



Sugar's Functional Roles in Cooking & Food Preparation



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Beyond Sweetening...

Whether you teach, give demonstrations, test recipes or write about food, questions concerning sugar's physical and chemical functions in food are almost certain to arise. This handbook is intended to help explain the answers to such questions as "What gives bread its crispy brown crust?"... "Why did the custard curdle and weep?"... "What gives the angel food cake and pound cake such tender texture?"... "Why is the lemon pie filling lumpy, and the meringue flat and pale?"... "Why are the yeast-leavened rolls taking so long to rise?"... "Why did the strawberries frozen two weeks ago, defrost limp and faded?" and "What gives barbequed ribs a crispy, brown texture?" This handbook is a quick and concise reference on the functional roles sugar plays in foods. It discusses how sugar reacts in food preparation and why it reacts as it does.

Sugar: The natural sweetener... 15 calories per teaspoon!

Sugar is the disaccharide sucrose ($C_{12}H_{22}O_{11}$), a carbohydrate found in every fruit and vegetable. All green plants manufacture sugar through photosynthesis, the process by which plants transform sunlight and soil nutrients into their food and energy supply. Sugar cane and sugar beets contain sucrose in large quantities; that's why they are used as the source of the sugar we use. The sugar removed from sugar cane and sugar beets is exactly the same as the sugar found in all fruits and vegetables. Fully processed beet sugar and cane sugar are identical products and may be used interchangeably for all purposes.



Types of Sugar

Because of its diverse functional characteristics, sugar is used in many types of food preparation. Although this handbook focuses on the functions of “regular” sugar, the most common type used in the home, sugar is available in many other forms.

Granulated Sugars

There are many different types of granulated sugar. Some of these are used only by the food industry and professional bakers and are not available in the supermarket. The types of granulated sugars differ in crystal size. Each crystal size provides unique functional characteristics that make the sugar appropriate for a specific food’s special need.

“Regular” sugar, extra fine or fine sugar

“Regular” sugar, as it is known to consumers, is the sugar found in every home’s sugar bowl and most commonly used in home food preparation. It is the white sugar called for in most cookbook recipes. The food industry describes “regular” sugar as extra fine or fine sugar and is the sugar most used because its fine crystals are ideal for bulk handling and are not susceptible to caking.

Fruit sugar

Fruit sugar is slightly finer than “regular” sugar and is used in dry mixes such as gelatin desserts, pudding mixes, and drink mixes. Fruit sugar has more uniform crystal size than “regular” sugar. The uniformity of crystal size prevents separation or settling of smaller crystals to the bottom of the box, an important quality in dry mixes and drink mixes.

Bakers Special

Bakers Special’s crystal size is even finer than that of fruit sugar. As its name suggests, it was developed specially for the baking industry. Bakers special is used for sugaring doughnuts and cookies as well as in some commercial cakes and produces fine crumb texture.

Superfine, ultrafine, or bar sugar

This sugar’s crystal size is the finest of all the types of granulated sugar. It is ideal for extra-fine textured cakes and meringues, as well as for sweetening fruits and iced-drinks since it dissolves easily. In England, a sugar very similar

to superfine sugar is known as caster or castor, named after the type of shaker in which it is often packaged.

Confectioners or powdered sugar

This sugar is granulated sugar ground to a smooth powder and then sifted. It contains about 3% cornstarch to prevent caking. Confectioners sugar is available in three grades ground to different degrees of fineness. The confectioners sugar available in supermarkets is the finest of the three and is used in icings, confections and whipping cream. The other two types of powdered sugar are used by industrial bakers.



Coarse sugar

The crystal size of coarse sugar is larger than that of “regular” sugar. Coarse sugar is recovered when sugar syrups high in sucrose are allowed to crystallize, thereby making it highly resistant to color change or inversion (natural breakdown to fructose and glucose) at high temperatures. These characteristics are important in making fondants, confections and liquors.

Sanding sugar

Another large crystal sugar, sanding sugar, is used mainly in the baking and confectionery industries to sprinkle on top of baked goods. The large crystals reflect light and give the product a sparkling appearance.

Brown Sugars

Turbinado sugar

This sugar is raw sugar which has been only partially processed, removing the surface molasses. It is a blond color with a mild brown sugar flavor and is often used in tea.

Brown sugar (light and dark)

Brown sugar retains some of the molasses syrup, which imparts a pleasant flavor. Brown sugar tends to clump because it contains more moisture than white sugar. Dark brown sugar has more color and a stronger molasses flavor than light brown sugar. Lighter types are generally used in baking and making butterscotch, condiments and glazes. Dark brown sugar has a rich flavor that is good for gingerbread, mincemeat, baked beans, and other full flavored foods.

Muscovado or Barbados sugar

Muscovado sugar, a British specialty brown sugar, is very dark brown and has a particularly strong molasses flavor. The crystals are slightly coarser and stickier in texture than “regular” brown sugar.

Free-flowing brown sugars

These sugars are specialty products produced by a cocrystallization process. The process yields fine, powder-like brown sugar that is less moist than “regular” brown sugar. Since it is less moist, it does not clump and is free-flowing like white sugar.

Demerara sugar

Popular in England, Demerara sugar is a light brown sugar with large golden crystals, which are slightly sticky. It is often used in tea, coffee, or on top of hot cereals.

Liquid Sugars

Liquid sugars

There are several types of liquid sugar. Liquid sucrose (sugar) is essentially liquid white sugar and can be used in products wherever dissolved sugar might be used. Amber liquid sucrose (sugar) is darker in color and can be used where color is not a problem in the product.

Invert sugar

Inversion of sucrose results in invert sugar, an equal mixture of glucose and fructose. Available commercially only in liquid form, invert sugar is sweeter than white sugar. Some liquid inverts are actually part invert sugar combined with part dissolved white sugar. Another type, named total invert sugar syrup, is almost completely invert sugar. It is used mainly in food products to retard crystallization of sugar and retain moisture.

Sugar in Action

The cook who once discovered—by accident perhaps—that pound cake could be vastly improved by creaming the sugar with the shortening probably never knew why this innovation worked so well. The fact that jams and preserves rarely spoil must have delighted home cooks without their ever having the faintest idea why this is so.

Understanding the reason why is as important as the fact itself. In the following pages, the reasons for sugar's use in food preparation are reviewed in sections on bakery foods, cooking, jellies and preserves, canning and freezing, candy making, frozen desserts and non-sweet foods.

Beyond its contributions as a sweetener and flavor-enhancer, sugar:

1. Interacts with molecules of protein or starch during baking and cooking process.
2. Acts as a tenderizer by absorbing water and inhibiting flour gluten development, as well as delaying starch gelatinization
3. Incorporates air into shortening in the creaming process.
4. Caramelizes under heat, to provide cooked and baked foods with pleasing color and aroma.
5. Speeds the growth of yeast by providing nourishment.
6. Serves as a whipping aid to stabilize beaten egg foams.
7. Delays coagulation of egg proteins in custards.
8. Regulates the gelling of fruit jellies and preserves.
9. Helps to prevent spoilage of jellies and preserves.
10. Improves the appearance and tenderness of canned fruits.
11. Delays discoloration of the surface of frozen fresh fruits.
12. Enables a wide variety of candies through varying degrees of recrystallization.
13. Controls the reformation of crystals through inversion (breakdown to fructose and glucose).
14. Enhances the smoothness and flavor of ice cream.

Sugar in Bakery Foods

Cakes, cookies, quick breads and yeast breads require sugar for flavor, pleasing color, tender texture, evenness of grain, moisture retention, improved shelf life, and yeast fermentation. Because these are keys to quality in baked goods, it is important to know how sugar works in batters and doughs and how it relates to other ingredients in recipes. And although a number of other sweeteners may be used in baked products, none is as versatile as sugar or can perform all of its important functions.

Flour, shortening, eggs, liquids, leavening agents and sugar are the basic ingredients. Working together, these ingredients function to form the final structure of the baked good. The amount and nature of these ingredients in the recipe determine the structural and sensory characteristics of the baked product.

Basic Functional Roles Sugar Plays in Baked Products

Gluten Development

During the mixing process, sugar acts as a tenderizing agent by absorbing water and slowing gluten development.

During the mixing of batters and doughs, flour proteins are hydrated (surrounded with water) forming gluten strands. The gluten forms thousands of small, balloon-like pockets that trap the gases produced during leavening. These gluten strands are highly elastic and allow the batter to stretch under expansion of gases. However, if too much gluten develops, the dough or batter becomes rigid and tough.

Sugar competes with these gluten-forming proteins for water in the batter and prevents full hydration of the proteins during mixing. As a consequence, less gluten is allowed to “develop,” preventing the elastic dough or batter from becoming rigid. With the correct proportion of sugar in the recipe, the gluten maintains optimum elasticity, which allows for gases to be held within the dough matrix. These gases, from

leavening agents and mixing, expand and allow the batter or dough to rise. By preventing the gluten development, sugar helps give the final baked product tender crumb texture and good volume.

Leavening

Sugar increases the effectiveness of yeast by providing an immediate, more utilizable source of nourishment for its growth.

Under recipe conditions of moisture and warmth, sugar is broken down by the yeast cells, and carbon dioxide gas is released at a faster rate than if only the carbohydrates of flour were present. The leavening process is hastened and the dough rises at a faster and more consistent rate.

Creaming

Sugar crystals become interspersed among the shortening molecules when shortening and sugar are creamed together.

In cakes and cookies, sugar helps promote lightness by incorporating air into the shortening. Air is trapped on the face of sugar’s irregular crystals. When sugar is mixed with shortening, this air becomes incorporated as very small air cells. During baking, these air cells expand when filled with carbon dioxide and other gases from the leavening agent.

Egg Foams

Sugar serves as a whipping aid to stabilize beaten egg foams.

In foam-type cakes, sugar interacts with egg proteins to stabilize the whipped foam structure. In doing so, sugar makes the egg foam more elastic so that air cells can expand and take up gases from the leavening agent.



Egg Protein Coagulation

In unshortened cakes, sugar molecules disperse among egg proteins and delay coagulation of the egg proteins during baking.

As the temperature rises, egg proteins coagulate, or form bonds among each other. The sugar molecules raise the temperature at which bonds form between these egg proteins by surrounding the egg proteins and interfering with bond formations. Once the egg proteins coagulate, the cake “sets,” forming the solid mesh-like structure of the cake.

Gelatinization

During baking, sugar tenderizes by absorbing liquid and delaying gelatinization.

In cakes, the heat of baking causes the starch in flour to absorb liquid and swell. This process is called gelatinization. As more liquid is absorbed by the starch, the batter goes from a fluid to a solid state, “setting” the cake. Sugar acts to slow gelatinization by competing with the starch for liquid. By absorbing part of the liquid, sugar maintains the viscosity of the batter. As a result, the temperature at which the cake “sets” (turning from liquid to solid state) is delayed until the optimum amount of gases are produced by the leavening agents. Carbon dioxide, air and steam produced from leavening agents, heated water and air become entrapped and expand in the air cells. The result is a fine, uniformly-grained cake with a soft, smooth crumb texture.

As described above, sugar is effective in delaying starch gelatinization in cakes and provides good texture and volume. Little data is available concerning sugar’s function in delaying gelatinization in breads; therefore its influence on gelatinization in yeast-leavened breads is less clear. In theory, as breads with higher sugar content bake, gelatinization is delayed by the same mechanism described above in cakes. A bread with more tender crumb texture results.

Caramelization

Sugar caramelizes when heated above its melting point, adding flavor and leading to surface browning which improves moisture retention in baked products.

At about 175°C (or 347°F), melted dry sugar takes on an amber color and develops an appealing flavor and aroma. This amorphous substance resulting from the breakdown of sugar is known as caramel. In baking a batter or dough containing sugar, caramelization takes place under the influence of oven heat, and is one of two ways in which surface browning occurs. The golden-brown, flavorful and slightly crisp surface of breads, cakes, and cookies not only tastes good but helps retain moisture in the baked product.

Maillard Reactions

At oven temperatures, sugar chemically reacts with proteins in the baking product, contributing to the food’s browned surface.

These Maillard reactions are the second way in which bread crusts, cakes, and cookies get their familiar brown surfaces. During baking of breads, cakes, and cookies, Maillard reactions occur among sugar and the amino acids, peptides or proteins from other ingredients in the baked products, causing browning. These reactions also result in the aroma associated with the baked good. The higher the sugar content of the baked good, the darker golden brown the surface appears. As described above, these browned surfaces not only taste good but help retain moisture in the baked product, prolonging freshness.

Surface Cracking

Sugar helps produce the desirable surface cracking of some cookies. Because of the relatively high concentration of sugar and the low water content in cookies, sugar crystallizes on the surface. As sugar crystallizes, it gives off heat that evaporates the water it absorbed during mixing and baking. At the same time, leavening gases expand and cause cracking of the dry surface.

Bakery Products

Yeast Breads

Breads leavened with yeast initially require sugar to accelerate the production of carbon dioxide. During the mixing phase, sugar absorbs a high proportion of water, delaying the gluten formation. Delayed gluten formation makes the bread dough's elasticity ideal for trapping gases and forming a good structure.

Sugar in the Maillard reaction contributes to the brown crust and delicious aromatic odor of bread. Also, some of the yeast fermentation by-products and proteins from the flour react with sugar contributing to bread's color and flavor.

Shortened Cakes

In shortened cakes, sugar aids during creaming to incorporate air into the shortening of these cakes. Sugar helps produce fine crumb texture and good volume during mixing and baking. During mixing, sugar tenderizes cakes by absorbing liquid and preventing complete hydration of gluten strands. During baking, sugar tenderizes shortened cakes by absorbing water and delaying gelatinization. In addition, sugar contributes pleasing, sweet flavors and tender browned surfaces to shortened cakes.

Cookies

Cookies, like cakes, are leavened with baking soda or baking powder. Cookies, however, have more sugar and shortening and less water proportionately. In cookies, sugar introduces air into the batter during the creaming process. Approximately half the sugar remains undissolved at the end of mixing. When the cookie dough enters the oven, the temperature causes the shortening to melt and the dough to become more fluid. The undissolved sugar dissolves as the temperature increases and the sugar solution increases in volume. This leads to a more fluid dough, allowing the cookies to spread during baking.

Sugar also helps produce the appealing surface cracking of some cookies, such as gingersnaps. Additionally, sugar serves as a flavorant, caramelizing while the cookies bake.

Pound Cake

Pound cakes, although prepared with shortening, usually contain no leavening agent other than air. The air is incorporated into the batter through a relatively large quantity of beaten eggs. Creaming the sugar with the shortening contributes fluffiness to the shortening by providing tiny air pockets that undergo heat expansion during baking. Sugar also acts as a tenderizing agent during mixing by inhibiting gluten development and during baking by delaying gelatinization. Thus, sugar helps produce pound cakes of fine grain and good volume.

Unshortened Cakes

Unshortened cakes such as sponge and angel food cake contain no fat, but include a large proportion of eggs or egg whites. Much of the cellular structure of the cake is derived from egg protein. Air is the leavening agent that has been beaten into the eggs. Sugar serves as a whipping aid to stabilize the beaten foam. Part of the sugar also is combined with flour before it is folded into the foam mixture. This sugar disperses throughout the flour, separating the flour's starch particles and keeping them from lumping when the flour is folded into the foam mixture.

By raising the temperature at which egg proteins set, sugar delays coagulation long enough to permit entrapment of optimum air. The resulting cakes have tender texture and excellent volume.

Quick Breads

Quick breads, such as biscuits or scones, are prepared with leavening agents that act more rapidly than yeast. Since some quick breads contain relatively small amounts of shortening and little to no sugar, they require special care in mixing to obtain a tender product.

In preparing quick breads, the chance of overdeveloping gluten because of the lack of sugar is a constant risk. With sugar scant or absent, the flour and liquid must be combined gently and stirred only enough to just moisten the dry ingredients. Overmixing results in muffins with large air tunnels and tough cell walls. As the amount of sugar increases, the risk of coarse, uneven grain and chewy texture caused by overmixing decreases.

Sugar In Cooking

In the preparation of custards, puddings, pie fillings and meringues, sugar is a key ingredient. The recipes for these foods depend on sugar to perform vital chemical and physical functions in addition to its role as a sweetener.

Custard

Sugar delays coagulation of egg proteins in custards and similar cooked egg dishes. Just as most baked products are essentially flour protein structures, custards are egg protein structures. If the egg white solidifies too soon from the heat in the cooking process, the liquid ingredients in the custard will be squeezed out in droplets. This is known as syneresis or “weeping.”

Sugar in a custard mixture breaks up the clumps of protein molecules so that they are finely dispersed in the liquid mixture. The temperature at which the custard sets is thus raised, permitting the egg proteins to coagulate slowly and enmesh the other ingredients, resulting in a smooth, stable consistency.

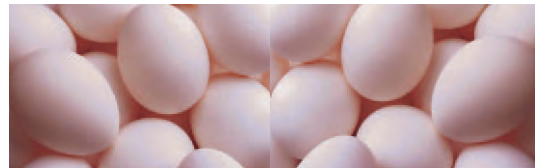
Puddings, Sauces and Pie Fillings

Sugar disperses among the starch particles of flour, cornstarch, or similar thickening ingredients used for pudding, sauce or pie filling. When dry starch is added directly to a hot liquid, the particles on the outside tend to cook first, enclosing raw starch particles in the interior. These lumps are unsightly and unpalatable, and they prevent proper thickening. When mixed with sugar before adding to the hot liquid, the starch particles disperse evenly into the mixture. Each particle comes in contact with the hot liquid at the same time, and all cook at the same rate.

So vital is the dispersion of starch that unless the amount of sugar used in the recipe is twice the amount of the starch, a small amount of cold liquid should be blended with the sugar-starch mixture to further disperse the particles before adding to a hot liquid. Raw cocoa, which is about one-third starch, should also be combined with sugar before adding hot water. Dessert sauces, chocolate pudding, and lemon, butterscotch and other pie fillings all benefit in body and smoothness from this function of sugar.

Meringues

Sugar stabilizes foams such as meringues. Beaten egg whites or a meringue hold air bubbles because the mechanical action of the beaters partially coagulates the egg protein. When sugar is added, often with another stabilizer such as salt or cream of tartar, the protein film becomes more adhesive and its ability to hold air bubbles is increased. This results in a stiffer, higher and more stable foam.



The amount of sugar added per egg white determines the nature of the meringue. For a meringue tart or pie shell that is to be filled with ice cream, fruit or other soft mixtures, four tablespoons of sugar are used for each egg white. The stiff, shaped meringue is then baked in a very slow oven to ensure even setting and thorough drying throughout. The baked meringue will be very crisp and dry, and there will be little, if any, browning.

For the meringue topping that is to be used on a pie or pudding, only two tablespoons of sugar are required per egg white, and the mixture may be baked in a hotter oven. This produces a softer meringue with a slightly crisp crust and a golden-brown color due to the caramelization of the sugar. If no sugar is added to the beaten egg white topping, considerable air shrinkage occurs during baking, and the resulting product is flat, pale, and gummy.

Tips for Cooking with Sugar

To minimize the starch flavor in corn, carrot and pea preparations, add sugar to the cooking liquid.

To balance salty, sour or acidic flavors in dressings, marinades, brines and sauces, add sugar.

To boost browning and add a delicious caramelized sugar flavor to pot roast, stews or braised meats, sprinkle meats with sugar before searing.

To preserve the quality of frozen fruit, pack fruits in sugar syrup or dry sugar before freezing.

To prepare most preserves, jams and jellies, use 1 part sugar to 1 part fruit. In recipes that incorporate commercial pectin, the proportion of sugar may be slightly higher or lower than the 1 to 1 ratio. High fructose corn syrup is sometimes used in commercial jellies. However, it may contain as much as 29% water. The extra water may be evaporated in the final stage of production, which can result in the loss of volatile fruit flavors.

To enhance the flavor of any protein, cover it with a dry rub. As a base recipe, start with 6 parts sugar (half white sugar and half brown sugar) and 1 part salt, and then add herbs and spices as desired. A general rule of thumb is 1 to 2 tablespoons of dry rub per pound of meat.

To make quick pickled vegetables, follow these specific guidelines:

- For shiitake mushrooms, steep in sweet pickling juice 1 hour.

- For baby eggplants, bring sweet pickling juice to a simmer, add eggplants, turn off the heat and let the eggplants pickle at room temperature 2 hours in juice. Refrigerate.

- For cooked beets, add to pickling juice and refrigerate 2 hours.

- For red onion rings, simmer with pickling juice 5 minutes. Let steep 20 minutes off heat. Store in the juice up to 1 week in the refrigerator.

To coat vegetables with a shiny, savory glaze, place vegetables (pearl onions, for example) with liquid (stock or water), sugar and butter in a partially covered pan or in a pan topped with a foil round or parchment round placed directly on the vegetables. Cook over medium-low heat until the vegetables release their juices. Reduce the liquid until it's thick and coats the vegetables.

Sugar In Candy Making

Sugar, as the principal ingredient of candy, displays a wide range of physical and chemical properties. By controlling sugar concentration, type and degree of heat, agitation and addition of other ingredients, an assortment of candy types can be produced. None of today's other sweeteners are a suitable substitute for sugar in candy making. Other sweeteners do not exhibit the unique sweetening, bulking and manufacturing properties of sugar.

Basic Candy Making Method

In candy making, sugar is first dissolved in water at room temperature to the point at which no more sugar will dissolve (approximately one pound of sugar to every cup of water). The result is a saturated solution. This saturated solution is placed over heat and stirred continuously, allowing more sugar to dissolve into solution. The solution is then heated to boiling, at which point no more sugar will dissolve into solution, creating a supersaturated solution. The supersaturated sugar solution is then heated to above boiling point forcing more and more water to evaporate and the solution to become even more concentrated.

Here is one of the keys to candy making: the degree of sugar concentration of the supersaturated solution can determine the candy's final consistency. By monitoring the stages of the supersaturated solution with a candy thermometer and by testing a small sample of the sugar syrup in cold water, one can determine the specific concentration of the sugar syrup. The temperatures and stages of candy hardness are shown for each type of candy in Table 1.

These concentrated, supersaturated solutions are very unstable since the sugar molecules are prone to prematurely recrystallize as the solution becomes increasingly concentrated. During heating of the solution, care must be taken not to agitate or to introduce foreign particles into the solution, both of which can cause premature recrystallization. The secret to making different types of candy lies in attaining the correct concentration of the supersaturated solution and then controlling the recrystallization of the sugar crystals.

Candy types can be divided into two categories: a) candies in which sugar is present in the form of crystals, and b) candies in which the sugar is present in an uncrystallized form.

Crystalline Candies

Crystalline candies can be subdivided into two groups: a) candies with perceptible crystals such as rock candy, and b) cream candies in which crystals are too small to be detected by the tongue, such as fondant and fudge.

Rock candy is prepared simply by immersing a string in a supersaturated sugar solution, heating the solution to the hardball stage and then allowing it to cool. Left to cool, sugar from the solution will recrystallize on the string. With no stirring or other interfering agents, sugar molecules will continue to clump and the crystals will increase in size as long as the mass is immersed. The resulting product is pure sugar since only pure sucrose will recrystallize.

Aside from rock candy and certain types of sugar crystal coatings desirable on candies such as bon bons and gumdrops, the cream form of crystallized candies is generally more popular. Cream candies are created through controlling the size of crystals and forming small, imperceptible crystals. A candy thermometer and/or the cold water sample test are used to heat the supersaturated sugar solution to a specific concentration (Table 1). The solution is then cooled and beaten to bring about the formation of very small homogenous crystals. During this step, the candy "creams."

Creaming is largely dependent on interfering agents which prevent sugar molecules from clumping and growing into large crystals. Fat and protein in candy ingredients, such as milk, butter, egg, cream, chocolate, and cold gelatin, are all interfering agents which inhibit recrystallization and facilitate creaming. The fat and protein coat the sucrose molecules and prevent the molecules from sticking together and forming large crystals.

Invert sugar, another type of interfering agent, also helps prevent recrystallization. Invert sugar is the result of the breakdown, or the inversion, of the sucrose into fructose and glucose. This process takes place when sucrose is

heated with moist heat or, as in candy making, when the water and sugar solution is heated. The amount of water used and the length and intensity of the cooking of the supersaturated solution both control how much of the sucrose is inverted. The process may be accelerated by added acid from candy ingredients such as cream of tartar, fruit, brown sugar, molasses, honey or chocolate. While it is highly undesirable for too much sucrose in the cream candy to invert, a considerable proportion of invert sugar is essential to keep the candy moist and to preventing graininess (due to the formation of too-large crystals).

Non-crystalline candies

Non-crystalline or amorphous candies are much simpler to make. The sugar solution must simply contain sufficient interfering agents or cook to a high enough temperature to prevent recrystallization. In taffies, butterscotch, brittles and caramels, invert sugar in the form of molasses, acid that will produce invert sugar, or corn syrup are added to the mixture to prevent the formation of crystals in the candy. These

candies are cooked to a higher temperature than crystallized candies so as to reduce the water content to 2% or less, which also prevents recrystallization.

Non-crystalline candy can be cooked by dry heat as well as moist heat. Some peanut brittles, for example, are made by melting dry sugar. The brittle does not recrystallize because lack of water during the cooling period causes it to take the form of a non-crystalline, glassy solid.

Sugar’s ability to recrystallize and to control recrystallization through development of invert sugar provides a delightful variety of textures in candies and confections.

Icings

Sugar’s role in icings are similar to those in candies. Its versatility contributes to the many tempting frostings that may be prepared for cakes. Icings enhance the flavor of baked goods as well as function as a barrier to moisture, extending freshness of the baked good. Sugar is the most important ingredient in icing, providing sweetness, flavor, bulk and structure.

Table 1: Stages of Sugar Syrup in Candy Making

Boiling Point (°F)	Candy	Cold Water Test
230-234	Syrups	Thread: Pulls into a thread but will not form a ball
235-240	Fudge, Fondant	Soft ball: Forms a soft ball that will flatten when removed from water
244-248	Caramel	Firm ball: Forms a firm ball that will not flatten when removed from water
250-266	Nougat, Divinity, Rock	Hard ball: Forms a hard ball that will not flatten when removed from water but is still plastic
270-290	Taffy, Butterscotch	Soft crack: Separates into threads that are not brittle
300-310	Brittle	Hard crack: Separates into threads that are hard and brittle
320		Clear liquid: Sugar liquifies and turns light amber in color
338		Brown liquid: the liquified sugar turns brown in color

NOTE: To do a cold-water test, use a teaspoon to portion a few drops of the concentrated syrup into a small amount of ice water. Use fingers to form a thread or ball.

Sugar In Jellies & Preserves

In jellies, marmalades, jams, and preserves, sugar helps to capture and preserve indefinitely the flavor, aroma, color and qualities of the various fruits. The fruit flavors are concentrated and intensified, resulting in unique texture and pleasing appearance of jellies and preserves.

The Food and Drug Administration has established Standards of Identity (standard recipes) for commercial preserves, jams and jellies. Cookbook recipes use approximately the same ratio of one part fruit to one part sugar. Jellies, jams and preserves differ by the form of the fruit used in the recipes. Transparent jellies are made with fruit juice squeezed or pressed from the whole fruit. While jams and preserves are considered equal by the Standards of Identity, preserves traditionally are made with whole or large pieces of fruit, whereas jams are made with crushed or smaller pieces of fruit. Whether used in preparation of preserves, jams or jellies, sugar plays important roles.

Gelling

Sugar is essential in the gelling process of jams, preserves and jellies to obtain the desired consistency and firmness. This gel-forming process is called gelation, where the fruit juices are enmeshed in a network of fibers. Pectin, a natural component of fruits, has the ability to form this gel only in the presence of sugar and acid. Sugar is essential because it attracts and holds water during the gelling process. In addition, acid must be present in the proper proportions and at an optimum pH between 3.0 and 3.5. Some recipes include lemon juice or citric acid to achieve this proper acidity.

The amount of gel-forming pectin in a fruit varies with the ripeness (less ripe fruit has more pectin) and the variety (apples, cranberries and grapes are considerably richer in pectin than cherries and strawberries). In the case of a fruit too low in pectin, some commercial pectin may be added to produce the gelling, especially in jellies. In recipes that use commercial pectin, the proportions of sugar may be slightly higher or lower than the one part fruit to one part sugar ratio.

Volume Equivalents

3 teaspoons = 1 tablespoon
4 tablespoons = 1/4 cup
5 1/3 tablespoons = 1/3 cup
8 tablespoons = 1/2 cup or 4 ounces
16 tablespoons = 1 cup or 8 ounces

Approximate Weight Equivalents

1 pound granulated sugar = 2 to 2 1/4 cups
1 pound confectioners sugar = 4 to 4 1/2 cups
1 pound brown sugar = 2 1/4 to 2 1/2 cups
(packed)
1 cup honey = 1 to 1 1/4 cups sugar plus 1/4 cup liquid

Preserving

Sugar prevents spoilage of jams, jellies, and preserves after the jar is opened. Properly prepared and packaged preserves and jellies are free from bacteria and yeast cells until the lid is opened and exposed to air. Once the jar is opened, sugar incapacitates any microorganisms by its ability to attract water. This is accomplished through osmosis (the process whereby water will flow from a weaker solution to a more concentrated solution when they are separated by a semi-permeable membrane). In the case of jellies and preserves, the water is withdrawn from these microorganisms toward the concentrated sugar syrup. The microorganisms become dehydrated and incapacitated, and are unable to multiply and bring about food spoilage. In jellies, jams and preserves, a concentrated sugar solution of at least 65% is necessary to perform this function. Since the sugar content naturally present in fruits and their juices is less than 65%, it is essential to add sugar to raise it to this concentration in jellies and preserves.

Color Retention

Sugar helps retain the color of the fruit through its capacity to attract and hold water. Sugar absorbs water more readily than other components, such as fruit, in preserves and jellies. Thus, sugar prevents the fruit from absorbing water which would cause its color to fade through dilution.

Commercial Products

Sugar is the main sweetener in home-made jellies and jams. The preserve and jelly industry uses a number of alternate sweeteners, in addition to sugar, for economic and marketing reasons. High fructose corn syrup (HFCS) is used in many commercial jellies and is comparable in sweetness to sugar. The major disadvantage of HFCS is that it is a liquid and may contain as much as 29 percent water. The extra water maybe evaporated in the final stage of production, a process that causes part of the volatile fruit flavors to be lost.

Other products use concentrated fruit juices as their sweetening ingredient. These products have the same caloric content as sugar sweetened products, since concentrated fruit juices are similar in composition to sugar syrups.



Sugar In Canning & Freezing

Sugar is used in the canning and freezing of fruits to improve flavor and texture, and to preserve natural color and shape. Through osmosis, sugar replaces some of the water in the fruit. This natural process preserves the fruit's inherent color, texture and shape by preventing the fruit's remaining water from leaving its cellular structures. As a result, the fruit's texture is protected against weakening during freezing and canning. In addition, sugar, upon entering the cells, also helps minimize oxidation, and prevents the fruit's firm texture from becoming mushy. Sugar both enhances flavor and preserves the color of the fruit which makes it more appealing to eat.

Canning Fruit

Fruit to be canned is placed in a syrup of greater sugar concentration than that of the fruit itself. The dissolved sugar in the syrup diffuses into the fruit (osmosis) and improves its flavor. As the fruit cooks in the syrup, the cell wall becomes more permeable, the fruit texture grows more tender, and the retention of the sugar renders the fruit plump and attractive. Whole fruits with tough skins, such as Kieffer pears and kumquats, are impermeable to the sugar syrup unless precooked or unless the skins are pierced.



Freezing Fruit

Fruits to be frozen benefit from either a dry sugar pack or from freezing in a sugar syrup. For a dry sugar pack, the fruit is gently mixed with sugar, in a given proportion, so that each piece is coated. The choice of dry or syrup pack generally depends on the use to which the frozen fruit is to be put. Fruits packed in syrup are usually chosen for dessert, while fruits packed in dry sugar are preferred for cooking purposes.

Some fruits such as blueberries, cranberries, raspberries, rhubarb may be frozen in a dry pack without sugar. However, these and all other fruits benefit greatly from the sugar pack regardless of the type used (dry or syrup).

Sugar helps protect the surfaces of frozen fresh fruit from contact with air which produces enzymatic browning—discoloration due to oxidation. In some cases, such as with peaches, nectarines and apricots frozen in a syrup pack, ascorbic acid is also added to help prevent darkening. The presence of sugar also lessens flavor change by retarding possible fermentation. In addition, texture, fresh fruit aroma and normal size are retained upon thawing when sugar is used in freezing fruit.

Sugar In Frozen Desserts

Sugar functions to enhance the creamy texture and pleasing taste of frozen desserts such as ice cream, ice milk, frozen custard and sherbet.

Freezing Point

Frozen desserts are made by freezing a liquid mixture of sugar with cream, milk, fruit juices or purees. In the liquid mixture, the dissolved sugar's ability to attract and hold water diminishes the water available for water crystallization during freezing. As a result, the freezing point of the liquid mixture is lowered. Since less "free" water is available, the ice crystals that form tend to be smaller.

As part of the liquid mixture begins to freeze, the sugar in the remaining unfrozen solution becomes more concentrated, further lowering the freezing point of the remaining unfrozen solution. Therefore, a temperature much lower than the freezing point of the liquid mixture is used to ensure rapid, consistent cooling. The combination of a lower freezing point provided by the dissolved sugar and a colder than freezing temperature environment produces a frozen product with tiny ice crystals. Tiny ice crystals give the frozen dessert its smooth, creamy texture. Large crystals are undesirable because they impart a "gritty" or "sandy" texture in the frozen dessert. Closely following the recipe procedures during hardening and storing of frozen desserts are the final steps to achieving a high quality frozen dessert.

Though other sweeteners can be used for frozen desserts, sugar is preferable because of its functional characteristics. A major disadvantage of substituting high fructose corn syrup (HFCS) is that it lowers the freezing point twice as much as sugar does, producing an icy texture.



Flavors and Mouthfeel

In frozen desserts, sugar also functions to balance flavors and mouthfeel. Since low temperatures tend to numb the taste buds, sugar acts to enhance flavors, thereby eliminating the need for additional flavor ingredients. Sugar also increases the viscosity (thickness) of frozen desserts, which helps impart a thick, creamy mouthfeel. It provides a clean, sweet taste preferable to the "syrupy" taste produced by corn-derived sweeteners. Corn-derived sweeteners also may mask or alter the flavor of other ingredients added to the frozen dessert. In frozen desserts flavored with added fruit, sugar also acts to balance their acidity.

About 16% sugar by weight is recommended for ice cream. Somewhat higher proportions of sugar are used for lower fat desserts, such as ice milk and sherbet, in order to counterbalance the reduced amount of butterfat. When cream is replaced with lower fat ingredients, such as milk or fruit puree, additional sugar is necessary to ensure a smooth, creamy mouthfeel and balanced flavor.

Sugar In Non-sweet Foods

Caramelization of Meats and Vegetables

Sugar enhances browning and flavor development in sautéed vegetables and meats. Caramelization is the process of cooking sugar to the browning stage. During sautéing, sugar helps brown vegetables and enhances their flavor. Sugar also increases the browning of meats, adding a depth of flavor to stew dishes featuring well-browned meat. Add sugar judiciously to sautéed vegetables and meats. Sucrose begins to brown at 338°F. Most foods will brown only on the outside and only through dry-heat methods (sautéing, roasting, grilling or broiling), which reach the high temperatures at which browning occurs. Foods cooked with moist-heat methods alone, as in some poached and braised recipes, do not become hot enough to brown or caramelize.

Barbecue Sauces

Sugar enhances or brings out the flavors that are already in the barbecue sauce. It enhances the tomato, vinegar or lime flavors that may be present in the sauces. Through its ability to caramelize, sugar also contributes to the browning process, which an artificial sweetener can't do.

Sugar has an optimum taste between 100°F and 125°F and tastes better when heated. Because sugar can withstand high temperatures, it is a good choice for barbecue sauces. Additionally, sugar provides superior taste, consistency and performance over other sweeteners in barbecue sauce applications.

Glazing Vegetables

Sugar creates a shiny, savory glaze on cooked vegetables. Glazing refers to cooking vegetables in a small amount of liquid (stock or water, usually with a little sugar and butter) over medium-low heat until the vegetables release juices, then reducing the liquid until it's thick. Sugar tenderizes the vegetables and helps create a shiny, savory glaze.



Sauces and Salad Dressings

Sugar balances sour, bitter and spicy components in hot and cold applications. Sour sensations come from acids such as lemon or lime juice, tomato products and vinegars. Salty sensations come from sodium chloride and other salts. Bitterness is a reaction to alkaloids such as quinine and caffeine. The body is more tolerant of sweet sensations than sour, bitter or salty ones. The addition of sweetness to sour, salty and bitter foods can make them taste better. That's why sugar is added to acidic dressings, salty brine solutions and coffee.

The interaction of taste and temperature produces various flavor sensations. Sucrose has an optimum taste between 100° F and 125° F. Fructose, the major component of honey, exhibits poor sweetening ability when hot, yet tastes very sweet in cold preparations.

Brining

Sugar softens and balances the flavor of delicate fish, poultry or meat in brine solutions. A brine is a very salty marinade that tenderizes foods, adds flavor and moisture, and reduces cooking time. Most brines have approximately 20% salinity, or 1 pound salt per gallon water. Brines often contain sugar, herbs and spices. Other additions can include wine, beer, fruit juices and vinegar.

The chemistry behind brining is simple: Meat naturally contains salt water. By immersing meat in a liquid with a higher concentration of salt, the liquid (and its flavorings) is absorbed into the meat. The sugar in a brine also draws out some

blood remaining in raw fish, beef and poultry. The longer a food is brined, the stronger the flavor will be. Poultry and seafood do not need to be brined as long as denser meats. After brining, the meat (or fish or poultry) contains extra moisture which will remain after cooking, producing a moist finished product.

Salt Curing

Sugar adds flavor to salt-cured raw foods. Salt curing is the process of surrounding a food with salt or a mixture of salt, sugar, curing salt, herbs and spices. Salt curing dehydrates the raw food, inhibits the growth of bacteria and adds flavor. It preserves meats such as ham and makes it safe to consume raw. Sugar adds a sweet flavor to cured foods and balances the salt flavor. Most often used with pork or fish, salt curing is NOT a quick procedure and must be carefully managed to meet food safety regulations.

Dry Rubs

Sugar enhances flavor, browning, and crusting of meat, fish, and poultry, and contributes to osmosis during the smoking step in the barbecue process. A dry rub or dry marinade is a mixture of sugar (often white and brown), salt, and crushed herbs or spices that is applied to a protein's surface prior to cooking. Other additions such as minced garlic, onion and grated citrus zest can be added to form a paste which will adhere well to meat, fish or poultry. Unlike a wet marinade, a dry rub remains on the food during cooking.

A dry rub is an important flavor-building component of smoking, which is the first step in traditional barbecue. Through osmosis, the salt in the rub draws moisture from the surface of the meat. The dry surface, combined with the savory rub, create a crust that adds flavor, texture and eye-appeal to the cooked meat. Sugar contributes to osmosis and so to the creation of the crust as well as caramelization and flavor enhancement.

Dry rubs are recommended over marinating for large pieces of meat such as briskets and pork butts because a dry rub will not sear or burn on the grill the way marinades can during the long, slow cooking required for these large cuts. Marinades primarily flavor the surface of meats, and that's sufficient for small cuts, which have large surface areas; but large meat cuts, with their smaller surface-to-interior ratios, benefit from the deeper flavor penetration of rubs.

Pickling

Sugar balances acid flavor and helps maintain the texture of pickled vegetables. Pickling means preserving food in a brine or vinegar solution. It is one of the oldest methods of food preservation, perhaps starting with the Chinese in the 3rd century.

Pickled vegetables can be brined (fermented), which involves curing at room temperature for several weeks. Or pickles can be "quick" (unfermented), made in a day or two by adding vinegar to the brine solution. It's critical to add enough vinegar to prevent bacterial growth.

Sugar is an important component in pickling. Besides balancing the flavor of the vinegar, sugar helps strengthen vegetable cell structures and makes vegetable fibers firmer. Either brown or white sugar can be used. Brown sugar produces a darker brine.

Bread Coatings

Sugar speeds browning in bread coatings. A combination of sugar and protein in a coating spurs browning. However, sugar must be carefully incorporated into a breading formula. Too much sugar can cause an onion ring coating, for example, to become overly brown before the onion has cooked.



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