



Property Risk Consulting Guidelines

XL Risk Consulting

A Publication of AXA XL Risk Consulting

PRC.17.23.2.6

SUGAR PROCESSING

INTRODUCTION

Sugar cane was probably domesticated in New Guinea around 8000 B.C. Sugar was first made from cane juice in northern India sometime between the 7th and 4th centuries B.C. By a similar process, sugar was first made from sugar beets in Ireland in 1925. Today, modern machinery performs this same process.

The two primary sources of sugar remain sugar cane and sugar beets. About two-thirds of the world's sugar is now made from sugar cane, the rest is made from sugar beets.

The crops for making sugar are available only after each annual harvest. Sugar cane must be processed soon after harvesting, or bacterial action will affect sugar quality. Keeping process equipment running is critical. Harvested beets can be stored before processing without affecting sugar quality.

The sugar processing industry uses a distinct and extensive terminology. PRC.17.23.2.6.A provides a glossary of terms pertaining to making sugar.

PROCESSES AND HAZARDS

Many of the steps in making sugar from cane are similar to steps in making sugar from beets, but the processes have some differences. The following sections describe these processes in turn.

Cane Sugar Processing

Cane sugar is processed in two major steps: producing raw sugar and refining it. Although both steps can be done in the same facility, the usual arrangement is for the sugar mill to produce the raw sugar and ship it to the sugar refinery. More recently, a trend has begun to build facilities that can both produce and refine the raw sugar.

The processes in the mill and refinery are very similar. However, the sugar mill usually operates only right after the cane harvest. The refinery can store raw sugar and operate year round.

Cane Sugar Mills

Cane sugar mills process cane juice into a material called raw sugar. Raw sugar can then be stored in piles until needed by the refineries. (See Figure 1.)

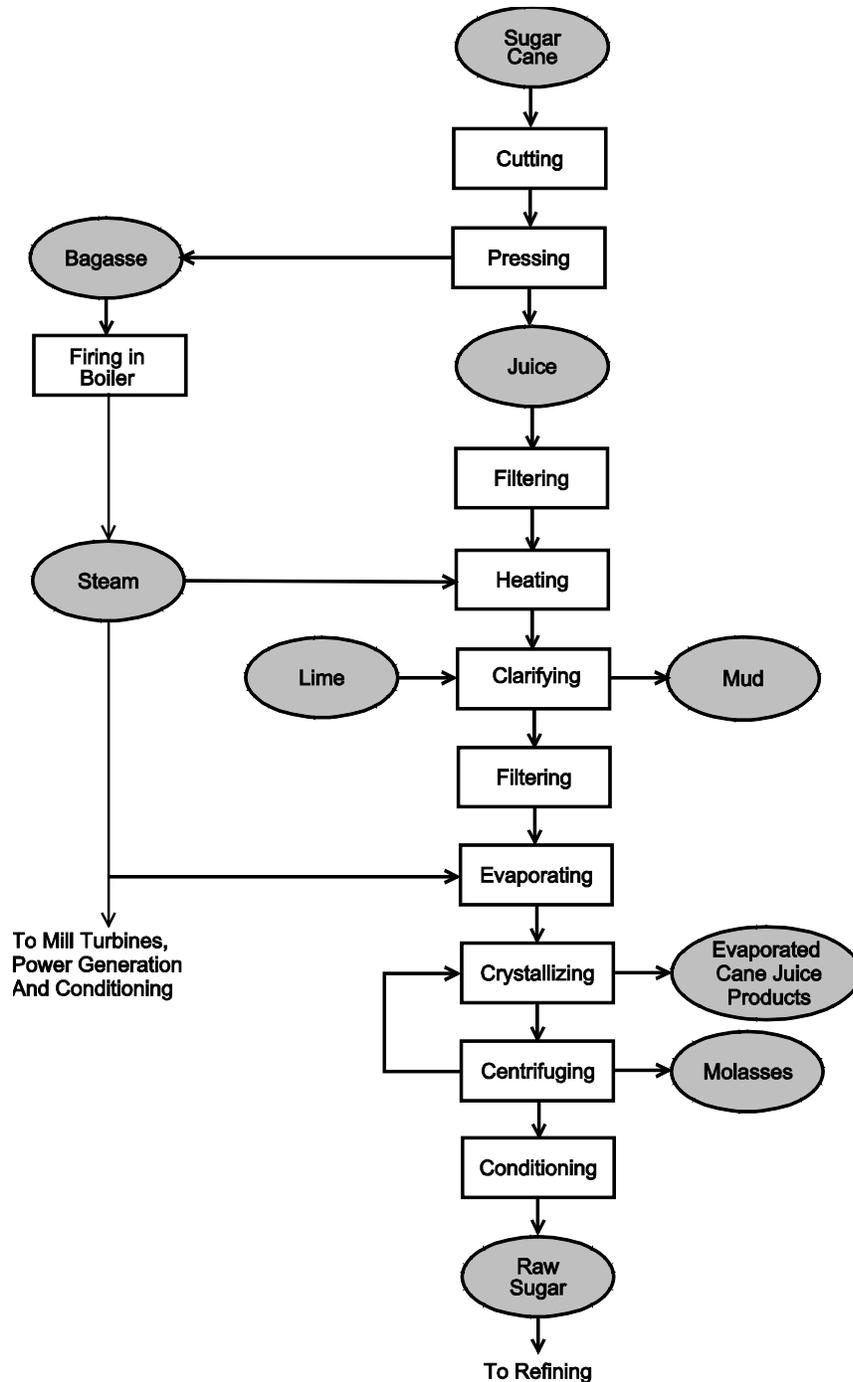


Figure 1. Flow Chart For Making Raw Cane Sugar.

Cutting And Pressing

Sugar cane is transported by rail or truck, and is unloaded onto a conveyor belt. Rotating cane knives cut the cane into smaller pieces, called billets. A series of turbine-driven presses, also called mills, tandems or stands, then squeeze out the juice. This operation is also known as grinding. The primary hazard at this point is breakdown of rotating equipment.

The spent cane, called bagasse, is sent to storage piles outside the mill. Many mills use bagasse as fuel for the boilers, some sell it as animal feed. Boilers provide the steam to heat process equipment, to drive mill turbines and to generate electric power. The hazards here are from rupture of steam

pressure vessels and breakdown of rotating power generation equipment. The hydraulic and lubricating oils used in power generating equipment also present a fire hazard.

Clarifying

The cane juice is filtered and heated. Lime is added, and impurities fall to the bottom of the clarifying vessel as a precipitate, or mud. The clarified juice is then filtered again. This part of the process presents little hazard.

Crystallizing

Clarified juice is sent to steam-heated evaporators. In the evaporators, water is boiled from the juice under vacuum. Then the juice is sent to crystallizers to cool under vacuum. The rate of cooling must be closely controlled. This leaves a mixture of sugar crystals and molasses called massecuite.

The steam heating system, the evaporators and the crystallizers are pressure vessels subject to rupture.

Centrifuging

Molasses is removed from the massecuite by rinsing the sugar crystals in centrifuges. Some sugar mills call these centrifugals. The molasses can be sold for animal feed, or it can be further processed for human consumption. The raw sugar is sent back through the crystallizing and centrifuging processes two or three more times. When finished, the raw sugar is sent to the refinery.

Centrifuges can suffer mechanical breakdown typical of rotating equipment.

Conditioning

Some grades of raw sugar are conditioned, or dehumidified, to reduce clumping. Conditioning is usually done in steam-heated fluidized bed dryers. The hazards include fuel fired equipment and baghouses.

Cane Sugar Refineries

Cane sugar refineries refine the raw sugar from the cane mill. Refined sugar is the common white table sugar consumers buy in grocery stores, or it may also be liquid sugar as used in beverages. Many steps are required to obtain the purity required of this product. (See Figure 2.)

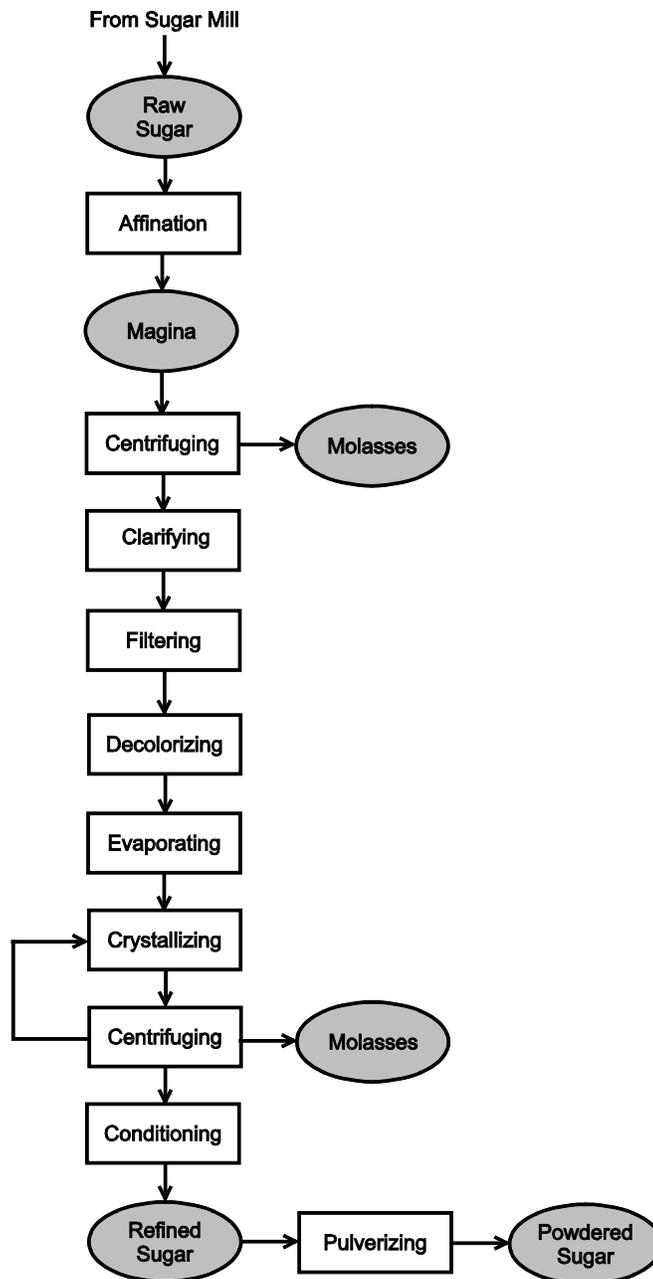


Figure 2. Flow Chart For Refining Cane Sugar.

Affination

Raw sugar is mixed with a heated syrup solution in a vessel called a mingler. The mixing loosens impurities on the surface of the sugar crystals. Using syrup instead of plain water permits loosening the impurities from the surface of the crystals without dissolving them. The solution of heated syrup and crystals leaving the affination process is called magma.

The primary hazards of this part of the process are those associated with the heating system.

Centrifuging

The magma is centrifuged to remove more molasses. At this point in the process, the sugar is called affined sugar. As in the sugar mill, these centrifuges can suffer mechanical breakdown typical of rotating equipment.

Clarifying

The magma is clarified in three or more steps. Phosphoric acid is added to make suspended solids float to the top, where they can be skimmed off. This part of the process is called phosphatation.

Next, lime and carbon dioxide are added to help precipitate more dissolved solids. Most refineries call this step carbonatation, but some call it carbonation. The final clarification step is filtering. This part of the process presents little hazard.

Decolorizing

Remaining molecules (primarily amino acids) that give the sugar a yellowish color are removed with bone char, activated carbon, ion exchange resins, or a combination of these materials. This part of the process also presents little hazard.

Activated carbon is usually in the form of charcoal. Spent charcoal is reactivated in a gas- or oil-fired regeneration furnace. The hazards of this part of the process include the fuel-fired equipment and the potential for accumulation of charcoal dust.

Crystallizing

Decolorized sugar solution is sent to steam-heated evaporators. In the evaporators, water is boiled from the solution under vacuum. Then the juice is sent to crystallizers to cool under vacuum. This process is very similar to the crystallization process used in the raw sugar mill.

Centrifuging

The sugar is centrifuged again, then it is sent back through crystallizing and centrifuging two or three more times. The sugar obtained from the final centrifuging process is considered refined sugar. This step is similar to the centrifuging step in the sugar mill.

Conditioning

Sugar is conditioned by drying it in a steam-heated, rotating drum granulator for approximately two to four days. Some refined sugar is conditioned in fluidized bed dryers like the ones sometimes used for drying raw sugar. Conditioning keeps the sugar from clumping during shipping and storage. The hazards in this step are those associated with fuel fired equipment and baghouses.

Pulverizing

If the finished product is to be powdered sugar (also called confectioners' sugar), the crystals are pulverized to achieve the desired particle size and consistency. This process generates very fine sugar dust, which can present an explosion hazard.

Beet Sugar Processing

Beet sugar is made by sending several intermediate sugar solutions through some of the previous steps in one major process. Therefore, beet sugar is usually produced in one facility. (See Figure 3.)

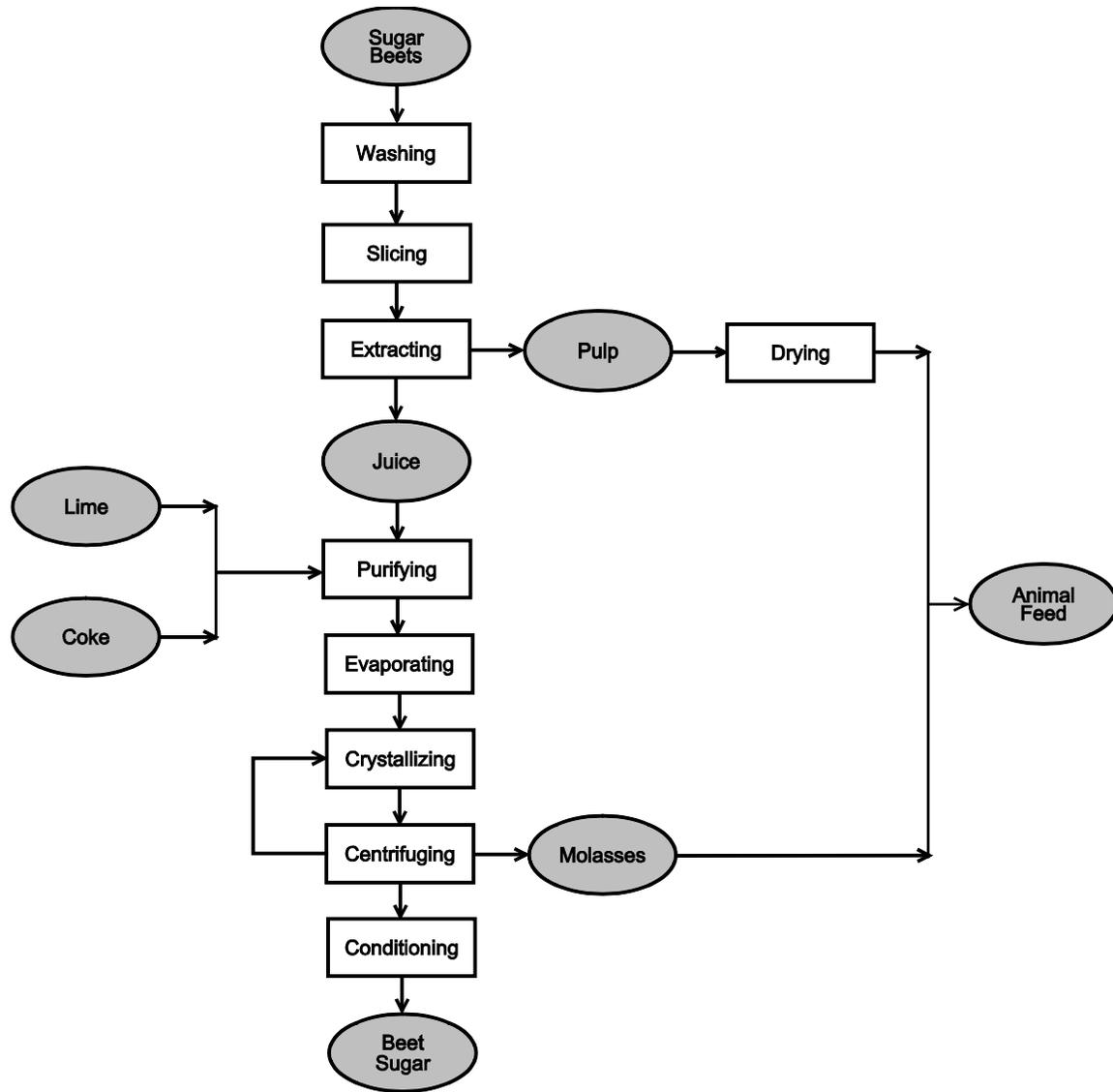


Figure 3. Flow Chart For Making Beet Sugar.

Extracting

Beets are received from the fields and stored on the ground, in sheds or in silos. They are then washed, thinly sliced, and passed through hot water diffusers to extract the juice. Spent beet pulp is usually mixed with molasses. The mixture is then dried and sold as animal feed.

The hazards of extracting juice include those associated with the slicers and water heaters.

Purifying

The beet juice is clarified in three or more steps. Lime and carbon dioxide are added to precipitate dissolved solids. Beet sugar facilities call this step carbonation.

After carbonation, the sludge (mud) is separated from the juice. Then, sulfur dioxide is added to prevent color-forming reactions. This step is called sulfitation.

This part of the process presents little hazard.

Crystallizing

Beet sugar is crystallized in what is called a three-boiling scheme. Intermediate and final sugar solutions are fed back to the previous boiling vessels, to enable white sugar to crystallize in the first vessel.

The hazards of this part of the process are those associated with the steam-heated boiling vessels.

Centrifuging

The sugar is centrifuged, then it is sent back through crystallizing and centrifuging two or three more times. This step is similar to the last centrifuging step in the cane sugar refinery. The centrifuges are subject to mechanical breakdown.

Conditioning

The moisture content of the sugar crystals is reduced by heating the sugar in a rotating drum granulator for approximately 48 hours. This conditioning step is similar to the one used for cane sugar.

Refined Sugar Storage

Some refineries store finished sugar, which can be in either granulated or liquid form. Granulated sugar can be packaged in individual-serving envelopes, small boxes or larger bags. Liquid sugar is stored in drums or other containers.

LOSS PREVENTION AND CONTROL

Management Programs

Implement effective management programs for loss prevention and control in all the areas discussed in *OVERVIEW*. Tailor these programs to sugar processing operations, placing special emphasis on the following areas:

Housekeeping

Keep all processing and storage areas free of accumulations of sugar and sugar dust. Keep all process areas and process equipment free of accumulations of residue from hydraulic and lubricating oils. Do not store combustible packaging materials in processing areas.

Maintenance

Test lubricating oil in accordance with PRC.6.0.8.3 and PRC.6.1.1.0.5. Inspect steam turbines in accordance with PRC.6.1.1.0.2. Maintain and test gear sets in accordance with PRC.6.0.3.1.

Test relief devices in accordance with PRC.7.0.5.2. Inspect and maintain boilers and pressure vessels in accordance with PRC.7.1.0.1, PRC.7.1.0.2 and PRC.7.1.0.5.

Process Hazard Evaluation

Evaluate the consequences of breakdown of harvesting equipment. Provide spares for critical processing equipment, including cane knives, grinding rolls, gears and bearings.

Evaluate the consequences of spills, such as from liquid sugar or from hydraulic oil. Lay out and protect processes to minimize the consequences of such spills. Include wiring and control equipment in this evaluation.

Evaluate the susceptibility to contamination of product in all parts of the process. Incorporate the results of this evaluation into the facility's plans for making up lost production.

Employee Training

Train employees in safe operation of all process equipment. Teach them how the process protective systems work, and have them stop operations when protective equipment is not working properly.

Construction

Segregate bulk storage of raw sugar into areas not exceeding 25,000 tons (22,700 t) of sugar. Cut these areas off from each other and from all other areas with 3 h rated fire walls and automatic closing 3 h rated fire doors.

Detach buildings storing finished sugar or cut them off from all other areas with 3 h rated fire walls and automatic closing 3 h rated fire doors.

Equip refined sugar storage bins and silos with deflagration venting in accordance with NFPA 68.

Detach buildings with operations involving powdered sugar. Provide deflagration venting for buildings and equipment in accordance with NFPA 68.

Locate boilers and electric power generating facilities in detached, noncombustible buildings. Cut off individual boilers and turbine generators from one another with 3 h rated fire walls and automatic closing 3 h rated fire doors.

Interior Protection

Install sprinklers in process areas in accordance with NFPA 13 and PRC.12.1.1.0. Design the sprinkler systems for Ordinary Hazard, Group 2 occupancies.

Protect warehouses with bulk storage of raw sugar, and with silo and bin storage of refined sugar, in accordance with PRC.10.2.10. Design sprinklers for bagged sugar storage in accordance with NFPA 13 and PRC.12.1.1.0, as appropriate for the storage arrangement. Consider refined sugar a Class III commodity.

Install sprinklers in electric generating facilities in accordance with NFPA 13 and PRC.12.1.1.0. Design the sprinkler systems in accordance with NFPA 850 and PRC.17.12.1.

Use electrical equipment suitable for Class 2, Group G classified locations in all areas handling refined sugar. Protect against dust explosions in accordance with NFPA 61.

Protection Of Equipment

Protect fossil fuel and bagasse fired boilers and pressure vessels in accordance with NFPA 85 and PRC.4.1.1. Equip feeds to pulverizers with magnets and screens to remove tramp metal. Protect and maintain all boilers in accordance with PRC.7.0.5.0, PRC.7.0.5.1 and PRC.7.1.0.6.

Install automatic fire suppression systems in baghouses. When bags are nested too tightly to install sprinklers, use a gaseous extinguishing or steam flooding system.

Provide appropriate means of vibration monitoring for rotating equipment as described in PRC.6.0.8.1.0 and PRC.6.0.8.1.1. Protect steam turbines in accordance with PRC.6.1.1.0.3 and PRC.6.1.1.0.4. Protect power generating equipment in accordance with NFPA 850, PRC.17.12 and PRC.17.12.1.

Protect belt conveyors in accordance with PRC.9.3.1.

SUGAR GLOSSARY

Affination - Mixing the raw sugar in a heated syrup solution to loosen impurities on the surface of the sugar crystals. Sometimes called mingling.

Affined Sugar - (See Sugar: Sucrose Products)

Affining - (See Affination)

Bagasse - The part of the sugar cane plant left after pressing out the juice.

Billets - The short pieces of cane cut by the cane knives.

Blackstrap Molasses - The thick, dark molasses that is the final liquid extracted after reworking the sugar crystals.

Brown Sugar - (See Sugar: Sucrose Products)

Cachaza - Waste from the evaporators, usually returned to the cane fields for fertilizer.

Cake - (See Mud)

Carbonatation - Adding lime and carbon dioxide to clarify the cane sugar solution in the refinery. This step is called carbonation in Europe.

Carbonation - Using lime and carbon dioxide to purify beet sugar solution. Also see Carbonatation.

Confectioners Sugar - (See Sugar: Sucrose Products - Powdered Sugar)

Cossettes - The thin, diamond-shaped slices of beet pulp that are cut to enable extracting the juice.

Demerara - (See Evaporated Cane Juice Products)

Dextran - A troublesome gum formed by microorganisms in the cane juice when the cane is not processed soon enough after harvesting.

Dextrin - A roasted starch, varying in color from white to light yellow, used to manufacture pastes, gums and adhesives.

Dextro-Glucose - (See Sugar: Types - Glucose)

Dextrose - (See Sugar: Types - Glucose)

Disaccharide - (See Sugar: Types)

Evaporated Cane Juice - The free-flowing sugar obtained from the first crystallization of cane juice.

Evaporated Cane Juice Products

Demerara - A coarse-grained sugar with distinct molasses flavor.

Golden Bakers - A very fine, soft and light-colored brown sugar.

Golden Granulated - A coarse-grained sugar with mild molasses flavor. This sugar is used like demerara, and is sometimes called turbinado.

Milled Cane - A fine-grained, golden-colored sugar with delicate molasses flavor.

Muscovado - A fine-grained sugar with heavy molasses flavor.

Panela - (See Rapedura)

Rapedura - A dark brown wax-like sugar made from boiled cane juice. Also called panela.

- Turbinado** - (See Golden Granulated)
- Extra Fine Granulated Sugar** - (See Sugar: Sucrose Products)
- Fructose** - (See Sugar: Types)
- Galactose** - (See Sugar: Types)
- Glucose** - (See Sugar: Types)
- Golden Bakers** - (See Evaporated Cane Juice Products)
- Golden Granulated** - (See Evaporated Cane Juice Products)
- Granulated Sugar** - (See Sugar: Sucrose Products)
- Integrated Sugar Mill** - A sugar mill that produces raw sugar from cane and refines the raw sugar into table sugar.
- Invert Sugar** - (See Sugar: Sucrose Products)
- Lactose** - (See Sugar: Types)
- Levulose** - (See Sugar: Types - Fructose)
- Liquid Sugar** - (See Sugar: Sucrose Products)
- Magma** - The mixture left after washing the molasses film off dissolved raw sugar crystals.
- Maltose** - (See Sugar: Types)
- Massecuite** - The mixture of molasses syrup and sugar crystals left after crystallizing the sugar.
- Milled Cane** - (See Evaporated Cane Juice Products)
- Mingler** - Vessel for affining sugar.
- Mingling** - (See Affination)
- Molasses** - The thick, brown, sticky byproduct of both sugar milling and sugar refining.
- Monosaccharide** - (See Sugar: Types)
- Mud** - The precipitate left after clarifying sugar juice.
- Muscovado** - (See Evaporated Cane Juice Products)
- Panela** - (See Evaporated Cane Juice Products - Rapedura)
- Phosphatation** - Adding phosphoric acid to float suspended solids from cane sugar solution in a refinery.
- Powdered Sugar** - (See Sugar: Sucrose Products)
- Rapedura** - (See Evaporated Cane Juice Products)
- Ratoon** - Sprouts from the mature cane plant used to start another crop of cane.
- Raw Sugar** - (See Sugar: Sucrose Products)
- Refined Sugar** - (See Sugar: Sucrose Products)
- Saccharide** - (See Sugar: Types)
- Simple Sugar** - (See Sugar: Types)
- Sludge** - (See Mud)
- Sucrose** - (See Sugar: Types)
- Sugar** - A family of sweet-tasting carbohydrates based on the saccharide unit. Sugars can contain one, two or more saccharide units. (See Sugar: Types - Saccharide)

Sugar: Sucrose Products (also see Evaporated Cane Juice Products)

Affined Sugar - The sugar crystals that remain after centrifuging and washing raw sugar with warm water but before further clarifying.

Brown Sugar - Refined white sugar sprayed and blended with molasses.

Confectioners Sugar - (See Powdered Sugar)

Extra Fine Granulated (EFG) Sugar - The most common granulated sugar in the U.S. It is 99.9% sucrose.

Granulated Sugar - Sugar graded according to the size of the granules.

Invert Sugar - Sucrose that has broken down into its component molecules of glucose and fructose.

Liquid Sugar - Either melted, refined white sugar or decolorized high-grade refinery syrup. Liquid sugar is most often used to sweeten soft drinks and other beverages.

Powdered Sugar - Granulated sugar that has been pulverized in a powder mill. Powdered sugar is used for making fancy confections.

Raw Sugar - Evaporated cane juice that has been centrifuged to remove a large part of the molasses.

Refined Sugar - Raw sugar that has been further processed into common white table sugar or powdered sugar.

Sugar: Types

Dextro-Glucose - (See Glucose)

Dextrose - (See Glucose)

Disaccharide - A sugar containing two saccharide units. (See Saccharide). The most common disaccharides are lactose, maltose and sucrose.

Fructose - The most common fruit sugar. Fructose is a left-handed isomer; the comparable right-handed isomer is glucose. Fructose is also called levulose.

Galactose - A simple sugar naturally occurring in lactose. Also called milk sugar.

Glucose - The simple sugar burned by the body to release energy. All sugars, including sucrose, are eventually broken down by the body into glucose. Glucose is a right-handed isomer; the comparable left-handed isomer is fructose. Glucose is also called dextro-glucose, or dextrose.

In industry, the term glucose often refers to a mixture of dextrose, maltose and dextrans.

Lactose - The natural sugar occurring in milk. It is chemically similar to maltose.

Levulose - (See Fructose)

Maltose - A sugar molecule containing two glucose molecules. Also called malt sugar.

Monosaccharide - A sugar containing one saccharide unit, also called a simple sugar. (See Saccharide). The most common monosaccharides are fructose, glucose and galactose.

Saccharide - The $C_6H_{10}O_5$ base unit of all sugars.

Simple Sugar - A sugar whose molecule contains one saccharide unit. Also called a monosaccharide.

Sucrose - The most common plant sugar, which refineries process into white table sugar. A sucrose molecule contains one molecule of glucose and one molecule of fructose. Though most concentrated in cane and beets, sucrose is also found in trees, flowers and honey.

Sugar-Cane Wax - A dark green to brown wax produced in solvent extraction of cane juice. This wax is used in pigments, carbon paper and wax paper.

Sugar Mill - A facility that produces raw sugar from sugar cane.

Sugar Processing Facility - A facility that makes finished sugar from beets.

Sugar Refinery - A facility that refines raw sugar into common table sugar.

Sulfitation - Adding sulfur dioxide to prevent color-forming reactions. This is usual in making beet sugar. Cane sugar can also be treated this way, but this is not commonly done in the U.S.

Turbinado - (See Evaporated Cane Juice Products - Golden Granulated)