Sugar Crystallization

MOST SOLID FOODS that are heated to high temperatures simply cook. Many remain in their original form. However, sugar is unlike most foods. It is a crystal, so when heat is applied, it melts. Depending on how hot it gets, sugar may crystallize in endless final textures and products when it cools, such as fudge, caramel, taffy, and toffee. Let's look closer to see how crystallization affects sugar and the products made from it.

Objectives:

1. Explain the stages of sugar crystallization.
2. List food products created at each stage of sugar crystallization.

Key Terms:

candy thermometer
caramelized sugar
cold water test
corn syrup
crystallization
firm ball stage
glucose
hard ball stage
hard crack stage
humidity
inversion
invert sugar
simple syrup
soft ball stage
soft crack stage
sucrose
syrup strength
thread stage

Sugar Crystallization Stages

Crystallization is the formation of sugar crystals in sugar syrup. Crystallization can occur quickly and can turn formerly smooth sugar syrup into a lumpy, dense, and gritty mass. Granulated sugar is always on a "mission" to return to its original crystalline shape rather than remaining dissolved in syrup. **Sucrose** is the chemical name for granulated sugar (table sugar) and is made of fructose and glucose. It is the main ingredient of most candies. Heating sucrose melts its crystals into syrup. Then depending on the final temperature of the syrup, what is added to it, and how it is handled, the melted crystals re-crystallize into different solid forms: jellies and jams, buttercream icing, peanut brittle, and taffy.

TEMPERATURE

The temperature of the cooking sugar syrup determines the level of crystallization taking place. A **candy thermometer** is a special thermometer designed to read the stages of cooked sugar with a clearly visible display of temperature readings. An instant read thermometer is not adequate for candy making. A candy thermometer should register temperatures up to 400°F; have 1- or 2-degree graduations between 100° and 400°F; be tested for accuracy; be warmed before inserting into cooking syrup; be inserted just above the bottom of the pan in which the sugar syrup is cooking; not "roll around" in the sugar syrup; and be cleaned by allowing it to stand in warm water. If syrup (or chocolate) dries on the bulb of the thermometer, you may not get an accurate temperature reading.

Many candy makers use a thermometer and a **cold water test** (a measure of the density or concentration of sugar in the syrup) to determine the stage of sugar crystallization in a syrup. A thermometer is a good guide, but the cold water test confirms or disaffirms the thermometer's temperature reading. To perform the test:

- Use a clean wooden or silicone spoon to drop about a half teaspoon of syrup into a small bowl of chilled, not ice, water. Each test should be conducted with a fresh bowl of chilled water.
- Quickly collect the sugar syrup between your thumb and forefinger. Judge its shape, resistance to pressure, and body. The candy syrup becomes increasingly stiffer as more and more water is evaporated.

FIGURE 1. This thermometer is for measuring candy and deep-fry temperatures. Notice that it measures temperatures above 500°F.

MOISTURE

The temperature of the syrup tells you the temperature of the sugar and how much moisture is left in the sugar. This is a key factor in making a good product. The more moisture in the syrup, the softer the final candy product. The hotter the syrup, the less moisture is left in the product and the tighter the crystalline structure. Less moisture results in a harder candy.

HUMIDITY

Humidity is the degree of moisture (wetness) in the air. Humidity affects the amount of moisture in the syrup, too. Cooking or crystallizing sugar is never recommended on humid days. Sugar absorbs moisture, and cooking sugar reduces moisture in the syrup. However,

humidity interferes with this process and can make the final product sticky and cloudy because humidity disrupts crystallization. Candy makers cook sugar to slightly higher than normal temperatures (about 2 degrees higher) to compensate for high moisture levels.

ALTITUDE

Altitude affects the cooking of candy syrups, so temperatures must be modified to accommodate the higher altitude. In general, for every 1,000 feet (300 meters) above sea level, it is necessary to subtract 2 degrees F (1 degree C) from the boiling point of the syrup.

BASIC SUGAR CRYSTALIZATION STAGES

The temperature of sugar impacts its texture and flavor. So it is crucial to monitor the temperature of dissolving sugar when making candy and other items that require sugar crystallization.

Simple Syrup

Simple syrup is a mixture of sugar and water heated until the sugar dissolves to a temperature of no more than 212°F. Sugar is commonly dissolved in water to assist the breakdown and dissolving of sugar into a solution. Simple syrup mixtures remain a solution even when cooled; no re-crystallization takes place.

Thread Stage

Thread stage is a string of candy that drips off the end of the spoon into the syrup pot in the form of a thread. The temperature range is from 215° to 234°F.

Soft Ball Stage

Soft ball stage is candy that is more compact than thread stage. When a small amount is dropped into chilled water, a soft and pliable candy (that flattens into a disc) results. The temperature range is from 234° to 242°F.

Firm Ball Stage

Firm ball stage is candy that is stiffer than soft ball stage, and it holds its shape when a small amount is dripped into chilled water. It is still soft enough to flatten if pressed between your thumb and forefinger. The temperature range is from 244° to 250°F.

Hard Ball Stage

Hard ball stage is candy that is more rigid than that in the firm ball stage, and the syrup forms thick threads as it drips from a wooden spoon back into the saucepan. It easily forms a

hard ball when dripped into chilled water, but it is flexible enough to compress when squeezed between your thumb and forefinger. The temperature range is from 250° to 266°F.

Soft Crack Stage

Soft crack stage is candy that is more brittle than hard ball stage candy. When you drop a small amount into chilled water, the syrup breaks into bendable threads. The temperature range is from 270° to 290°F.

Hard Crack Stage

Hard crack stage is candy that is more brittle than soft crack stage candy. When a small amount is dropped into chilled water, the syrup separates into hard, brittle threads that break easily. The color of the syrup is that of weak honey. The temperature range is from 298° to 310°F.

Caramelized Sugar

Caramelized sugar is candy syrup that continues to cook to temperatures beyond 310°F and turns from a honey color to a light brown to a dark brown. The browning of sugar adds depth of flavor and character to the taste. It will eventually turn black, bitter, and burned at about 400°F. The resulting product is called Black Jack.

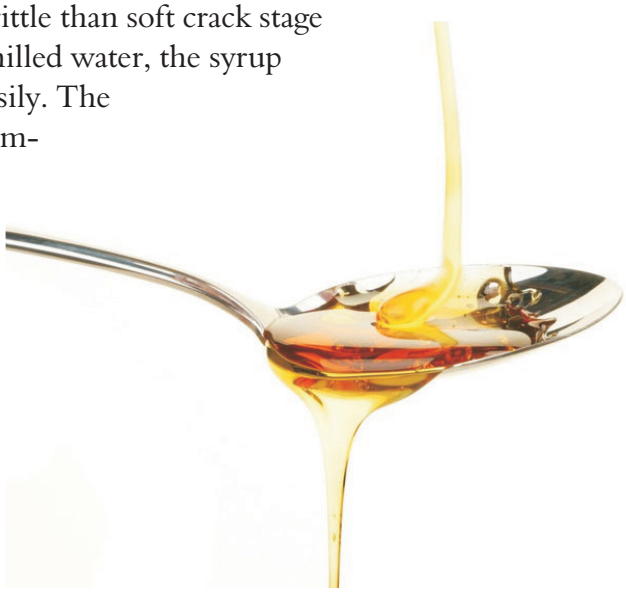

FIGURE 2. As sugar syrup reaches temperatures of about 320°F, it begins to change from clear to amber in color as caramelization begins.

Products Made From Crystallized Sugar

Syrup strength is a measure of the concentration of sugar in the mixture. As water evaporates from the sugar and water solution (syrup), the temperature of the syrup gradually rises. If all the water evaporates, the sugar melts. At this point, the sugar will begin to caramelize. There are essentially two types of candies: crystalline (e.g., rock candy, fudge, or fondant) and non-crystalline (e.g., brittles and toffee).

CRYSTALIZATION AND INVERSION

Grittiness or Graininess

Grittiness or graininess is a common problem when you make candies and desserts. Graininess happens when cooked sugar crystals turn into smaller sugar crystals rather than remaining

dissolved in the syrup mixture. Interfering agents (e.g., cream of tartar, lemon juice, corn syrup, molasses, or vinegar) are added to sugar syrup mixtures to prevent the formation of crystals. To avoid crystallization in the early stages of sugar syrup development, do the following:

- Wash down the sides of the pan with a brush dipped in water while the syrup is boiling.
- Cover the pan and boil the syrup for a few minutes at the beginning of the cooking. This washes the pan of crystals, too.
- If the recipe calls for butter, you can lightly butter the inside of the saucepan before adding the remaining ingredients.
- Avoid stirring the syrup once it begins to boil.

Inversion

Inversion is a chemical change in sucrose into another form of sugar. Syrups cooked to a high concentration of sugar sometimes crystallize after they are cooled. Inversion resists crystallization. You can add an acid at the beginning or during the cooking that "inverts" the sugar. Common acids are cream of tartar and lemon juice.

Invert Sugar

Invert sugar is created when a sucrose solution is heated with an acid. When heated, some of the sucrose break into equal parts of dextrose and levulose. A mixture of equal parts of dextrose and levulose is **invert sugar**. The result is a sweetener that is sweeter than sucrose was before the inversion.

EXPLORING OUR WORLD...

SCIENCE CONNECTION: Making Rock Candy

Rock candy is made by using the fundamental re-crystallizing properties of cooked sugar. Hard ball stage sugar syrup is at a very vulnerable stage, and unwanted re-crystallization can occur if uncooked sugar crystals are introduced into the syrup. A chain reaction occurs, making the syrup solidify or crystallize in an unwanted way.

Use the re-crystallizing technique to make rock candy. Introducing a stick coated with regular sugar crystals into the cooking syrup begins the process of making rock candy. Then the liquid sugar syrup reacts to the stick by creating more and more sugar re-crystallizing on top of the sugar crystals on the stick. It creates large, irregular crystal formations that solidify from the syrup onto the stick or string as hard candy.

While the fragile nature of sugar at the hard ball stage allows for re-crystallization that creates rock candy, it can also be manipulated to make marshmallows and tender chewy candies, such as gummy candies and jellies. The difference is how the sugar is allowed to crystallize.

Liquid Sweeteners

Liquid sweeteners all contain small amounts of acid, which inverts some of the sugar. Liquid sugars, including **corn syrup** (a thick liquid derived from corn) and **glucose** (a very thick liquid form of sugar, sweeter than corn syrup) are used in candy making. These liquid sweeteners add more moisture to the candy. These products also have different textures than those made with sucrose.

- Simple syrup is used to make sorbets, slushies, dessert sauces, fruit punch, and cocktails; to flavor and moisten cake layers or cookies; to prepare candied fruit; and to dilute fondant.
- Thread stage syrups are used to make syrups of all types; glazes and icings; liqueurs; jelly and jams; candied orange peel and candied fruit; and decorative spun sugar confections.
- Soft ball stage syrups are used to make soft textured fudge, fondant, Italian meringue, some buttercream icing and candy truffle fillings, caramel corn, and pralines.
- Firm ball stage syrup is used to make chewy and soft caramel products and marzipan.
- Hard ball stage syrup is a very versatile stage, and it is used to make a variety of candies: marshmallows, nougat, divinity, gummy-type candies, some peanut brittle, and some rock candy.
- Soft crack stage syrup is commonly used to make taffy and some nougat. Both of these candies have chewy textures. Taffy uses invert sugar to allow for mixing to get the chewy texture without re-crystallizing in a grainy mess.
- Hard crack stage syrup makes crunchy toffees, brittle, butterscotch, and all hard candies.
- Caramelizing sugar stage is melted sugar rather than sugar syrup. It is used to make hard caramel for crème caramel and flan deserts, spun sugar and caramel cages, and pulled sugar creations.

FIGURE 3. Fudge is made from soft ball stage sugar syrup.

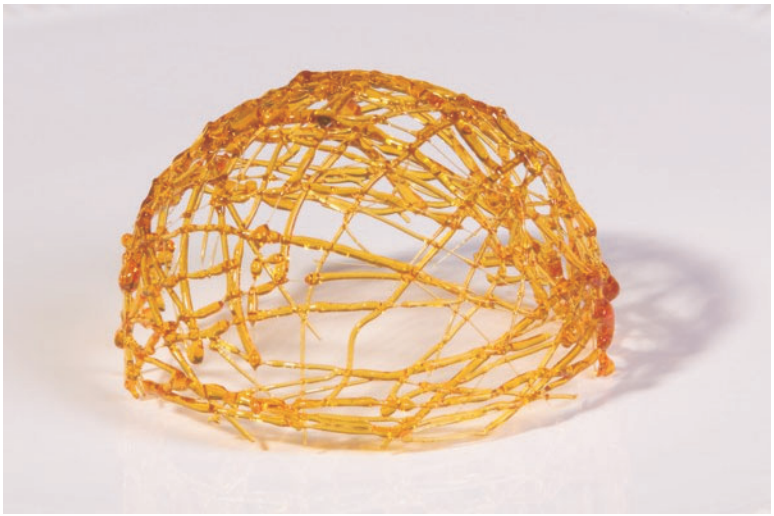

FIGURE 4. Caramelized sugar can be formed into numerous shapes, such as this caramel cage to enhance a dessert.

Summary:

Sucrose or table sugar is commonly found in crystallized form and can be melted by heating. The higher the temperature of the melted sugar, the less moisture is left and the harder the cooled syrup will get. The sugar re-crystallizes into different textures based on temperature. The range extends from 215°F (known as thread stage) up to 310°F (hard crack stage), after which caramelization and burning occurs. The crystallization can be manipulated through inversion of sugar or the addition of acid to break sucrose into its natural form of glucose and fructose.

Checking Your Knowledge:

1. What effect does humidity have on the crystallization of sugar?
2. Why is a candy thermometer essential to cooking sugar?
3. What are the stages of sugar crystallization?
4. At what temperature does sugar begin to caramelize?
5. What products can be made from crystallized sugar at each stage?

Expanding Your Knowledge:

There are a number of ways to slow, interfere with, or stop sugar crystallization while cooking sugar, all with various results that create different candies. Try making several different types of candy, keeping the following in mind.

Corn syrup contains glucose, which has enough acid to prevent re-crystallization during the cooking process. It is an excellent addition to sugar when making caramel, brittle, and hard candies. Cream of tartar is a powdered, flavorless acidic powder that can be added to sugar syrup; it provides the same results as glucose.

Brown sugar and molasses retard crystallization by changing the ratio of glucose to fructose. They keep the crystals small and prevent a gritty texture. Honey has a natural non-crystallizing property and can be used as an addition to sugar or can replace it, resulting in particularly smooth candy textures (though honey brings its own flavor with it).

Fats (e.g., butter and cream) coat sugar crystals, preventing their growth and formation. It explains the smooth texture of foods such as toffee, fudge, and marshmallows. Gelatin added to sugar syrup actually changes the crystalline shape of sugar, swelling up with absorbed moisture and resulting in smooth gum or jelly type candies.

Web Links:

Crystallization of Sugar
http://www.foodscience-avenue.com/2010/04/crystallization-of-sugar.html

How Sugar Crystals Are Formed
http://www.ehow.com/how-does_5418701_sugar-crystals-formed.html

Making Candy and the Role of Sugar Crystals
http://www.baking911.com/candy/101_crystallization.htm

Temperature and Stages of Making Sugar Syrup Chart
http://www.baking911.com/candy/chart.htm