circumstances, sucrose is hydrolyzed or split into invert sugars and then either continues to degrade into multiple flavor compounds (caramelization) or reacts with amino acids to form flavor compounds (Maillard reaction). Flavors perceived from these compounds include caramel, cooked, roasted, sweet, burnt, pungent, and nutty, among others (van Boekel, 2006). To intensify flavors, start with higher invert sugar syrup (2 – 4%) and heat the syrup slowly to allow the caramelization and Maillard reactions to occur and form flavor compounds. One factor to consider is that as desirable flavor compounds form, undesirable flavors can also form.

Scorching occurs when sugar is exposed to high temperatures for an extended period of time. Scorch flavor compounds are byproducts of invert sugar degradation. During production, the sugars and flavor compounds can continue to react with the heat and amino acids to form acids that impart sour, fruity (Knol et al., 2010), and burnt flavors, among others (Chen et al., 2021). Flavor development is complex, and literature on scorch flavors is limited. To prevent scorching, use equipment that will reduce hot spots and stir the syrup solution during heating.

Post-Production Processing

Drying. To reduce condensation and clumping, allow the sugar to cool prior to packaging. Immediately following sugar production, sift or spread the sugar onto a thin, flat surface. Allow the sugar to cool and dry at 50 – 70 °F and <65% RH for 1 to 24 hours. Stir the sugar periodically during drying.

Storage Considerations. To extend the shelf-life of sugar, store between 20 – 65% RH. When exposed to <20% RH, sugar can lose moisture; inversely, at higher RH (>65%), sugar can accumulate moisture, leading to clumping (Fig. 3). In high moisture sugars, similar to brown sugar, consider storing between 40 – 65% RH or adding a humidity control in the packaging. Humidity controls must be approved for food use and may include moist fired clay or humidity control packets. Store sugar in moderate (polyethylene terephthalate (PETE or PET)) or high (e.g. polyethylene (PP), glass) moisture barrier packaging containers to prevent moisture exchange with the environment.

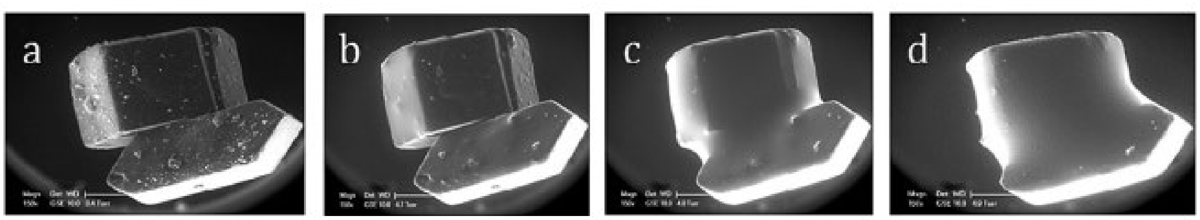

Figure 3. Sucrose crystal dissolution over time (a to d) in a 65 – 93% RH environment (with permission Samain et al., 2017).

USDA Grade Standards

Sugar from sugar cane and sugar beets are sold voluntarily following USDA grade standards that include granule sizes for granulated sugar and powdered sugar (USDA, 2015). No guidelines are available for brown sugar or maple sugar granulation size. Producers may choose to separate sugars using U.S. Standard test sieve sizes. Examples are shown in Fig. 4.

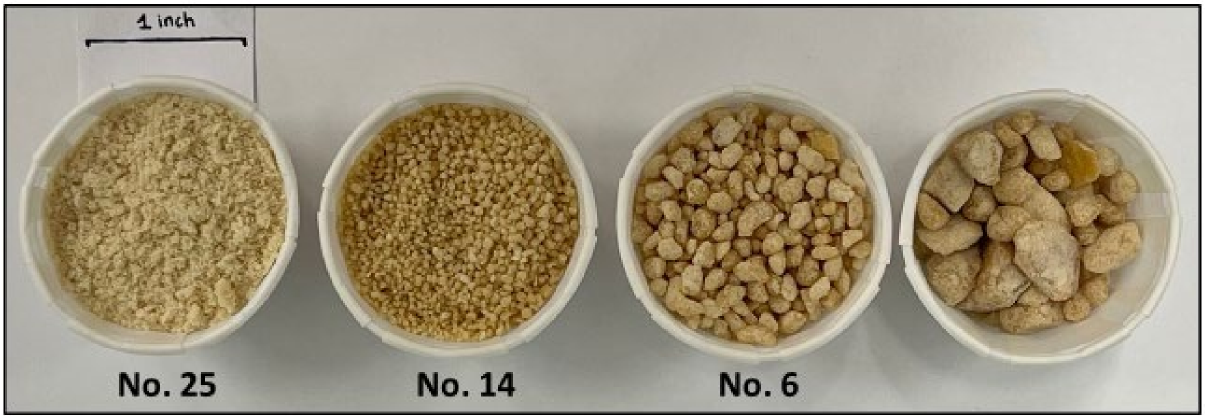

Figure 4. Maple sugar separated by granule size using U.S. Standard test sieves. Sugars passed through the sieve size listed below image. Screen sizes for each sieve were 710 µm (No. 25), 1.4 mm (No. 14), 3.35 mm (No. 6), and >3.35 mm.

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Citations

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