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COOPERATIVE EXTENSION SERVICE
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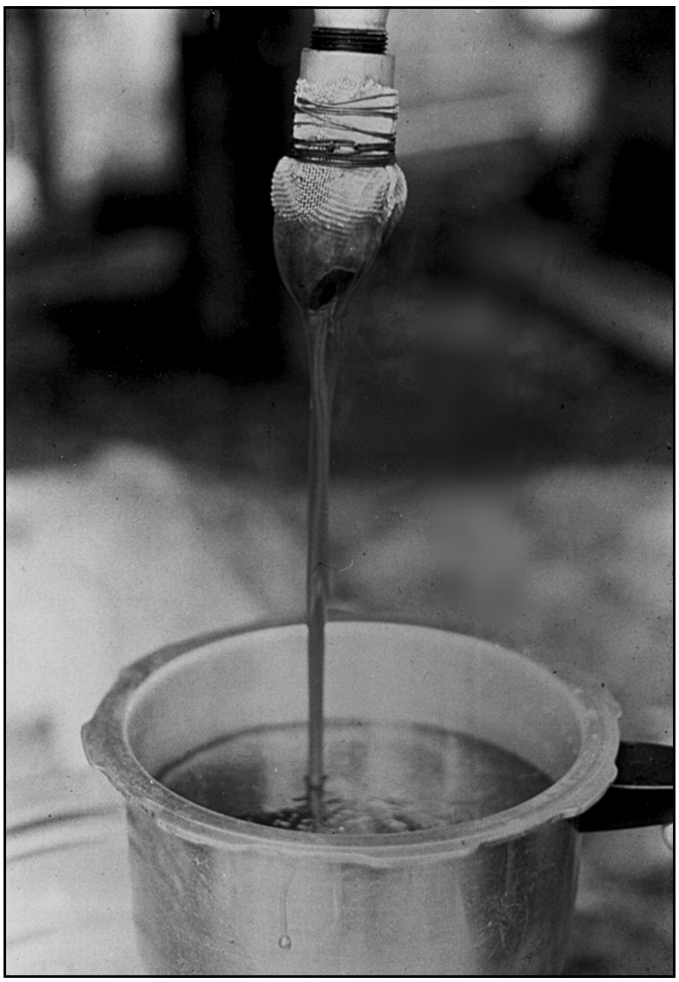
PROCESSING SWEET SORGHUM FOR SYRUP

*Morris J. Bitzer and Joe D. Fox**
Part Two of Two-Part Series



The finished product

Processing sweet sorghum is the most critical aspect of making a high quality syrup. The yield and quality of sorghum syrup are influenced by the equipment and process used in manufacturing and by the syrup maker's knowledge and skill. However, there are as many ideas and methods of processing as there are producers of sweet sorghum. To improve the overall quality of your sweet sorghum syrup, pay close attention to the cookoff process.

Harvesting the Crop

The last step in producing the crop and the first step in obtaining high quality sorghum syrup is harvesting the crop at the proper stage of maturity. As the crop matures, changes in the composition of the juice and soundness of the stalks influence the syrup quantity and quality. Since the sugar content usually continues to increase as maturity approaches, the best harvest time for most varieties will be before the plants are mature. Judging the right time for harvesting is essential.

Early Deheading

Early deheading helps to increase the sugar level in the juice earlier in the fall and reduces the chances of lodging before harvest. The proper stage to dehead is critical as many new branches will form on the top of the sorghum plant and will produce seed. These branches form about 2 weeks after the first head has been removed. The best stage of maturity to start deheading is at the milk stage of the seed. Research shows that the Brix reading (sugar level) will decrease when deheaded after the milk stage and be lower at harvest in those plants not deheaded earlier. This occurred in trials both in Kentucky and Wisconsin. Average Brix levels at harvest when deheaded at the following stages: Bloom-19.4, Early Seed-19.4, Milk Stage-18.4, Soft Dough-16.7 and Hard Dough-14.6. The head should be removed at least below the top node and at least 2 nodes from the top on varieties such as Dale, Della, and M81E.

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A horse-drawn mill without the horse

When to Harvest

When the stalks reach their full size, the entire plant's maturity advances at about the same rate as the seed head's maturity. So you can easily determine how mature the plant is by looking at the seed head. Plants will differ as to when they mature, depending on the variety and on climatic conditions from one year to another.

The best stage for harvesting most varieties is when most of the seeds reach the soft- to hard-dough stage of maturity. The steps in the stages of maturity of the seed are early-flowering, flowering, late-flowering, early-milk, late-milk, soft-dough, hard-dough, and ripe. Seeds are ripe when they are firm and hard and cannot be cut with the thumbnail. Most varieties produce a poorer quality of syrup when harvested too mature, mainly because the juice's starch content increases. Also, crystallization and gelling of the syrup are more likely to occur. Some varieties susceptible to diseases, such as Sugar Drip, may produce a higher quality syrup when harvested in the late-milk stage. Dale makes a higher quality syrup when harvested close to the hard-dough stage.

Another method of determining maturity is to measure the amount of sugar in the juice with a Brix hydrometer or a sugar refractometer. The crop should be harvested when an approximate reading of 15.5° to 16.5° Brix is reached.

How to Harvest

The stalks may be harvested by hand, cut with a mower or binder and picked up, or mechanically cut and squeezed in the field. Very large producers should consider a harvesting system that chops the stalks into 6- to 8-inch sections. When harvesting the stalks, remove the seed head (if not removed earlier) and peduncle (between top node and base of seed head) because they contain less sugar than the rest of the stalk. You may do so ahead of time with a mechanical deheader as described above, by hand shortly after cutting the stalk down, or with a chain saw after the stalks are loaded on a wagon. Seed heads may be saved at this point to use the seed for next year's crop. Store them in a cool, dry location and let them dry. Then thresh and clean the seed some time later. A germination test should be used before planting the seed again.

You can make excellent syrup without stripping off the leaves. However, when leaves are not removed, do not crush the stalks when the leaves and stalks are wet. If leaves are removed, stripping should be done while the stalks are standing. Leaves can be stripped with a narrow paddle, a cane stripper, or the knife used to cut the stalks.

When leaves are not removed, they should be allowed to dry before squeezing the juice from the stalks. A small amount of juice will be carried across by the leaves, but this is more than offset by the reduced labor and time it takes to remove the leaves.

It may be advantageous to delay milling for 3 to 5 days after harvest. The stalks will lose some water, and natural enzymes will invert more of the sucrose, making the syrup less likely to crystallize. Cookoff will be easier and faster. You may dry stalks in the field, but spread them out evenly. Regardless of how mature they are, stalks must be harvested before freezing temperatures because a hard freeze will ruin the juice for syrup making.

The Mill and Juice Extraction

A horizontal 3-roller power mill with crushing capacity to provide enough juice to keep ahead of the evaporation process is desirable. However, vertical mills are adequate for many small operations. To set the mill rollers initially, evenly space the feed roller 3/8-inch from the top roller. The feed roller is not intended to grind the cane but to mash it so that the extraction roller can grind it. The space between the extraction roller and the top roller should be 1/16-inch. The rollers should be tilted so that the front opening is at least 20° below the rear opening to let the juice flow quickly away from the extraction roller. Usually, in small mills the speed of the top (large) roller is 10 to 12 revolutions per minutes (RPM). For large mills, the speed may be adjusted to 6 to 8 RPM.

A typical large mill for squeezing the stalks

The size of the mill or number of mills employed will be determined by the size of the processing plant. Smaller producers (25 acres or less) will need at least one 3-roller mill (horse-drawn or power) with feed rolls from 12 to 18 inches long and 6 to 12 inches in diameter. A large processing operation will need one or more 3-roller power mills with feed rolls up to 24 inches long and 12 inches in diameter. Because the processing season is short (fewer than 60 days) and the amount of syrup produced depends on the quantity of juice extracted, it is imperative to have reliable and efficient milling equipment. Because no commercially available new mills are being made, you may need to buy an old mill and have it regrooved and repaired.

Check the mill to see how much juice it extracts. Under normal conditions, an efficient mill will deliver 45 to 50 pounds of juice from 100 pounds of clean stalks. Weigh 100 pounds of stalks, run them through the mill, catch and weigh the juice. If necessary, tighten the rollers to increase extraction of juice. A mill should be strong enough to apply from 50 to 100 tons of pressure on the stalks.

As a general rule, juice is lost if the crushed stalks contain visible juice and are not broken at the joints as the stalks come from the mill. Many older mills are not capable of being adjusted tightly enough to reach this total amount of extraction without breaking. When adjusting, always tighten rollers down slowly.

Use of Crushed Stalks

Removing the crushed stalks—called bagasse—from the processing area may become a serious problem if you do not plan properly. A conveyor can help remove them some distance from the mill or load them into wagons for disposal. The bagasse can be put in piles on a field and used directly as feed for livestock. Another use for the stalks is to deliver them by conveyor or arrange them in a windrow to be picked up by an ensilage cutter. The ensilage should be blown from the cutter into trucks or wagons and put into an upright or stacked silo. The ensilage produced from the bagasse has a lower feed value than that made from whole sorghum, but with proper supplementation, it can make an excellent roughage for livestock. A sample of this ensilage should be analyzed before feeding to determine its feed value.

The Processing Building

The building where the juice is evaporated into syrup should be a sanitary area suitable for food preparation. The area should be covered and screened to keep out flies, birds, and other animals including pets. The floor should be made of concrete or other impervious material and should be graded to drain so it can be washed with water after the day's operation. A pressurized, approved water source for cleaning and hand washing should be available. Hand-washing facilities, complete with soap and single-service towels, must be available in the processing area. A sanitary toilet should be conveniently located. The general sanitary conditions in and around the processing area should be kept high at all times. For specific Kentucky regulations on the requirements for the processing building and area, contact the Department for Human Resources, Food Control Branch in Frankfort.

Filtering and Settling the Juice

As the raw, pea-green juice runs from the mill, it should be strained through a wire screen into a juice box. This straining removes the larger pieces of suspended matter such as stalk fragments.

The juice should then be run through a pipe or hose to the juice settling tanks where it is strained through a fine mesh screen or fine nylon cloth as it enters the tank (Figure 2). Use 2 or 3 tanks, each big enough to hold the juice from 2 to 3 hours of milling.

Let the juice settle from ½ hour to 3 hours before drawing it off, depending on its quality. Holding it more than 3 to 4 hours without refrigeration or without heating (as described later) may cause it to ferment and spoil. Do not draw it from the bottom of the settling tank, but at least 1 inch above the bottom of the tank so the settled material is not drawn into the evaporator. A separate opening in the bottom of the tank will be necessary for cleaning out the tank after drainoff.

For larger operations, the juice is heated in the settling tanks, enzymes are added, and skimmings are removed before the juice is moved into the evaporator pan. More details about preheating and enzymes are presented later.

The Furnace and Evaporator

Furnace Fuel

Many of the older furnaces in use are still using wood as a heat source. However, as wood becomes scarcer or as new operations are installed, the major source of heat is petroleum fuel. Steam is the most ideal method of heating especially for large operations.

Evaporator Design

Evaporators may be batch (kettles) or continuous flow types. The 12-ft continuous flow evaporator is the most common. Designs, blueprints, and information for constructing the evaporator and furnace are available from county Extension offices (Figures 1 and 1a). A detailed description of several furnaces and evaporator systems in Tennessee was published by Wilhelm and McCarty (1985).

Materials

Juice evaporators are made of galvanized iron, stainless steel, or copper, but the most common type used in Kentucky is made of stainless steel. Copper and stainless steel are preferred over galvanized iron because of efficiency of heat transfer, more years of useful life, and ease of cleaning. However, stainless steel evaporators require a much more

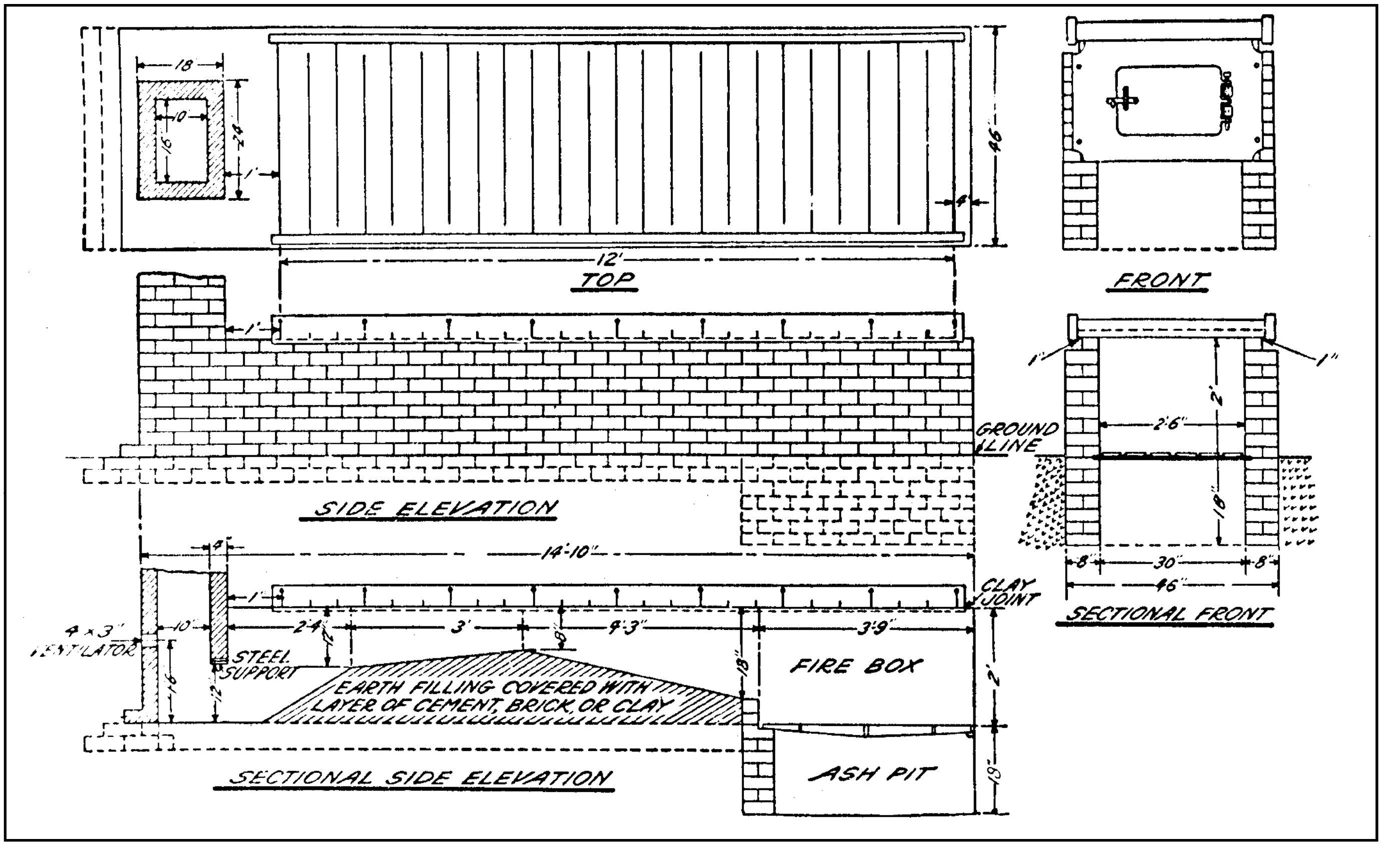

Figure 1. A 12-ft continuous evaporator and furnace. [Freeman et al. USDA Agr. Handbook no. 611]

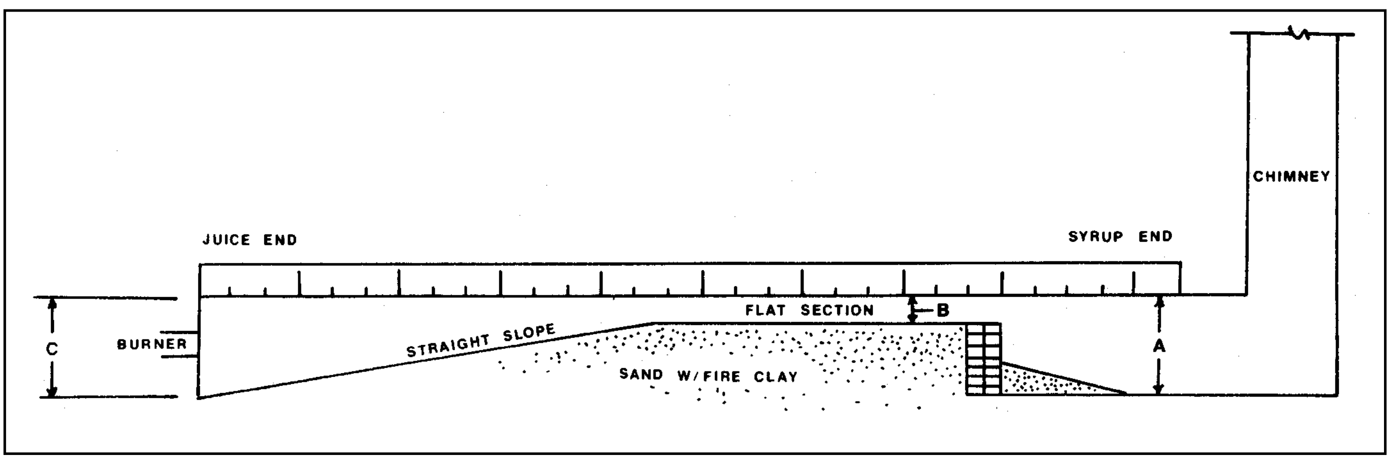

Figure 1a. Typical configuration for propane burner heat source. Dimension A, B, and C are typically 18 inches (0.46 m), 5 inches (0.13 m), and 18 inches (0.46 m) respectively. [Wilhelm and McCarty, 1985, University of Tennessee]

uniform heat source for even heat distribution. Syrup of good color can be made in galvanized iron pans. However, when iron becomes exposed, the syrup is likely to be somewhat dark. Most new pans are made of stainless steel as old galvanized pans are replaced. The ideal furnace and evaporator design uses steam as the heat source with all juice containers and evaporators constructed of stainless steel.

Most pans in Kentucky are the continuous type with dimensions about 3.5 ft by 12 ft by 6 inches, but the size can vary considerably. They are divided into many sections by baffles that extend across the pan and are arranged so that the open end of one is opposite the closed ends of those either side of it. A skimming trough may be attached to each side of the evaporator, which greatly reduces the labor for skimming the juice (Figure 3). A “water jacket” in the final 6-inch section of the evaporator pan moderates the temperature of the finished juice and helps keep the syrup from overheating.

Figure 2. Shown above is a uniquely designed evaporation pan for large operations. The juice comes through the pan to the right, goes through a very fine wire strainer, and then up the pan to the left. Mrs. Donald Eck, Bartlett, Kansas, is holding the wooden skimming paddle.

Pre-Heating the Juice

Pre-heating the juice prior to evaporating reduces the amount of skimmings left in the juice and lessens the time for cookoff. After the juice has been squeezed from the cane, it can be placed into large stainless steel containers, pre-heated to 160° to 180°F, and allowed to settle for 1 or 2 hours. During this process, many of the impurities in the juice will rise to the top and others will precipitate to the bottom of the tank. The juice is then drawn from about 2 inches above the bottom of the pan (above the settled material) until the skimmings on top of the juice reach that level. Clean out the impurities from the tank, and it is ready to be refilled with fresh juice.

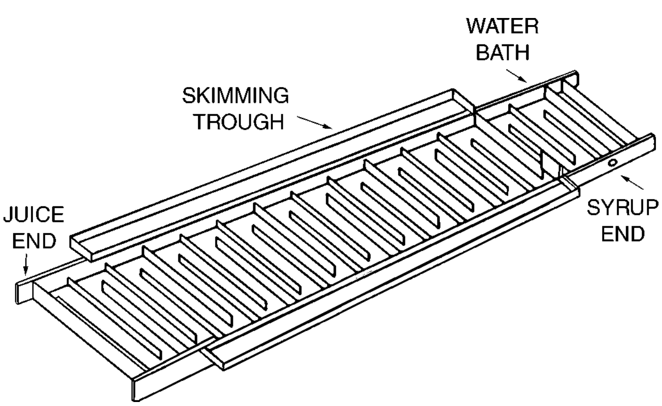

Figure 3. Sketch of a typical continuous flow evaporator pan with skimming troughs and "water bath." The pan's inside dimensions are 14.75 ft (4.50 m) by 3.56 ft (1.11 m). [Wilhelm and McCarty, 1985, University of Tennessee]

The Evaporation Process

Evaporating the juice is not difficult, but it must be done intelligently if a good quality syrup is to be produced. As the extracted juice is heated, some undesirable properties in the juice such as proteins and non-sugar substances are coagulated. These coagulated materials (skimmings) will rise to the surface and need to be removed. Continuous flow pans are somewhat more efficient but require more skill in their operation. Regardless of the evaporation method used, the boiling juice must be continuously skimmed to produce high quality syrup. The skimmings are rich in protein and starch as well as some sugar and can be used for animal feed. However, most skimmings are discarded into a waste area or buried.

To enable the juice to evaporate uniformly from the pan, you need to control the temperature along the pan's length. The temperatures shown in Figure 4 indicate that boiling of the juice starts about 25 percent of the length of the pan from the juice end and remains at a constant temperature until the skimmings are completely removed before reaching the

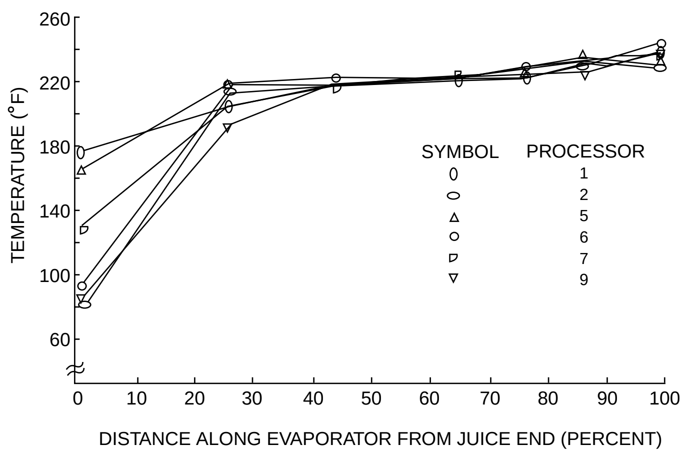

Figure 4. Temperature in evaporator pan as a function of location. Distances are measured as the percentage of total length from the juice end of the pan. The large variation in temperature at the zero end may be due in part to variation in positioning the sensor. [Wilhelm and McCarty, 1985, University of Tennessee]

last 25 percent of the pan. As the syrup density increases, the boiling temperature will rise gradually. Evaporation should be done as rapidly as possible but not so fast that you let the syrup burn. Juice cooked off too fast will be dark and contain small, dark particles of non-removed impurities. The pan should be at least 1 inch higher at the syrup end than at the juice end. This allows the juice to be about 2 inches deep at the juice end and from 3/4 to 1 inch deep at the syrup end. As the syrup is removed, the juice will push the unfinished syrup toward the finish end to keep the juice from getting too shallow and thus prevent burning.

Remove the syrup from the evaporator when it reaches 226° to 230°F (108° to 110°C) or when it reaches a density of 78° to 80° Brix with a syrup hydrometer or sugar refractometer. Inexperienced operators (and sometimes experienced ones) should use a good thermometer to determine when the syrup is finished.

Draining off the finished syrup is not especially difficult, but remember that no part of the pan should be dry for more than an instant or the syrup quality may be impaired. The semi-syrup in the center of the pan must be allowed to follow closely behind the syrup being moved to the outlet.

As the finished syrup is removed from the pan, it should be cooled and strained before being placed in a large container. Cool the syrup to 140° to 160°F as it is removed from the pan. Some producers pump the finished syrup through a pipeline that passes through an enclosed cool water tank to lower the temperature quickly. A simpler method involves running the syrup down a wide trough for 6 to 10 ft with a cool water jacket beneath the trough. The syrup should then be strained through muslin, two thicknesses of cheesecloth, or 45-mesh screen wire before going into holding containers for canning. Excellent straining cloth may be obtained from any bee or honey supply outlet. This quick cooling maintains the syrup's more natural color compared to slower cooling methods.

The finished syrup is thoroughly sterilized by boiling. If canned above 150°F in clean containers, it will not spoil or ferment. The container must be airtight to prevent fermentation or surface mold growth. Thoroughly wash large containers such as metal drums several times with boiling water or steam and dry them thoroughly before adding syrup. Large wooden containers such as kegs or wooden barrels are not recommended for storing syrup because they are so hard to sanitize. It takes from 6 to 12 gallons of raw juice to make one gallon of sorghum syrup. The finished syrup will weigh about 11.5 pounds per gallon.

Table 1. Average Composition of Sweet Sorghum Syrup (1 Tbs)*

Weight	20 g	Sodium	4 mg
Calories	52	Phosphorous	5 mg
Carbohydrates	13.4 g	Potassium	120 mg
Calcium	30 mg	Riboflavin	0.02 mg
Iron	2.4 mg	Niacin	Trace

*These values will vary from sample to sample

Care of the Evaporator

It is seldom desirable to make syrup day and night; therefore, after each day's run the evaporator must be cleaned. To do so, run water instead of juice into the pan in the late afternoon, and let it follow the syrup as it is finished and drawn off. Leave at least 1 inch of water in the pan overnight. For galvanized pans, add 1 cup of chelated alkaline cleaner; for stainless steel pans, add 1 cup of a strong alkaline detergent and let soak overnight.

ln the morning, scrub out the pans with a nonmetallic abrasive cleaner. A 1 to 2 percent nitric acid solution should also be used on the stainless steel pans following the first cleaning. Nitric acid is preferred over sulfuric acid for cleaning stainless steel pans. The alkaline detergents (used the night before) will remove the mineral deposits, and the acid solution (used the next morning) will completely remove the salt precipitates from the stainless steel pan. Always wear rubber gloves when using any of these cleaners. These cleaners are available from any dairy supply store.

The used solution should be discharged to a covered pit away from trees or streams to prevent injury and pollution. Thoroughly flush out the evaporator with clean water before you start to cook.

General Sanitation

Maintain sanitation as you would for any food preparation at all times. Everyone in the exposed product area must always wear clean clothing and hair restraints. Use good manufacturing practices during all processing operations. Even though bacteria will not grow in sorghum syrup, yeast and molds do grow. Small areas of residual syrup, especially if it is diluted with water, can harbor tens of millions of yeasts and molds per teaspoonful and will increase the probability of product spoilage. Therefore, all surfaces coming into contact with the juice or finished syrup should be washed, sanitized with ½ cup sodium hypochloride (Clorox) per gallon of water and allowed to air dry. If you put the syrup into clean jars while it is still hot and seal it hot, you will also help prevent spoilage. Use food grade products, including the grease used on the mill, for all operations.

Labeling Your Containers

Each container must be labeled with a true statement as to what the product is; i.e., pure sorghum, sorghum syrup, sorghum and corn syrups, or corn syrup with sorghum syrup. Any optional ingredients having a functional role in the end product and occurring in significant amounts in the product must also be listed on the label. All ingredients must be listed in decreasing order of the amount used. Substances occurring in insignificant amounts and having no functional purpose in the finished product (enzymes, anti-foaming agents, etc.) do not have to be listed on the label. The name and address of the manufacturer or distributor and the contents of the package (volume or net weight) must also be on the label. For specific labeling details, obtain a copy of the Guide to Labeling Food Products in Kentucky from the Department for Human Resources, Food Control Branch in Frankfort.

Using Enzymes for Processing Sorghum Syrup

To Prevent Gelling

Depending on the growing season and variety of cane grown, sorghum syrup will occasionally gel when cooked to the required sugar concentration. Gelling results from higher than normal amounts of starch in the raw juice and is usually associated with over-mature sorghum. When made from sorghum harvested at the proper stage and allowed to settle out for 1 to 3 hours, most sorghum juice will not contain too much starch. Occasionally, however, gelling will take place even though the juice was allowed to settle.

Handling starch in the juice is often the most difficult problem in producing consistently high quality syrup. Starch is easily scorched in cooking, darkening the syrup and causing an off flavor. When the juice is boiled, the starch thickens the way it does when used to thicken gravies or cream pies.

Understanding Enzyme Action

If settling the juice does not remove enough of the starch to prevent gelling, the only other method to prevent gelling is to use enzymes to break the starch down into sugars and dextrans. This process may be accomplished in several ways. Any of the methods can be used successfully if you have a basic understanding of starch and enzymes. Starch occurs as granules which are protected from enzyme action because they are not soluble in cold juice. Therefore, before the enzymes can be used, the starch granules must be ruptured so the enzymes can act on them. Depending on the type of starch granules present, they will rupture when heated to a temperature between 140°F and 180°F. Since the specific temperature at which the starch granules in sweet sorghum rupture is unknown, the juice should be heated to more than 180°F so you can be sure the granules have ruptured.

Another important consideration when you decide how hot to heat the syrup is the nature of the enzymes. Because all enzymes are protein, they are destroyed by heat. Fortunately, some enzymes are more heat stable than others. Of the three types of amylase enzymes (enzymes that will convert starch into sugar or dextrans), two are relatively heat stable, while the other is easily destroyed by high temperatures. Although any of the three enzyme types can be used, the heat-stable enzymes are probably the safest since they are less likely to be accidentally destroyed. Since enzymes initiate reactions but are not used up by the reaction, only small amounts of the enzyme are necessary. The amount of enzyme to be used is a function of that particular enzyme's activity, but the recommendations should work for most of the commercial, high temperature enzymes available. Detailed instructions are available from the enzyme supplier.

Methods of Enzyme Use

One method of removing starch is to heat the raw juice to about 210°F for a few minutes to rupture the starch granules. After heating, allow the juice to cool to 185°F or below and then add about 2 Tablespoons of the enzyme (liquid) per 100 gallons of juice. Mix the enzyme thoroughly with the juice, either by hand stirring with a paddle or mechanical agitation, and allow it to set for an hour or more so that the enzyme will have time to convert the starch to sugar. Then evaporate the juice in the usual manner.

Another way to remove the starch is to add 2 Tablespoons of a high temperature enzyme (liquid) to 100 gallons of the raw juice and slowly heat the juice during evaporation. The juice is heated slowly enough so the starch granules will rupture, and the enzymes convert the starch to sugar before the heat destroys the enzyme. The juice is then evaporated as usual.

Probably the best method of removing the starch is to:

1) Evaporate the juice to a semi-syrup.
2) Draw the juice off into large containers and let it cool to 185°F.
3) Add 2 Tablespoons of a high temperature enzyme (liquid) per 100 gallons of the raw juice equivalent to the semi-syrup.
4) Let it stand for one or more hours to convert the starch into sugar.
5) Finish the semi-syrup in the usual manner.

Sometimes, finished syrup will gel even though the juice was allowed to settle thoroughly. In this case the finished syrup can be heated to 160°F to 180°F and treated with 2 Tablespoons of the enzyme per 100 gallons of the finished syrup and then rebottled. Although reboiling the syrup to destroy the enzyme may be desirable, it is not necessary since the enzyme acts only on the starch in the syrup.

To Prevent Crystallization

Often, sorghum syrup will crystallize during storage and become a problem for producers who store their syrup through part of the winter. Crystallization is caused when the sugar sucrose is present in concentrations greater than its solubility at the storage temperature. You can prevent crystallization if some of the sucrose is converted to glucose and fructose (other forms of sugar) with the enzyme invertase.

As with the amylase enzymes, invertase can be added at several times while the syrup is being processed. The recommended method is to finish the syrup in the usual manner and cool it to below 140°F. Then add 1 pound invertase per 100 gallons finished syrup and immediately bottle. The enzyme will slowly convert the sucrose into glucose and fructose over the next few weeks. The syrup will probably become slightly thinner, but the sweetness will remain the same.

NOTE: Enzymes are not stable over long periods of time. Depending on the source of the enzyme, liquid enzymes should be stable for six months or more and dry enzymes for about 12 months or more. Some suppliers have analyzed enzymes after four years of storage at refrigeration temperatures and found them to have an activity of 75 percent of their original activity. However, as a matter of caution, it is recommended that you do not buy a large supply of enzyme at one time, expecting to use it for several years. Also, remember to store all enzymes in the refrigerator.

Enzymes may be obtained through a member of the National Sweet Sorghum Producers and Processors Association. This information may be found in the association's July newsletter or by contacting a representative at 859-277-9017.

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