SWEET SORGHUM
Production and Processing

A simple guide to small-scale, ecological production of pure sorghum syrup.

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Poteau, Oklahoma
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G. K.

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The Kerr Center for Sustainable Agriculture, Inc. (KCSA) strives to provide leadership, education, and technical assistance to the agricultural community in seeking ecologically and economically sound methods of producing food and sustaining farm livelihood. Also, we acknowledge the interdependence of biological, social, and spiritual relationships in promoting stewardship and health of the land and people it supports.

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HOW TO USE THIS BOOK

*SWEET SORGHUM Production and Processing* is divided into two sections.

Section I discusses the KCSA Sorghum Project and details our procedures. It describes a small-scale, commercial operation and explains how we handle our equipment and circumstances.

Section II consists largely of background information gathered from literature and from communications with producers, researchers, and extensionists. It is intended to give the reader a broader view of what other producers and processors are doing. It is also meant to acquaint the reader with other technical information not provided in Section I.

A reading list, addresses for specialized equipment and supplies, and a glossary have also been included.
WHAT IS SORGHUM?

Sorghum is a natural sweetener made by processing juice from the stems of sorgo, a particular type of sorghum plant. Many people call sorghum “molasses.” This name is technically incorrect, because molasses is a by-product of sugar manufacturing. Sorghum is a primary product, a syrup made by boiling down pure plant juice. It is used in a variety of ways but primarily as a sweetener in baking or as a table syrup.

Having a distinct flavor, sorghum is often mixed with corn or sugarcane syrups to prepare blended products. Molasses, cane molasses, and cane syrup are definitely not sorghum. However, a farmer may choose to name his or her product “molasses” because of tradition or as part of a marketing strategy. The only way to be reasonably sure of the contents is to check the label. It should read Pure Sorghum, Sorghum, or Sorghum Syrup.

Since it costs more to produce, pure sorghum will be more expensive than other sweeteners and blends. Buying pure sorghum helps support the small, family farmers who prepare it.

Making sorghum has a long tradition in the United States, especially in the Southeast, mid-South, and lower Midwest. Sorghum mills were an important element of community fellowship. Typically, only one or two farmers had a milling operation, and everyone would bring their cane for milling and cooking. A percentage of the syrup, usually 40 to 60 percent, was kept by the mill owner for services delivered.

Harvesting sorghum had always been a family-centered enterprise. Stripping, cutting, heading, and loading the stalks are all labor-intensive activities begging for large families. At that time, mills were powered by horses or mules. Many an old-timer speaks of the days when it was his or her job to ride a horse in an endless circle to grind the cane. Cooking was commonly done on a copper pan over a wood fire, without all the instrumentation most modern processors rely on today. The person who cooked the sorghum was regarded an artisan. Since sorghum is made from September through early November, it is part of the fall harvest tradition. Fall festivals and parties were, and continue to be, centered around cooking and eating.

In many rural areas, sorghum and honey were the only sweeteners affordable, or even available, well into the 1900s. In some communities it was a major crop. One of the principal states, Kentucky, recorded 21,982 acres of sweet sorghum in 1899. Interest and acreage declined because of the availability of less expensive granulated sugars and corn syrup, changes in consumer demand, and the on-farm shift toward specialization and mechanization until Kentucky had less than 500 acres in 1972. Between 1972 and today many of these trends have been reversed. Sugar prices increased, diversification became a catchword for farmers, and the demand for natural, regional, and specialty foods increased dramatically. Kentucky’s current plantings total well over 1,500 acres.
Sweet sorghum also has other potentials that have sparked interest in recent years. The energy crunch of the 1970s resulted in considerable study of alcohol as a likely motor fuel. Sweet sorghum was considered a prime “energy crop” because of its high sugar content. Improved techniques for crystal sugar extraction also raised the possibility that it may be a new source of processed sugar. Another area showing great potential is in the food ingredient market.
KCSA’S METHOD OF PRODUCTION AND PROCESSING

KCSA Sorghum Project
Plant and Crop
Harvesting
Mills and Milling
Handling Juice
Processing Facility
Cooking on an Inclined Pan
Cooking on a Flat Pan
Finished Syrup
KCSA SORGHUM PROJECT

KCSA began growing and processing sweet sorghum in 1986. One acre of Dale sorghum cane was grown, hand-stripped, hand-cut, and hauled more than 20 miles to a small farm in the backcountry of southeastern Oklahoma. For three days, a small army of staff, student interns, and volunteers cooked close to 100 gallons of some of the saddest-looking sorghum ever seen. It was thin and grew mold, but it didn’t taste all that bad.

We were ashamed, of course, but not nearly as ashamed as we were exhausted. Making sorghum was some of the hardest work many of us had ever done. Even with such a discouraging start, we were hooked. Growing and processing sorghum has become a significant part of the KCSA program for the past several years.

During the late 1980s, KCSA managed an integrated small farm called Poteau Mountain, a diversified, u-pick, horticultural operation. The project needed another enterprise which would improve cash and customer flow in fall and which would supply a storable product to sell in winter. Sorghum syrup production seemed to be that enterprise.

Preliminary research showed that small- and intermediate-sized sorghum producers in the South and Southeast were turning sufficient profits. Sweet sorghum was also a traditional crop in southeastern Oklahoma. Interest in the region had waned because of declining demand in the 1940s and 1950s and the lack of education and research that could provide technology for the changing times.

We felt that KCSA might revive interest in sorghum by introducing new, appropriate technologies. Many advances had been made in recent decades, and they needed to be demonstrated.

When KCSA staff began their inquiry of sorghum production, it became increasingly clear that there were more than a few ways of doing things. We soon concluded that there were as many "correct ways" as there were producers, advisors, and storytellers. It appeared that no sorghum maker had even attempted to write a manual because of the expected controversy.

We do not claim our approach to be a preferred one. However, we do maintain that what we are doing now is working and can serve as a starting point for someone wishing to begin a sorghum enterprise on his or her own farm.

In spite of the variety of opinions, the best way to start is by learning from as many people as possible. Of greatest value to us has been our membership in the National Sweet Sorghum Producers’ and Processors’ Association (NSSPPA), which meets annually in Nashville, Tennessee. At the conference one can not only attend formal presentations by farmers, researchers, and extensionists but also interact directly with large- and small-scale processors.
PLANT AND CROP

Variety Selection

In the past five years, KCSA has grown and processed seven different varietics of sweet sorghum. Many more exist. Some are as much legend as reality. Old-timers have often told us of sorghum cane the size of tree trunks from which the best syrup was made. Seed for these varieties is always impossible to find.

KCSA has planted a number of varieties each year, not only to evaluate their performance but also to lengthen the harvest season. The best yielding varieties for our soils have been M81E and Dale, followed by Theis. Sugar Drip and White African had low yields, because both of these traditional varieties have not been improved by modern breeding.


Sugar Drip is especially prone to lodging, while M81E appears to be the strongest standing. Theis, which has grown especially tall, is also prone to lodging where wind is a problem.

We have found M81E, Theis, and Sugar Drip the easiest to cook. To us, this means these varieties have the cleanest juice and require the least skimming while cooking. The syrup from these varieties also tends to be lighter in taste and appearance. We have less experience with White African, but it seems to cook the same.
KCSA's Method of Production and Processing

Our greatest disappointments in both quantity and quality of syrup were Ho-K and Brandes. Both were drought susceptible, and their shortcomings were probably due to these conditions. Since short-term droughts are a frequent feature of southeastern Oklahoma, neither is a good choice for the region.

Crop Culture

We try to grow sorghum in rotation and follow a crop or green manure that contains no more than 50 percent legumes. It is a myth that good sorghum can only be made from cane grown on poor ground. That myth, however, probably arose as a result of valid observations. Excessive nitrates, whether from decomposing legumes, fresh manures, or synthetic fertilizer, can affect syrup quality.

On occasion we have planted sorghum for two consecutive years on the same fields. This practice presents no great risk, but we think it contributes to disease buildup and requires more fertilizer.

Getting a good, early stand in the unreliable weather of southeastern Oklahoma has always been a challenge. This has been complicated by inappropriate planting equipment. In 1986 the first field was planted using a Planet Jr., designed for small vegetable seeds. It is a drill rather than a precision planter, and our inexperience resulted in an uneven stand.

Later a single-row, Powell precision planter was used. It worked well except when the seed plates failed to seat securely in the hopper. Because sorghum seed is small, it would slide under the plate and grind the planter to a halt. We credited this to a fault in the manufacture of our implement, not to the design.

Most of the time we used an older, International Cub tractor for both planting and cultivating. Because it is designed for single-row operations and is offset for improved visibility, this tractor worked exceptionally well for weed management and caused little soil compaction.
For the last two years, much of the sorghum has also been grown employing draft-animal power. Cultivation equipment used with draft stock has a wider range of control than tractor-mounted tools and provides superior weed control. These factors are worth considering in herbicide-free crop culture.

KCSA has flat-planted sorghum rather than using lister rows or other bed culture. This has worked well on our lighter, better drained soils. Flat-planting can present problems in heavy and bottomland soils. Listing or some other bedding system is preferable.
KCSA's Method of Production and Processing

In order to facilitate topping (removal) of seed heads, skip-row planting has been done in recent years. The pattern involves planting four consecutive rows and skipping two. Yield loss with this method is little, because the outside rows take advantage of the extra sunlight and grow thicker stalks.
Chapter 3

HARVESTING

Judging Maturity

We have combined both traditional and modern techniques in judging the maturity of sorghum cane for harvest. The traditional approach is based on determining the stage of seed head development. The soft-dough stage is supposed to be the optimal point for harvesting.

A refractometer is an accurate and inexpensive means of determining the optimum time for harvest.

The modern technique uses a refractometer to gauge sugar content of the juice. For varieties we are most familiar with, we prefer having a minimum of 12 percent sugar or "degrees Brix." Degrees Brix is a measure of the dissolved solids in a liquid. In a sugar crop, degrees Brix is essentially equal to percent sugar. Most of the time, harvest is delayed until 16 to 17°Brix is reached. In one instance, our field sugar content was as high as 20°Brix. Highest Brix readings usually occur at or close to the soft-dough stage and continue through hard-dough.

Weather, soil type, fertilization, and many other factors influence Brix. For this reason we also continue to observe seed head development. Should the crop reach the soft-dough stage, yet only have a Brix of 9 or 10, harvest is in order. The sugar content is not likely to go much higher.
Likewise, a crop may have a high Brix level well in advance of seed head maturity allowing earlier harvest. This seems to produce a slight greenish cast to the finished syrup, but we need more experience before we can be certain.

**Cutting and Topping Cane**

Leaf stripping and hand cutting a single acre of sorghum cane in 1986 left a strong impression on KCSA staff. Those involved insisted that in the future all sorghum be grown in the Caribbean, so they could visit the beaches afterward. By the 1987 season, we had bought an old, ground-driven row binder and had cancelled all flight plans to Jamaica. Later a pto-driven binder was also purchased. We believed it would be faster and better. To our dismay, it took much more time than expected to learn how to run the pto-driven binder. Binders are intended to operate with the gathering chains traveling at a speed comparable to ground speed. This serves to keep the stalk in an upright position until it is bundled. Increasing chain speed causes the stalks to lie flat, jamming the binder.

![A ground-driven row binder.](image)

Until 1990 cane was cut and bundled with seed heads intact. They were then trimmed while the bundles were on the ground or after they had been stacked uniformly on a wagon or truck. Using a binder to cut cane with seed heads often causes problems with tall or weak-stalked varieties. The heavy seed head of the stalk frequently breaks over at a point two to four internodes below the seed head, making it wrap in the discharge arm. When this happens, another person is required to keep the machinery clear and operating.

In 1990 KCSA bought a piece of equipment remotely resembling the Martian invasion vehicles described in *War Of The Worlds*. It consists of a sickle bar and a double-pinwheel gathering arrangement attached to the end of a hydraulically-operated, front-end lift. This is mounted on a stripped down, Hi-Boy sprayer carriage. It tops two rows of sorghum cane in a single pass and is a primary reason for the skip-row planting pattern.
Converted from a Hi-Boy sprayer, this self-propelled machine trims seed heads from standing sorghum cane.

**Stripping Cane**

Many producers and consumers raised in the old school methods of sorghum cooking insist that quality syrup cannot be made unless leaves are completely stripped from stalks before milling. The milling of fresh, green leaves along with the cane may produce undesirable flavors and can cause starch problems.

Stripping sorghum cane is a very labor-intensive undertaking.

We choose **not** to strip our sorghum cane. In large part, this is an economic decision. While large families, cooperatives, and the like may be able to pool willing, low-cost labor, KCSA is obliged to pay a competitive, hourly wage. The costs of hand stripping several acres of sorghum...
KCSA's Method of Production and Processing

cane would be difficult to recover in all but the best of years. Had we faced the dilemma of expensive hand stripping or accepting a low-quality product, KCSA would never have started this enterprise. Fortunately, we satisfied ourselves that economic alternatives to hand stripping were available. Also, these alternatives are accessible and affordable to most small- and intermediate-scale growers and processors. The techniques come from experienced farmers and researchers in other states and are only being reapplied by KCSA. We credit our ability to produce a clean, excellent tasting syrup to three distinct actions:

1. Letting leaves thoroughly wilt on the cut stalks before milling.
2. Settling all sorghum juice a minimum of two hours and discarding the settlings.
3. Using alpha-amylase enzymes during preheating of the juice.
MILLS AND MILLING

Leaves should be completely wilted before milling the cane. This can take anywhere from two to ten days depending on the weather. The delay actually provides several added benefits. During this time, a small amount of water evaporates from the stalk, further concentrating the sugars. Also, naturally occurring invertase enzymes in the stalks facilitate the breakdown of sucrose, reducing the likelihood of the sorghum crystallizing.

Milling cane with wilted or dried leaves has been challenged, because juice is lost from reabsorption into the leaves. While reabsorption does happen, the percentage of juice lost is quite small when compared to the costs associated with hand stripping, or the loss of quality accompanying the milling of green leaves.

Since 1987, KCSA has relied on a 1905 Golden mill. This is a three-roller, horizontal mill with the main, top roller measuring 15 inches across and 12 inches in diameter.

The mill was set up on a natural rise above the processing building for gravity flow of juice to the holding tanks. A 7 hp single-phase, electric motor was the power source. A three-phase motor would have been preferable, but the option was not open to us at the time.

A continuous-belt, multi-purpose elevator was used to remove the crushed cane waste or “pumies” from the mill area. It is probably a corruption of the word “pomace,” the vegetative matter left after the extraction of juice.
In 1989 milling in the field was first tried. A small, three-roller horse mill, powered by a Wisconsin gasoline engine and speed-regulated by a truck transmission, was mounted on a 16-foot, dual-axle trailer.

The process went slowly because of the failing performance of the engine and the small capacity of the mill. It was clear, however, that the benefits of field milling were many. In 1990 the large mill was removed from its stationary mounting and placed on the trailer. The power source is now hydraulic and has controls and safety devices that the little, gas-powered engine lacked.

Labor savings with field milling are enormous. A small army of workers had been employed every year to load, haul, and unload cane before milling. More labor was also hired to dispose of the pummies at the stationary mill site. The entire operation now requires fewer, but more knowledgeable, workers. Fuel savings were also realized. The only material now removed from the field is juice. The waste cane is dropped back onto the field. This also means that no energy is expended in further handling of wastes. Finally, there are direct benefits to the land by leaving the cane waste where it can be tilled into the soil. Too often, cane hauled to a stationary mill fails to be returned to the soil from which it was taken.

The old literature has always advised pushing the butt end of the cane into the mill first. Being the thickest part of the stalk, one can tell the maximum load on the rollers immediately and avoid overfeeding. On the other hand, if one begins pushing with the smaller, top ends, the mill operator quickly finds the mill overloaded as the butt ends near the rollers.

Common sense is the best guide to feeding the mill. Cane stalks should be fed continuously and as close as possible to the maximum capacity of the mill. This ensures efficiency of labor and machine and improves the extraction percentage.
KCSA's first attempt at portable field milling.
Our current portable field mill.

A view of the field mill showing controls and protective shielding.
HANDLING JUICE

The equipment we bought to start the sorghum enterprise dictates the way we handle raw sorghum juice. We purchased a small operation that was going out of business. We also bought a bulk cooler, originally salvaged from the dairy industry. This has enabled long-term cold storage of more than 300 gallons of sorghum juice at about 34°F. We have also added more cold storage capacity.

A 300-gallon, bulk milk cooler.

Cold storage allows advance accumulation of a large quantity of juice and flexibility in scheduling. It also provides time for settling. A minimum of two hours of settling is desirable for sorghum juice. We have observed that settling overnight is even better.

The holding tanks are fitted with risers so that 1 1/2 to 2 inches of settlings are held back and discarded from each tank. This is extremely important. The discarded settlings consist of soil particles, plant fibers, proteins, and a lot of starch.

Settling and decanting sorghum juice is not a new finding or recommendation. Many of the old USDA, state experiment station, and Extension publications also advised settling. Unfortunately, many traditional producers still ignore this recommendation. A probable reason is the lack of cold storage, which greatly helps the process. It is difficult to time cooking if settling is done without
refrigeration. Sorghum juice can spoil when held too long at the warm temperatures common during harvest season.

Besides settling, we also strain the juice twice before cold storage. A preliminary straining is done at the mill using burlap to remove seeds, large fibers, and other contaminants. A second straining using cheesecloth or pantyhose is done as the juice is transferred to the settling tanks. These straining cloths clog frequently. Workers should resist the temptation to stir the backed-up juice to increase flow through the cloth. Stirring negates the purpose of the straining cloth by forcing the impurities to reenter the juice. While it is frustrating and time consuming, it is better to keep several straining cloths handy and rotate them. Clogged cloths can be cleaned while milling or juice transfers continue.

Sorghum juice should be treated gently. The more violent the agitation or the higher the pressure, the more contaminants are broken into smaller particles and the more difficult they are to remove. As much as possible, low-pressure or gravity should be used in moving juice. Centrifugal pumps whip air into the juice and handle it too violently. A gear pump or some other positive-action pump suitable for moving sugar solutions is needed. Originally sorghum mills were located on hillside to take advantage of gravity flow. This is still of value today, not only to save capital and energy investment in pumps and pumping, but also to preserve juice quality (Figure 1).

![Diagram](image)

Figure 1. A sorghum processing facility making maximum use of gravity flow.

Once a settling tank is full, alpha-amylase enzymes are added and gently mixed. Settling can begin, and more stirring can be avoided. Alpha-amylase aids the breakdown of starch to sugar. We use a particular type called Hi-tempase, which is most active in the preheating end of the cooking pan. Little or no breakdown of starch will occur during the settling process in spite of the presence of alpha-amylase. Heat is needed.

When milling in the field, handling the juice requires attention and concern, especially in hot weather. Microbial growth may accelerate because of the time needed to accumulate and haul juice from the field to the settling tanks. This increases the chance that the juice may sour before cooking.

We use the slow agitation system in our bulk milk tank to rapidly cool juice as it is brought in from the field. This is a slow, gentle motion. Violent shaking, as previously discussed, would be counterproductive. Our agitator is turned off as soon as the juice is cooled, and enzymes have been added to allow maximum time for settling. When a batch of juice is not refrigerated, it is best to schedule cooking as soon as possible after the minimum two hours required for settling.
PROCESSING FACILITY

Our own facility at Poteau Mountain was designed using guidelines from the Tennessee Department of Agriculture. To our knowledge, no specific rules have been established for Oklahoma or for most other states. We felt that adherence to these requirements would place us favorably if and when we were inspected by any food or health agency. The Tennessee guidelines are listed below.

**Basic Requirements for Sorghum Mills in Tennessee, April 11, 1979.**

1. The water supply must be from a potable source and approved by the local health department.
2. The mill must be power driven to eliminate potential problems associated with animals, such as dust, manure, flies, etc.
3. A sanitary toilet, conveniently located, must be provided.
4. Hand washing and utensil washing facilities must be provided with soap and towels.
5. The pan room must be screened and free from flies and other pests including pets. The floors should be of concrete or other impervious material which can be washed down completely at the close of production.
6. Persons in exposed product areas must wear clean protective garments and hair restraints. Good manufacturing practices should be practiced during all operations.
7. Skimmings should be disposed of in a manner to minimize fly attraction.
8. All consumer-type containers must bear labels meeting the requirements specified under the Tennessee Code and its regulations.
9. Manufacturing, packing, or storage areas should be free of adverse conditions which might cause food products to become adulterated.

The KCSA facility was planned to minimize the use of pumps to move either juice or syrup. The original intent was to extend the building so that a bottling area could be built at a lower elevation. Currently buckets of syrup are carried from the end of the cooling tray, and the syrup is poured into bottling tanks (Figure 2).

A large fan mounted on the wall removes heat and moisture from the building. An ideal option would be a ventilation hood installed directly over the length of the pan. Do not rely on passive heat removal in an enclosed building. We tried it once and had three cases of severe heat cramps.
KCSA's Method of Production and Processing

KCSA's sorghum processing building.

A gravity-flow juice line.
Unrefrigerated settling tanks.

Filling a settling tank.
An exhaust fan removes heat and moisture from the building (upper left).

A Maxon burner with safety sensors and pilot.
Figure 2. An overhead and cross section view of KCSA’s sorghum processing building.

Sorghum juice flows from settling tanks to the evaporator pan through flexible hoses. Syrup is poured from the bucket into bottling tanks. A straining cloth is spread over the bottling tanks to ensure cleanliness.

(A) Refrigerated settling tanks, (B) Unrefrigerated settling tanks, (C) Maxon gas burner, (D) Continuous-flow evaporator pan with self-skimming trays, (E) Cooling tray, (F) Stainless steel bucket, (G) Syrup holding/bottling tanks, (H) Bottling table
COOKING ON AN INCLINED PAN

An Overview

It has been said that to make good sorghum the cook has to have aged 70 years and be full of bull. Since all of KCSA's sorghum cooks are under 40 years of age, the statement is only partially true.

Reading and rereading our procedures "will not a sorghum cook make." Time spent cooking sorghum is still the best teacher. Our goal is to provide a starting point and to prepare the novice for a few of the many surprises.

Cooking sorghum is a process of evaporation. Water is boiled from the juice to concentrate the sugars. A juice starting at about 16°Brix will be cooked until it reaches 76 to 80°Brix.

We use a 16-foot, stainless steel, continuous-flow evaporator pan with self-skimming troughs. It is mounted on a firebox made from firebrick. A Maxon blowtorch burner supplies heat.
Mounting the Pan

The firebox, built for KCSA by local craftsmen, is of double-wall firebrick construction. The pan is laid over the firebox and sealed at all contact points with fireclay. While the pan is inclined from the juice to finish end, it must be set level across the width.

The juice end of the sorghum pan is actually two inches lower than the finish end. This might seem illogical at first since the liquid would have to go uphill. However, as juice changes from semisyrup to syrup, water is evaporated resulting in a loss of volume. Setting the pan at an incline anticipates this change in volume.

The width of the firebox is narrower than the cooking pan. During cooking, various coagulants called skimmings rise to the surface of the juice. Skimmings naturally “ride” the bubbles during boiling and will accumulate on the edges of the pan (Figure 3). As the firebox heats up, bubbles will actually float the skimmings over the edge of the pan onto the skimming trays, where they can flow back to the juice end.

Figure 4 shows the positioning of the blowtorch burner and the sloped hill, designed to concentrate heat at select portions of the pan. The hill, made of sand covered with fireclay, breaks away just before the finish end of the pan. This slows the cooking in the last stages and prevents scorching. In KCSA’s operation, the hill breaks away before the finish end by two to three baffle spaces. In Wilhelm and McCarty’s (1985) report, the hill stops abruptly at the beginning of the finish end. We tried this design our first year and had finished syrup at the lower end of the finish section instead of the upper end. By starting the downward slope closer to the juice end of the pan, heat is diffused in this section, and the cooking rate is slower and in better synchronization with other parts of the pan.

The pressure of gas and flame from the burner creates a small valley in the sloped hill. The hill should be repaired at the start of each season and mid-season if a lot of cooking is done. This is also an opportunity to remount the cooking pan, which may have shifted or lost portions of its fireclay seal.

Another feature of KCSA’s pan design that contributes to higher quality is the water bath just above the finish end. Water in this compartment helps prevent scorching.
Cleaning the Pan

Before cooking, we carefully clean our pan, because we are preparing a food product. Dust, syrup, and most stains are easily removed with water and a bit of elbow grease. Starch deposits and accidental scorches require some extra effort. We use a product called Buckeye Acid Bright, and it has proved quite satisfactory. It is especially effective if the pan has been soaked overnight in a dilute solution of the acid before scrubbing. Avoid buying cheap brushes; they eventually lose bristles and leave other debris in the pan. Nonmetallic, abrasive scrubbers are preferred.

Place a fine-particle filter system on the water source. Many water supplies carry fine sand and other sediments that should not be in the syrup. Once in the pan, they are difficult to remove. We have added small irrigation filters to the water lines. These filters are used in small, drip irrigation systems.

Keep in mind that syrup is a food product, and good sanitation is imperative. Floors should be cleaned frequently, and working surfaces should be wiped with a dilute, chlorine bleach solution.

Starting to Cook

Before igniting the burner, raw, settled juice is run into the pan at the juice end. A dam of wet rags is placed about nine baffle sections up. The terms referencing portions of the evaporator pan are shown in Figure 5. These will be referred to throughout the chapter.

The juice should be maintained at least 1/4 inch below the tops of the forward baffles. Enough water is also kept in the remainder of the pan to ensure that the entire bottom surface is covered with liquid. Failure to do this can result in severe damage to the pan from the intense heat.

Temperature of the juice is continually monitored using a thermocouple and probe. Be certain the temperature reading is of the juice—not the pan. Hold the probe a fraction of an inch from the pan surface.
When the juice temperature reaches 214°F, a second dam of rags is built. Figure 6 shows the temperatures at which we begin to move the juice to the next section, along with the locations of dams for each advance. Scoops are then used to empty most of the water from the sections closer to the finish end of the pan. As the water level is reduced, a pushrag and paddle are used to force the remaining water uphill. The juice flows behind the water by opening the lower rag dam. Water is continuously scooped from the spaces in front of the pushrag until the juice reaches the upper dam. The pushrag and original rag dam are then removed. Figures 7, 8, and 9 depict these procedures. They are repeated whenever juice is moved up the pan to displace water.
Figure 6. Arrows show positions of progressive rag dams. Temperatures indicate when to move juice or semisyrup to the next section.

Figure 7. An overhead view of the evaporator pan at the start of an advance. Note the positions of rag dams at A and B. A portion of the water between the dams is scooped toward the syrup end.
Figure 8.
Midpoint in an advance. The pushrag (C) is moved from Dam A using a paddle (D), forcing water ahead of it. Dam A is opened to let juice flow behind the pushrag. Water between the pushrag and Dam B is scooped toward the syrup end as it accumulates. Raw juice is added at E.

Figure 9.
End of an advance. Dam A and pushrag are removed. Juice immediately below Dam B is scooped back to remove any mixed with water. Raw juice is added at E until level is 1/4 inch below forward baffle F.

Juice must be added to the lower end of the pan during this process to make certain all sections are filled with liquid. Again, juice should only fill the sections to 1/4 inch below the top of the forward baffle. If water has accidentally mixed with the juice during the first advance, use the scoops to ladle some or all of the juice in the first baffle area back to the lower end of the pan to remix with the cold juice.
During an advance, it becomes clear why the juice level is held 1/4 inch below the forward baffle. If an attempt were made to move deeper juice, it would flow over the baffles ahead of the pushrag, mix with water, and increase both cooking time and frustration.

Juice temperature is again monitored, and the next advance is made when it reaches 216°F. The same procedure is followed:

1. Build an upper dam, Point C in Figure 6.
2. Scoop water.
3. Release juice behind the pushrag.
4. Fill the vacated space with juice.
5. Remove the lower dam and pushrag.

The time required between advances varies. It depends on depth and Brix of the juice, applied heat, atmospheric pressure, humidity, and other factors. This method of determining juice movement was inferred from a study conducted by the University of Tennessee of operating sorghum pans (Wilhelm and McCarty, 1985). There may be more efficient ways, but this does work. Two people, alternately moving the pushrag and scooping water, make the procedure go smoothly. More helpers are usually a hindrance.

Water must cover the pan area ahead of the juice to prevent damage to the pan. The level of water is not critical, but we try to maintain it comparable to that of the juice. This keeps even pressure on the rag dams and reduces the chance of accidentally mixing the two liquids.

The juice, now called semisyrup, flows into the finish end. Instead of scooping water from the finish section, we drain it from the syrup spout at the upper end of the pan. The entire pan is now filled with juice and densities of semisyrup.

At this stage, the thermocouple and probe are positioned with a clamp about six inches from the syrup spout to monitor the temperature of finished syrup. Make certain the point of the probe is not in contact with the metal of the pan. When the temperature of the semisyrup nears 234°F, Brix readings are taken using a syrup refractometer.
KCSA’s Method of Production and Processing

A Brix of 78 or 79 for finished syrup is a common standard. However, some sorghum cooks prefer a product of over 80° Brix. Once the desired Brix is reached, the temperature at which to draw off finished syrup is known. We recheck the Brix several times to prevent error. The system is reliable and lends consistency to the product.

We keep a barometer mounted on the wall of the cooking building and write down the atmospheric pressure at the time our finish temperature is determined. This provides a guideline for cooking temperatures in the future. By checking the barometer, we can note if conditions change during a cooking day, requiring any adjustments in the finish temperature.

Changes in atmospheric pressure alter the temperature at which sorghum juice or any liquid boils. When atmospheric pressure is low, boiling occurs at a slightly lower temperature, and syrup will also finish at a lower temperature. Atmospheric pressure also decreases with increasing elevation. Water that normally boils at 212°F at sea level will boil at 206°F at 3,000 feet elevation.

Relative humidity is another weather factor that affects cooking. An atmosphere already saturated (high humidity) is slow to accept water being boiled from a pan of sorghum. A high relative humidity slows the rate of evaporation but does not influence the temperature of boiling.

Running the Pan

If the pan is mounted properly, skimmings will float from areas of active boiling to cooler portions along the edges and back toward the lower end of the pan. Here they can and should be removed with “skimmers.” Good skimmers resemble scoops with either fine screen on the bottom or small drilled holes.

Skimming is one of the work activities most associated with cooking sorghum and most intriguing to visitors and volunteer helpers. It is also one of the most overdone tasks. Skimmings should be allowed to accumulate until they are thick, like a curd. Having 1/2 inch or more of this material covering the preheating area presents no problem.

When cooks are too zealous and rush to remove noncurled skimmings, they succeed in capturing only a small portion. Most noncurled skimmings slip through the skimmer. They are usually boiled back into solution and are then almost impossible to strain. The result is a lower quality syrup. If lucky, reboiled skimmings will coagulate again, but near or in the finish section of the pan making more work and distraction for the cook.
As cooking progresses and heating efficiency increases, the self-skimming trays come into play. Skimmings riding the larger bubbles will roll onto the trays, flow back and into the juice end of the pan.

Decision making during cooking should not be done on a consensus basis. The old adage, too many cooks ruin the soup, applies here. One cook should clearly be in charge. Helpers should keep their enthusiasm under control. This can be accomplished by education and guidance or a quick swipe with a hot, sticky skimmer.

The syrup level in the finish end should be shallow. This allows for rapid cooking and a continuous flow of syrup from the pan. The level is controlled largely by regulating the flow of cold juice into the lower end of the pan. Some control can be achieved with the sliding gate at the entry to the finish end.

If too much semisyrup is in the finish end, problems can happen. Since less heat is applied here, cooking will slow, whereas the area of the pan immediately below it will continue to cook rapidly. Sometimes syrup finishes in the middle of the pan while semisyrup is still in the finish end.

When this happens, we usually draw off some of the semisyrup from the finish end at a lower Brix to reduce the level and accelerate cooking. We collect the lower Brix semisyrup in a bottling tank and try to compensate later by adding syrup of higher than average Brix.

Uneven flow of air over the evaporator pan may also cause more rapid evaporation in one portion of the pan. Uniform placement and management of windows, doors, and exhaust fans will help prevent this.

When operating optimally, a small but steady stream of juice should be pouring into the lower end of the pan, while a steady trickle of syrup is drawn off at the finish end. Much of the time, the flow in and out of the pan is stop-and-go. This does not reduce quality; it just makes more work.
Another way of controlling flow and boil is "chasing" the syrup and semisyrup using push paddles without rags. This is usually done if a large batch of syrup finishes at the same time and needs to be moved out of the pan quickly. Semisyrop is chased into the space being emptied and accompanied by an inflow of raw juice at the lower end of the pan.

A certain amount of "swapping" can also be done if semisyrop is finishing too rapidly in the central part of the pan. Swapping involves shifting juice or semisyrop from the lower end of the pan into the rapidly cooking area (Figure 10). This is usually accomplished by employing scoops. It delays finishing for a period of time and lets the helpers empty syrup from the finish end.

Swapping should be considered a rescue procedure. It is not good to mix lower Brix juice into semisyrop, because less opportunity exists for dissolved skimmings to coagulate. If swapping is required, avoid shifting liquid from the lowest baffle sections.

A paddle is used to chase syrup.

Figure 10. If pan area A nears syrup stage too early, it can be diluted by swapping semisyrop forward from area B.
Another problem comes from cooking juice that contains too much starch. Semisyrup high in starch will boil slowly and continuously without giving off steam, and the temperature and Brix will not increase. It will begin producing large bubbles and releasing smoke as it turns red and scorches. The only recourse is to immediately shut off the heat and chase the semisyrup out of the pan into buckets or holding containers. Juice from the lower end should also be removed. While removing semisyrup and juice, make certain water enters all sections of the pan. Radiating heat from the firebox may be sufficient to warp the pan even when the heat source is extinguished.

More settling and decanting of the juice is needed before cooking resumes. The semisyrup should cool to below 220°F. Then Hi-tempase alpha-amylase may be added. The semisyrup should be covered to retain heat and left for 8 to 12 hours (Houston, 1987). If proper methods of settling, decanting, and mixing alpha-amylase enzymes are used at the outset, these problems should not occur.

When a pan is full and functioning properly, a gradient of temperatures should exist. Preheating (slow or non-boiling) juice should fill the lowest end of the pan, approximately three to six baffles. As suggested earlier, skimmings should accumulate here. If problems arise that delay the flow of cold juice into the pan, a boil may begin at this end. To prevent any skimmings from boiling back into solution, skim at this time.

Always remember, if things get out of hand and panic starts, turn off the heat source. It seems like the obvious solution but is often forgotten under stress.

Our gas pressure for cooking is about 6 psi. We have not determined whether more or less pressure is better.

The Cooling Tray

As a general rule, the longer the liquid is exposed to heat, the lower the quality of the syrup. For this reason, we use a cooling tray at the finish end of the pan.

Cooling trays are clean, stainless steel surfaces over which the syrup flows to disperse heat. To speed cooling, KCSA's tray is equipped with a water-spray system on the undersurface of the pan. Another option is to extend the pan surface to increase the distance the syrup travels while losing heat.

The need for a cooling tray became painfully obvious to us our first year. At that time, we were pouring hot syrup from the evaporator pan immediately into the bottling tank. The syrup, still extremely hot, continued to cook and foam. The results were problems in bottling, dark coloration, and low-quality taste.

Our goal with cooling has been to stop cooking by reducing the temperature to below 180°F as quickly as possible, yet maintain a high enough temperature at bottling to ensure a tight seal and minimal microbial contamination. Apparently, reducing the temperature even further may be better from a quality standpoint.
Shutting Down

The KCSA staff gathered information from the NSSPPA, individual producers, Extension personnel, and old literature before setting up operations at Poteau Mountain. We also spent time getting hands-on experience with local, small-scale processors.

However, no one was around to advise us when we fired up for the first season. Things were going reasonably well at the start, suggesting that we had learned our lessons. Then we ran out of juice. None of us had any idea what to do. In our panic we let the syrup scorch severely, ruining much of that batch and condemning us to many hours of hard labor in cleanup.
Until then, we had only cooked on flat-mounted pans. Shutting down a flat-mounted pan when the juice runs out is much like starting up, only in reverse. Inclined pans, however, have juice and semisyrup levels higher than the baffles from midpan back to the lower end making such methods unworkable. Shutting down an inclined pan involves these steps:

1. Dividing the pan in half using a rag dam.
2. Replacing the juice and semisyrup in the lower end with water.
3. Continuing to cook using only the upper half of the pan.

As the last of the raw juice is added to the evaporator pan and allowed to preheat, all skimmings should be removed from the juice end before they are caught in a rapid boil and redisolved. Once the preheat portion of the pan has been boiling for a few minutes, shut off the heat source. This slows the pace of cooking and lets the cook and assistants work in a more relaxed manner.

A rag dam is placed at Point C as shown in Figures 6 and 11. Juice is drained into buckets from the lower spigot. As the level below the rag dam diminishes, a pushrag and paddle can be used to chase the juice and semisyrup, immediately followed by water to prevent the pan from warping. Keep in mind, the firebox may release enough heat without the blowtorch heater to buckle the unprotected evaporator. This process continues until all juice and semisyrup in the lower end of the pan is transferred to buckets, and water has been substituted. The heat source is now restarted.

Figure 11.
When raw juice runs out, a rag dam is built at C. Juice and semisyrup are drained into buckets. A paddle and pushrag (D) are used to force juice and semisyrup from the area below Dam C. A water hose is used to fill the area behind the pushrag.

The cook is now working with roughly half the cooking surface as before. The juice and semisyrup levels throughout the pan are all below the tops of the baffles and relatively easy to control. While finished syrup is collected and evaporation continues, the juice and semisyrup originally drained from the lower end of the pan can be carefully poured into the semisyrup end of the shortened cooking area (Figure 12).

When this supply of juice is exhausted and the semisyrup levels begin to drop, a pushrag and paddle are used to chase the semisyrup from the rag dam toward the finish end. Simultaneously, the dam is broken so that water can flow in behind the pushrag. A new dam is then made closer to the finish end.
This is repeated until all the semisyruop is contained in the finish end, and a rag dam is constructed at the gate. We treat the last of the semisyruop as a batch. Using push paddles, we combine the liquid from all the baffle areas in the finish section until it is uniform.

When finish temperature is reached, the heat source is turned off for the final time. The syrup is chased out, followed by water. This must be done very slowly and carefully, because water cannot mix with the finished syrup. A rag dam is left at the spigot to prevent water from leaking onto the cooling tray while the last of the syrup flows away.

At this point, the pan should be full of water and kept full until heat in the firebox subsides. Since so much hot water is available, this is an excellent time for cleaning paddles, scoops, skimmers, buckets, and other equipment. Self-skimming trays and outside edges of the pan should be scrubbed before any of the materials dry. Starch deposits and scorches on the pan surface are easier to clean after soaking in an acid cleanser.
COOKING ON A FLAT PAN

The more traditional sorghum pan seen on small farms in our region resembles the one below. When compared to KCSA's 16-foot inclined pan, it is often two to five feet shorter and lacks the self-skimming trays. It may also lack a lower drain spout and be more shallow. These pans are usually mounted flat on the firebox.

Flat pans are operated using a batch cooking procedure. The methods for moving juice and semisyrup described in Chapter 7 will work but can be accomplished easier. Water is removed merely by chasing it out in advance of the semisyrup, and scoops are seldom needed. Shutting down is also easier since water can be poured into the sections as semisyrup and syrup are evacuated.

The disadvantages are maintaining the pan in batch sections and moving these each time with pushrags. It is much more labor intensive than the inclined pan.

The batch sections may vary in number and position as the cooking day progresses (Figure 13). It depends largely on the judgement of the cook. Generally speaking, cooking on a flat pan may reduce output, but quality of syrup is not affected.
Figure 13. An overhead view of a flat pan divided into batch sections using rag dams.
FINISHED SYRUP

Bottling

After cooking, syrup is stored temporarily in stainless steel, bottling tanks. Bottling is done as soon as possible to reduce darkening of the syrup. Darkening comes from residual heat exposure. Filled jars are placed in the open air to cool. Immediate packing in boxes will retain heat and further darkening.

We bottle syrup at 130 to 140°F. Few bacteria, yeasts, or mold survive at these temperatures. Another benefit is the vacuum seal created in the jar or can as the syrup cools (Collins et al., 1987).

In trying to develop a lighter, milder tasting product, we are considering cooling the syrup longer and bottling at a lower temperature. To prevent contamination and spoilage, special attention will be needed to guarantee proper sanitation.

KCSA packages its syrup primarily in glass containers. While attractive plastic bottles are now available, we have been reluctant to use a packaging material that may not be recycled by the consumer. For shipping purposes, we also supply limited quantities in traditional syrup cans.
Marketing

The KCSA sorghum project inspired and paralleled the development of a sorghum festival held in October near Poteau. This has been a profitable outlet for much of our product. Other regional processors are also invited to sell their sorghum. KCSA syrup is also sold directly at Poteau Mountain, the main office, and the local farmers’ market.

Because demand has always exceeded our supply, we have not used creative marketing strategies, which may be necessary in the future. Presently the market for sorghum far exceeds production. Potential markets exist among health-conscious consumers in the northern states and overseas who have yet to taste sorghum syrup.

The current KCSA label.
OTHER METHODS OF PRODUCTION AND PROCESSING

Plant and Crop
Harvesting
Mills and Milling
Cooking
Enzymes
Packaging, Labeling, and Pricing
Economics
Sorghum and Sustainable Agriculture
PLANT AND CROP

Variety Selection

Sorghum is a tropical grass native to Africa. It first came to the Americas with imported slaves. Sorghum resembles corn in many of its characteristics and in the manner it is grown.

Sorgo, the term used for sweet sorghum, is only one of several types of sorghum. The sorghum family includes grain sorghums, such as milo and hegari; forages, like sudangrass and kafir; broomcorn; and Johnson grass, a perennial sorghum.

Also called cane, sorgo is distinguished by the abundance of sweet juice in the stems and typically tall height. Sorgo cane should not be confused with sugarcane, another tropical grass from which a sweet syrup can be made.

Several sweet sorghum varieties are currently available. All are open-pollinated or nonhybrid. They can be divided into traditional and improved categories. Sorghum is drought tolerant, particularly when compared to corn. Yield and syrup quality of any sorghum variety will suffer under a drought, although tolerance will vary.

Traditional varieties have been cultivated for generations and are still grown, almost religiously, by some farmers. When compared to improved types, they are more prone to lodging and disease. Yields are also lower. High syrup quality, whether real or perceived, is the main reason they are grown. One value of traditional varieties may be in specialty marketing where gourmet tastes are targeted.

While the loyalty of growers to traditional varieties appears to be nothing but nostalgia, these farmers have done the rest of us a favor by preserving raw, genetic material. When new varieties are developed, plant breeders search for desirable genes in commercially available seed and wild relatives. As quality and nutrition become important in gene selection, the diligence of these “hard-headed” folks will be appreciated.

Locating seed from traditional varieties can be challenging. Sugar Drip is the only one commonly sold through farm cooperatives and seed catalogues in the mid-southern states.

Other traditional varieties include Honey Drip, Texas Seeded Ribbon Cane, Sart, Orange, and Black Amber. Because so many names have been given to the same varieties over time, one may have difficulty knowing the true identity of the traditional types.

Improved varieties have come from breeding efforts during the last few decades. They are usually high yielding, relatively disease and lodging resistant, and produce high-quality syrups.
Disease resistance is an important factor, especially in traditional growing regions and areas where Johnson grass carries maize dwarf mosaic virus. Other diseases of significance are anthracnose, downy mildew, and bacterial leaf diseases.

Dale is probably the most widely grown of the improved varieties. It is a mid-season variety and widely adapted.

M81E, released in 1981, is a late-season type. In southeastern Oklahoma, it has produced a syrup somewhat lighter than Dale, and yields have been comparable.

Theis is a late-season variety, makes a mild syrup, and grows tall.

Brandes, somewhat later than Theis, has lodging resistance as its strong suit. It is susceptible to drought and should be grown on soils with good moisture-holding capacity.

Bailey, a release from Georgia, produces good quality syrup only at high elevations.

Della is the latest improved variety. Developed in Virginia by Robert Harrison, it was released in 1990, and little performance data is available. Della is similar to Dale but has improved seedling vigor and matures about one week earlier.

Many sorghum varieties are susceptible to damage by cotton insecticides, particularly organophosphates, like methyl parathion. Dale, Theis, and M81E are tolerant to these pesticides. Brandes, on the other hand, is easily damaged.

Table 1, distributed by Dr. Morris Bitzer at the 1990 NSSPPA meeting, compares yields of several traditional varieties to Dale. The yield advantage of an improved variety is clear.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Date Seed Head Emerged (a)</th>
<th>25 Stalks (lb)</th>
<th>Juice (b) (lb)</th>
<th>Brix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dale</td>
<td>8/03</td>
<td>27.2</td>
<td>14.6</td>
<td>19.0</td>
</tr>
<tr>
<td>Sugar Drip</td>
<td>7/24</td>
<td>16.9</td>
<td>6.4</td>
<td>20.5</td>
</tr>
<tr>
<td>Silver Drip</td>
<td>8/03</td>
<td>23.5</td>
<td>7.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Orange</td>
<td>7/21</td>
<td>15.1</td>
<td>5.3</td>
<td>20.0</td>
</tr>
<tr>
<td>Waconia Orange</td>
<td>7/29</td>
<td>21.2</td>
<td>8.3</td>
<td>18.5</td>
</tr>
<tr>
<td>Texas Double Sweet</td>
<td>7/25</td>
<td>21.5</td>
<td>7.9</td>
<td>19.0</td>
</tr>
<tr>
<td>Iowa-Miss. Line</td>
<td>8/02</td>
<td>22.0</td>
<td>8.8</td>
<td>20.5</td>
</tr>
<tr>
<td>Mennonite</td>
<td>7/24</td>
<td>18.1</td>
<td>6.5</td>
<td>21.5</td>
</tr>
<tr>
<td>Ames Amber</td>
<td>7/19</td>
<td>17.6</td>
<td>7.4</td>
<td>20.5</td>
</tr>
<tr>
<td>Simon</td>
<td>7/17</td>
<td>14.6</td>
<td>4.7</td>
<td>21.5</td>
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<tr>
<td>Umbrella</td>
<td>7/31</td>
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</tr>
<tr>
<td>Blackstrap</td>
<td>7/17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honey Cane</td>
<td>8/01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) Extracted from 25 stalks on September 11, except Dale milled on October 6.
One can extend the productive life of a variety using cultural methods that suppress diseases and insect pests and enhance the vigor of the crop. Crop rotation is particularly important, because several improved varieties have become susceptible to diseases that can be controlled by this practice.

**Saving Seed**

Since sorghum is largely self-pollinating and none of the varieties are hybrids, saving seed for planting in later years or for sale is a viable option. In most varieties, the soft-dough stage signals the time for syrup harvest. However, the developing seed is less vigorous than fully matured seed. To overcome this problem, growers leave one or more rows of sorghum specifically for harvesting seed.

If more than one variety is grown in a limited area, cross-pollination is a possibility. While some desirable characteristics may arise, growers are seldom able to capture them. Keeping varieties pure guarantees more predictability in crop performance year to year. To ensure reasonable purity of farm-grown seed, allow at least 650 feet between varieties. More distance is required where prevailing winds increase the likelihood of cross-pollination.

Once harvested and cleaned, seed should be put in a tight container and stored in a cool area. A freezer is an excellent place to store sorghum seed. After a number of years, Foundation seed stock should be purchased to certify the purity of improved varieties. Seed companies are listed in Appendix 2 of the manual.

**Crop Culture**

Yield and quality of sorghum syrup are dependent on many factors: variety, soil type, fertility management, insects, diseases, climate, weather, and cultural practices. While field production of sorgo for syrup is straightforward for those already accustomed to growing grain sorghums or corn, certain points need special attention.

**Site and Soil Selection**

Well drained loams and sandy loams are ideal, although production is done on a much wider range of soils. Poorly drained and clayey soils are not recommended. Shallow soils and soils low in organic matter may cause problems during a drought. Soils high in organic matter, such as mucks, are also not advised, because excessive nitrates lower syrup quality.

**Crop Rotations**

A traditional saying is, "Sorghum is hard on the soil." There is considerable basis for this belief. It is probably rooted in one or more of the following: fertility depletion, moisture depletion, or nitrogen tie-up.

In most harvesting methods, the entire stalk is removed from the field leaving little plant residue. Removing the whole plant takes significant quantities of essential nutrients. The lack of residue also increases the chance of erosion, another factor in soil depletion.

A drought tolerant crop, sorghum roots forage the soil more thoroughly for moisture than most row crops. In regions of marginal rainfall or untimely drought, this can affect the following crops and cover crops.

The high sugar content in the roots of sorghum can cause the tie-up of available soil nitrogen by bacteria as they decompose the subsurface residue. The breakdown of sorghum roots in the
Other Methods of Production and Processing

soil by bacteria requires much nitrogen from the soil—making it temporarily unavailable to the next crop.

A winter cover crop of inoculated legumes, such as vetch, clovers, or winter peas, should follow sorghum. Because sorghum is harvested quite late in the fall, establishing a cover crop may be difficult.

Crops planted the next spring or summer will likely be unaffected by moisture depletion unless the winter is exceptionally dry. Spring- and summer-planted, nonleguminous crops should not suffer nitrogen depletion if sufficient time is allowed for decomposition of the sorghum roots and residue.

Since moisture depletion and nitrogen tie-up are temporary conditions, their effect on long-term soil fertility relates primarily to the difficulty in establishing winter crops or other soil cover following sorghum. Fertility depletion, however, should be addressed through sustainable farming practices.

Proper crop rotation has long been a means of maintaining soil fertility. It is also a strategy for managing weeds, insect pests, and diseases. In sorghum, crop rotation can help suppress several bacterial leaf diseases, anthracnose, wireworms, and other pests.

It is possible to grow sorghum after most crops with the exception of tobacco (Bitzer, 1987). Tobacco is a heavily fertilized crop, and the carryover has a negative effect on syrup quality. Because syrup quality is lowered by excessive soil nitrates, sorghum should not follow leguminous green manure crops or spring-plowed legume forages. Where winter cover crops are plowed down in advance of planting, small grains, other grasses, or brassicas are better than winter legumes.

Sorghum has successfully followed corn and cotton (Stokes et al., 1957), small grains, soybeans, spring-planted English peas, southern peas, most vegetable crops, and fallow. Weeds may be a problem when planting sorghum after corn.

Irrigation

Based on the experience of a limited number of growers, sorghum appears to respond well to irrigation. Also, our observations during the 1989 season suggested irrigation may increase juice Brix.

The crop forms seed heads in late summer. Moisture stress at this stage results in a type of dormancy. Irrigation or late rains restore plant growth and trigger the development of secondary seed heads. It is unclear to what extent this influences syrup quality, but yield loss is likely due to the dormancy period.

Fertilization

A persistent myth is that good syrup can only be made from cane grown on poor soil. While much research needs to be done, this generalization has not been proven.

Research has shown that high soil nitrate has a negative effect on syrup quality. Excessive nitrates in the soil can come from green manures, fresh barnyard manures, or commercial fertilizer.

As suggested earlier, not planting forage or plowdown crops of pure legumes will help prevent excess nitrates. Also, while manures may certainly be used for sorghum production, they
must be managed properly. Unless well composted, do not spread manures in late winter or spring before planting. According to experienced growers, proper management of poultry manures is especially important. Application and incorporation during the summer or fall of the previous year should provide sufficient time for necessary decomposition and the reduction of nitrate and other salts.

Commercial fertilizers should have a ratio of 1:1:1 and not exceed 50 pounds N on average soils or 40 pounds N on more fertile ground. Do not use nitrogen fertilizers for side-dressing. Organic fertilizers, such as tankage and cottonseed meal, are good starter fertilizers. Side-dressing with organic nitrogen sources is also not recommended. These fertilization guidelines reduce the possibility of excessive soil nitrates.

Ideal soil pH appears to range from 6.0 to 6.4. The amount of lime applied should be determined by soil calcium levels and base saturation rather than pH. Avoid using dolomite (high magnesium) lime, because this material often causes soil nutrient imbalances.

Farmers may also use colloidal clay phosphate and/or rock phosphate, other rock powders, humates, and basic slag to increase soil fertility for the long term. Their selection and application should be guided by regional availability, soil test results, and comprehensive information on the product being considered.

Composted materials are also used to improve fertility. Caution is warranted when dealing with urban and industrial wastes. They may be contaminated with heavy metals, such as lead and arsenic, and should be avoided.

**Planting Dates**

Recommended planting dates for grain sorghum can be used for planting sorgo. Soil temperature should be 65°F or higher. Early planting is not encouraged when the risk of cold, wet weather is significant. Sorgo seed is not vigorous under these conditions, and poor stands can result. Shorter season varieties can be planted late, through June in southern Oklahoma and Arkansas. Planting much later increases the risk of loss to midsummer droughts and early freezes. Late planting also increases susceptibility to diseases.

**Seeding Rates and Row Widths**

Sorgo can be sown with equipment used for corn, cotton, or grain sorghum production in row widths from 30 inches to more than 40 inches. On-farm research in Alabama tested skip-row planting and had favorable results (Sluten, 1987). It was adopted in a modified form by KCSA.

A final stand of two to three plants per row foot is the current recommendation in most areas. Many traditional growers leave as much as 14 inches between plants. Helm and Beasley (1942) suggested leaving 8 to 10 inches. Wide spacing was probably done to reduce labor in hand stripping and harvesting and to increase drought survivability.

Typically, two to four pounds of seed per acre are required. The actual number of seeds per pound varies little from variety to variety. Dale has about 26,000 seeds per pound; Sugar Drip, 25,000; and M81E, around 24,500. Germination tests should be done before planting.

Thinning with a hoe to achieve desired spacing and to control in-row weeds is another traditional practice, more common in the days of cheap labor. Hoeing is limited mostly to small plantings and large families. It is best to wait until the plants are about three inches tall. Complete thinning early to avoid root damage to remaining plants. If weeds are a problem, cultivate first. Less time will be spent hoeing weeds that the cultivator may remove.
Other Methods of Production and Processing

A farmer from Kentucky, Danny Townsend, proposed the concept of transplanting seedlings as an option for sorghum production at the 1991 NSSPPA meetings. Employing equipment and techniques used for tobacco, transplanting may eliminate early weed pressure.

Weed Management

Weeds are controlled in sorghum by integrated methods: namely, fertility management, crop rotation, prevention, and cultivation.

Many weed problems originate from poor tillage and fertility. Various weeds function in nature to bring soil back into balance by fixing certain nutrients or by aerating the soil. Their presence can actually be used to guide soil management (McCaman, 1985). Some individual weed problems can be managed by proper liming to adjust pH, provide calcium, and stimulate biological life in the soil.

Annual crop rotation controls weeds in large part by alternating the cultural practices and the nature of the competing vegetation. It is especially handy in controlling perennial and biennial weeds.

Use cleaned seed for all crops in rotation. When buying seed, read the label for information on weed seed content. Such precautions can keep problem weed infestations isolated and prevent the introduction of new weed species. Also check equipment when driving to different fields for accumulations of weed seeds, roots, or rhizomes.

Slow seedling emergence and growth make weed control by tillage difficult in the early part of the year. "Blind" cultivation using harrows and rotary hoes may be risky after germination, because sorghum seed is small and not planted as deeply as corn, soybeans, or sunflower. Delaying planting until conditions for germination approach optimal is a good strategy.

Once cultivation begins between the rows, traditional wisdom advises that it be repeated as soon as possible after each rain. The soil has to be dry enough for working even though many weeds may not be visible. Weeds are most easily killed when young and just emerging.

In most cases only shallow cultivation is needed. This is important as the crop matures since root systems can be easily pruned, reducing yield and increasing susceptibility to drought. As the crop grows, tractor speeds can be increased and shallow tillers used to throw soil at the base of the plants to smother weeds in the row.

Where perennial weeds, such as quackgrass or bindweed, are problems, deeper tillage using narrow cultivating shoes may be needed. This should be limited to the early part of the season. Cultivate deeply only toward the middle of the furrow.

No herbicides are currently labeled for sorgho because of its limited acreage in most states. We encourage growers to try alternatives to herbicides as a general rule. In our opinion, reducing the use of agrochemicals contributes to the long-term sustainability of our agriculture. If circumstances dictate the use of a herbicide or any other pesticide, please read and follow all label directions.

Other Pests

Most insects and diseases can be managed by planting resistant varieties, clean tillage, crop rotation and by controlling alternate-host vegetation, like Johnsongrass.
Birds are a problem in many areas but only to the seed crop. Among the more effective deterrents are the Avalarm system, which emits a simulated distress cry, and the Scare-cye balloon, which mimics predatory owls.
HARVESTING

Judging Maturity

The decision to harvest is made after evaluating seed head maturity, juice Brix, crop condition, and maturity dates for specific varieties. Sorghum cane should ideally be harvested at maximum sugar content. Since conditions vary year to year and bottlenecks in processing happen, perfect timing is illusive.

Sorghum can hold peak sugar content for one to two weeks. After this point, conversion of sugar to starch accelerates. The farmer can anticipate starch problems when processing overripe sorghum cane.

Most varieties approach maximum sugar yield between mid- to late-dough stage of seed development. Many producers continue to rely on this method for scheduling harvest.

Others use refractometers to determine sugar content. Refractometers are hand-held instruments designed to measure the bending or refraction of light rays as they pass through liquids. The greater the amount of dissolved solids in a liquid, the higher the refraction. This is measured on a scale called degrees Brix, or percent dissolved solids.
In performing this test, juice is extracted from several representative stalks in a field and viewed through the refractometer. Most growers begin harvest at about 16°Brix. Brix readings of more than 20 degrees have been recorded on well managed soils in Georgia and Alabama.

A single Brix reading may not be representative of the actual sugar content of the crop at any one time. For instance, if a sample is taken shortly after a rain, the Brix may read low. During a drought, it may register high. Degrees Brix should be monitored with time, taking into account weather conditions before and during the time of plant sampling.

Determining the Brix of harvested juice is also of value in predicting syrup yield. Table 2 gives expected syrup yield based on Brix and Baume readings.

<table>
<thead>
<tr>
<th>Baume of Juice</th>
<th>Brix of Juice</th>
<th>Gallons of Juice per Gallon of Syrup</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>10.68</td>
<td>10.0</td>
</tr>
<tr>
<td>6.5</td>
<td>11.57</td>
<td>9.0</td>
</tr>
<tr>
<td>7.0</td>
<td>12.46</td>
<td>8.5</td>
</tr>
<tr>
<td>7.5</td>
<td>13.35</td>
<td>8.0</td>
</tr>
<tr>
<td>8.0</td>
<td>14.24</td>
<td>7.5</td>
</tr>
<tr>
<td>8.5</td>
<td>15.13</td>
<td>7.0</td>
</tr>
<tr>
<td>9.0</td>
<td>16.02</td>
<td>6.5</td>
</tr>
<tr>
<td>10.0</td>
<td>17.80</td>
<td>6.0</td>
</tr>
<tr>
<td>11.0</td>
<td>19.58</td>
<td>5.5</td>
</tr>
<tr>
<td>12.0</td>
<td>21.36</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Source: 1987 NSSPPA meeting.
* Based on 76°Brix syrup.

Refractometers can be purchased for as little as $150. One is needed to measure juice Brix (0 to 32 percent), and a second one is needed to gauge syrup Brix (45 to 82 percent). More expensive models, designed to measure the full range of Brix, can also be used in the cooking process. This may present a savings when compared to the cost of two refractometers; however, the finer graduations on the wide-range models are often more difficult to distinguish, and accuracy may be sacrificed.

An alternative to the refractometer is the hydrometer, a standard instrument used to measure the density of liquids (Figure 14). It works on the principle that objects will float higher in a liquid with a high percentage of dissolved solids. Hydrometers are usually calibrated in the Baume scale. They are slower and more clumsy to use than refractometers and less precise.

Hydrometers will not work well in heavy, thick liquids, like finished sorghum syrup. Also, hydrometers containing mercury are prohibited in the manufacture of food by the Food and Drug Administration (FDA).
Stripping and Topping Cane

Many old-time sorghum cooks insist that quality syrup can only be made if all leaves are removed or stripped from the stalk before milling. This probably remains the single greatest conflict among producers today.

Supporters have argued that milled leaves contribute undesirable taste and color to the final product. Stripping leaves has benefits including:

1. More crop residue remaining on the field.
2. Less tonnage in hauling, milling, and handling waste.
3. Higher juice recovery during milling.
4. Less filtration and settling required.
5. Great physical exercise.

While many producers have talked about designing mechanized stripping equipment, we are not aware of any. Stripping leaves remains a highly labor-intensive activity.

Traditional leaf stripping is usually accomplished by equipping field workers with lightweight wooden “swords,” which are used to strike the leaves from the stalk. Under optimal conditions, two to four strikes per plant removes most leaves. According to the literature, one person may strip from 1/5 to 1/2 acre per 8 hour day depending on plant population, stamina, and enthusiasm.

Removal of seed heads is also an important task in sorghum cane harvest. Seeds clog the strainers at the mill and can cause an unacceptable flavor. Since the top internode (peduncle) contains considerably less sugar than the remainder of the stalk, it should also be removed.

A traditional method in hand-harvest systems involves laying the bundled or loose cane in a uniform row on a truck or wagon, with the seed heads extended over the edge. A chain saw or gas-powered hedge trimmer can then cut off the seed heads. When row binders or choppers are used, powered sickles, rotary mowers, and small bushhogs can be mounted on adjustable-height, front-end loaders to trim the seed heads immediately in front of the binder. The modified Hi-Boy trimmer is another application of this method.
Cutting Cane

The optimum cutting height for sorghum cane is about six inches above the ground. Cutting methods range from labor-intensive hand cutting to mechanized forage heads mounted on choppers or field mills.

Hand cutting can be done with any tool suitable for severing thick-stalked vegetation. Machetes and corn knives are two of the more effective implements (Figure 15). Some old-time growers use a sharpened hoe attached to a shortened handle. A novel concept features a sharp knife attached to a stirrup, allowing the worker to hold the cane while cutting the stalks with a kick (Figure 16). Hand cutting has been done in two or three person teams. One or two people hold the stalks while another cuts the cane using a long-handled pole with a hooked blade at the end or a full-length, sharpened hoe. Estimates for one person hand cutting an acre of sorghum cane vary from 15 to 21 hours depending on the reference.
A horse-drawn tool employed in the past for cane and corn harvesting consisted of a small sled with a seat in the center. Large, winged blades set on the sides cut a row of cane as the sled was drawn alongside. The rider would catch the cane across his or her arm until a suitable amount had collected. This was then dropped to the side.

More common today in both horse-drawn and tractor operations is the use of vertical row binders. Patented by A.S. Peck of Geneva, Illinois, in 1892, these implements have been used to cut and bundle-tie sorghum and corn. Binders may be powered by tractor pto or by a ground-driven “bull wheel.” Binders having a bull wheel were designed for draft animals.

Manufacturers developed two basic types of heads for these machines, long and short. Binders had either bundle carriers, which dropped the bundles on the ground and away from the next row or bundle elevators, which carried the bundles to a wagon where they were stacked by hand.

Like sorghum mills, vertical row binders are now archaic technology. No major company continues to make these machines, and replacement parts are difficult to find. At KCSA several
scrap binders were bought for parts to keep others operating. Farmers who have experience in running and maintaining such equipment are the best sources of information. Information can also be found in used book stores or in reprints and articles in current, popular journals (see Appendix 1).

Many of these binders were intended for draft animals, and they should be handled accordingly. Horse-drawn implements were designed to withstand the stresses and speeds associated with draft animals, not high-powered tractors. If attached to a tractor, horse-drawn equipment will last longer if treated with this in mind.

Large-scale production systems require more mechanization. Because sorghum machinery is scarce, farmers have taken the initiative and created what they needed. Forage harvesters, for example, have been converted into sorghum cane harvester/choppers. The harvesters field chop the cane, which is then hauled to a stationary mill. The plant material is run through a shaker-blower to remove leaves and other chaffy debris before milling. One homemade unit incorporates the shaker-blower and the mill as part of a self-propelled machine.

Another option bypasses the chopper entirely. After cutting, the stalks are immediately fed into rollers. Because green leaves are also milled, questions of syrup quality have been raised. Considerable detail on these harvesters is given in “Single-Pass Harvesting of Sweet Sorghum” (Miller et al., 1990).

Handling Stalks

Generally, any activity that breaks the rind of the stalk will cause loss of juice and increase handling difficulty. Reasonable care should be taken to avoid driving over bundles or damaging the stalks in any way.

Whether stripped or not, stalks can be stored seven to ten days following cutting with no loss of syrup yield or quality. This delay may actually enhance syrup quality, because desirable enzymatic changes happen within the stalk. These changes involve the action of naturally-occurring invertase. Invertase breaks down sucrose into simple sugars, preventing crystallization of the syrup. Allow at least three days between cutting and milling, particularly when the cane is unstripped.

The weather influences the way cane is handled between cutting and milling. Rain-soaked cane can have quality problems. Many producers report darkened syrup from wet cane. When leaves are left intact, molds and stalk and leaf rots are a possibility. This is especially true if hauling and milling are delayed.
MILLS AND MILLING

Mills

The three-roller mill has become the standard in extracting cane juice. It was invented by Pietro Speciale, the Prefect of Sicily, in 1449. The rollers were fastened vertically, and this type of mill supplied almost all of the world's sugar for close to 350 years.

The design is typified by horse- or mule-driven mills, commonly seen in very small sorghum operations and in traditional demonstrations at festivals and fairs. They are still easily found in the South and Midwest. Many have been adapted to gasoline engines or electric motors.

Larger and more modern mills are of a horizontal design but still have three rollers. Power is usually supplied by stationary engines, electric motors, tractor pto, or hydraulics.

Most small- and medium-scale producers purchase and refurbish old mills, although a few have built new ones. The major problems with using old mills are metal fatigue and the difficulty in finding replacement parts. While most foundries have the capability of making them, the cost is often prohibitive. Like row binders, get a second mill for backup, or keep several old mills of the same model for parts.
Maintaining a mill requires the same common sense applied to other equipment upkeep. Because bearings work at low speed, lubrication can guarantee a long life if not otherwise abused. Running the mill at a correct feeding rate and speed will make it last longer and decrease downtime.

It is important to use only food-grade grease on any portion of the mill where the lubricant might come into contact with either stalks or juice. This includes all roller bearings. Food-grade grease can be bought from most apiary (beekeeper) supply houses and from suppliers to the food industry.

**Milling**

Efficiency of juice extraction is the goal of milling. It is accomplished by proper maintenance of the roller surfaces, accurate spacing of the rollers, correct roller speed, and skilled feeding of the mill.

Most rollers on three-roller mills are grooved. The surfaces are neither convex nor concave, so any adjustment is uniform along the length of the rollers’ interface.

After several seasons of use, the center of a set of rollers may become concave since cane is normally concentrated there during milling. Regrinding and regrooving are required for continued extraction performance. When rollers have been repeatedly ground and can no longer be properly adjusted, they can be sleeved with new metal and lathed to original size.

Spacing of rollers on three-roller mills is standard; however, each unit should be checked for imprinted instructions to the contrary. A 3/8 inch gap is needed between feeder and top rollers, and a 1/16 inch gap between the expeller and top rollers. Adjustment bolts are positioned on each end of the smaller rollers and are used to set the gaps.
The current recommended speed for a three-roller mill with a top roller diameter of 12 inches is 7.5 rpm for the top roller. The speed of top rollers on smaller mills is closer to 9 rpm. This contrasts with earlier recommendations that called for top roller speeds of 9 to 11 rpm for large mills and 10 to 12 rpm for small mills (Freeman et al., 1986). A study in Tennessee found top roller speeds ranging from 4.8 to 11.4 rpm, with most averaging close to 8 rpm (Wilhelm and McCarty, 1985). Trials carried out by farmers have shown that as much as 20 percent of the potential juice yield is lost by increasing mill speeds from 7.5 to 12 rpm (Wilhelm, 1987).

One way to check a mill for extraction efficiency is to weigh 100 pounds of stalks, mill them, and weigh the extracted juice. An effective mill will squeeze about 45 to 50 pounds of juice per 100 pounds of cane.

Efficient feeding of the mill requires steady pushing of the stalks, butt end first. Capacity of mills will vary, but maximum capacity should be maintained as much as possible. A properly set and operated mill will expel stalks with joints breaking over as they leave the last roller. Cane waste should be dry to only slightly sticky.

Mounting sorghum mills for optimum performance is important and highly dependent on the situation. Most mills are stationary mounted. Sorghum cane is brought from the field to the mills for juice extraction. Increasingly, mills are placed on wagons or trailers, and crushing is done in the field. In all cases, no matter the power source, mills must be firmly anchored and set at a comfortable, safe height for hand feeding.

Most mills intended for draft-animal power have rollers fixed vertically, although some horizontal ones were built. Traditional horse-driven mills are often supported by upright posts sunk into the earth. A long, wooden drive pole is laid across the mounting bar of the drive shaft. It is important that the end of the drive pole opposite the horse hitch is counterbalanced to reduce stress on the mill and mountings.
Where draft animals are used to operate the mill, a light lead pole is attached at 90 degrees to the drive pole, with a rope run back to the halter. This makes the animal walk in a circle. It is wise, especially with skittish stock, to use a lightweight linkage between the hitch and the drive pole to prevent unseating the mill in event of a runaway. The draft power needed at the end of the drive pole is actually quite low, so a light linkage can deter costly damage.

In some instances, small-scale producers have substituted small tractors at the end of the drive pole to run their mills. One southeastern Oklahoma farmer actually lets the tractor “run free.” The tension of the drive pole causes the wheels to naturally angle and guide the tractor in a circle, without a driver. Since the potential for an accident is high, such arrangements are discouraged.

Energy from electric motors or gas or diesel engines has also been successfully applied to vertical horse-driven mills. Some form of speed reduction must be used between the power source and mill. Truck and tractor transmissions have often been recycled to serve this purpose.

Horizontal mills, designed for engines and motors, have also been modified to draft-animal power. Horse-driven treadmills are one example.

Horizontal mills are usually made with gear reduction attachments, allowing direct hookup to the power source. Belt and pulley drives from farm tractors are common and easily adjusted. Engine speeds usually range from 375 to 425 rpm (Walton et al., 1938). Adjustments in engine rpm should always be based on proper roller speed.

Safety is a major consideration at any mill. Shielding of belts and gears and an easily accessible, rapid shut-off should be maintained.
Chapter 13

COOKING

Using Wood

As costs of fossil fuels rise, cooking with gas will become less economical and less suitable from a planetary viewpoint. Using firewood to heat evaporator pans will probably increase, especially among those considering a small-scale enterprise (Figure 17).

![Figure 17. A 15-foot, batch-type evaporator pan mounted on a wood-fired box.](image)

A damper built into the chimney helps control heat during cooking. However, avoid closing the damper as much as possible. Restricted airflow results in the release of unburned hydrocarbons from the wood fire, adding to air pollution and reducing fuel efficiency.

A garden hose with a jet nozzle provides added control, especially with an extremely hot fire. It is also handy for extinguishing the fire when cooking is finished for the day.
Several farmers use sawmill slabs for fuel. Depending on the size of the firebox, wood is cut into pieces three to five feet long. Old fence posts sawed in half also work well. Scrap construction wood is good, but check for any pieces with exposed nails. It takes little force to puncture the bottom of an evaporator pan if something sharp is carelessly thrown against it.

While using a renewable fuel has its advantages, there are drawbacks. Controlling the fire in a consistent manner is difficult. More labor is needed for stoking and damping. Opportunities for contaminating syrup with particulate matter also increase. Burning wood to produce steam is a better option if affordable.

Using Steam

Steam supplies the ultimate control in cooking. Training and licensing is required to install, operate, and maintain a boiler. It is also expensive and better suited to a large-scale operation. However, smaller boilers are available and may be adapted to a smaller facility.

Steam is highly desirable from a production standpoint. Besides heat for cooking and hot water for cleaning, steam can be used to preheat the sorghum juice. Preheating to a slow boil of 190 to 205°F:

1. Allows mixing of alpha-amylase enzymes to break down starch before cooking.
2. Increases formation of coagulants, which are easily skimmed before cooking.
3. Permits filtration of juice.
4. Allows juice to be held overnight at a high temperature instead of refrigeration.

Preheating tanks can be of many types. The most efficient are rectangular with a skimming trough at one end. A wooden skimming pole is used to remove coagulants in one motion. Placement of heating elements is critical and should be well studied before new tanks are designed and built.

Preheating and skimming allows the processor to filter juice. Cold, raw juice cannot be filtered, only coarsely strained. The abundance of fine, uncoagulated materials in raw juice clogs filters. Preheating and skimming removes most of them. Diatomaceous earth filters are one type used in filtering sorghum. They are expensive and may not be appropriate to small-scale operations.
Preheating tanks at the Donald Eck Farm, Bartlett, Kansas, 1990.

Preheating can be a drawback when the processor holds the juice for an extended period of time, like overnight. Heat increases the formation of color and flavor compounds that may reduce the quality of the syrup.

**Multiple-Pan Systems**

Another benefit of steam is that it enables the use of multiple-pan cooking systems. It is common to find these systems among intermediate- and large-scale producers.

A modified Stubbs pan at the Donald Eck Farm, Bartlett, Kansas, 1990.
Other Methods of Production and Processing

Typically, one pan is used to make semisyrop. One type of semisyrop pan is a modified Stubbs pan (Henrickson, 1958). Semisyrop leaves the pan at 38 to 45° Brix and is transferred to a finish pan. Finish pans can be a batch design, continuous-flow, or another modified Stubbs.

Some larger setups also combine a vacuum kettle as a third cooking unit to finish the syrup. Final evaporation can be done at a lower temperature with a vacuum kettle. This reduces exposure to high heat, the threat of scorching, and development of color compounds.

Processing on a Large Scale

A diagram of a large-scale processing center is shown in Figure 18. It is based on an operation in Arkansas. Steam supplies the heat for all activities. Sorghum pummies, the cane waste, furnish a large portion of the fuel for the boiler.

![Diagram of a large-scale processing center](image)

Figure 18. A diagram of a large-scale processing center.

A second type of large-scale processing facility is presented in Figure 19 and depicts an enterprise in eastern Tennessee. A batch cooking system is employed, and steam can instantly be turned on and off without the danger to the cooking pans as described in Chapter 7. Semisyrip or syrup can be completely emptied from a pan without chasing the liquids. Juice is converted to semisyrip in the three large pans as individual batches. Each batch, in turn, is routed to the single finishing pan, where it is cooked to a syrup and removed.

Batch cooking is not limited to large, steam operations. A description of a small-scale batch method is in the book *Foxfire 3* (Wigginton, 1974).
Figure 19. A diagram of a large, batch-type cooking facility.
ENZYMES

Enzymes are proteins that act as catalysts in accelerating certain chemical changes. They are among the contemporary improvements in sorghum production. Two types of enzymes are currently used—alpha-amylase and invertase.

Alpha-amylase

Alpha-amylase enzymes have the specific function of breaking down starch into sugars and dextrins. Depending on a number of conditions, such as weather and variety, sorghum juice will contain varying amounts of starch. High levels of starch act as a thickening agent. Thickening can occur during cooking, resulting in scorching and other problems. It can also happen much later in the syrup. Then it is called gelling.

Starch occurs naturally in packet-like units called granules. In these granules, starch remains insoluble, nondispersible, and generally resistant to the action of enzymes. For enzymes to be effective, granules must be ruptured, and the starch must be soluble. This can be done by preheating the juice to between 140 and 180°F.

Being proteins, enzymes are destroyed (denatured) at high temperatures. Several amylase products have been developed to function at higher temperatures. The Hi-tempase enzyme acts in a temperature range of 150 to 220°F. Mixed into the cold juice before settling, it does not actually work until the juice is preheated at the lower end of the pan. Where processing is done with steam and juice is preheated, the enzymes can be added to the preheated juice.

The enzymes have a limited time to break down starch before the juice reaches 220°F. Fortunately, a little (about one ounce per 100 gallons) goes a long way and works rapidly. In three to four minutes, enough starch is converted to prevent gelling.

Invertase

Crystallization of sorghum syrup develops because of the predominance of sucrose, a disaccharide sugar. Invertase can be used to convert sucrose to the monosaccharide sugars, glucose and fructose.

Invertase can be added at several stages in the process. Since it becomes totally denatured at 150°F, it cannot be blended with hot juice or semisyrup. Cool the finished syrup to 140°F, mix the enzyme (approximately one quart per 100 gallons), and bottle the syrup.

There are several problems with invertase. First of all, sorghum is a three-sugar syrup containing sucrose, glucose, and fructose. Under ideal circumstances, these sugars should be
Other Methods of Production and Processing

present in roughly equal proportions. Too much glucose, like sucrose, can also cause crystallization. Unless one knows the approximate proportions of sugars in either the juice or syrup, one cannot tell whether using invertase will be a waste of money or possibly even create a new problem. Tests to determine the percentages of various sugars are unfortunately too complex and costly for farm application.

A second problem was recently reported. A processor added invertase to finished syrup. It was not reheated (above 140°F), and the invertase continued to work in the bottles until nearly all the sucrose was inverted to glucose and fructose. Because no sucrose was found after running standard tests, the FDA charged the producer with mislabeling the sorghum syrup. Fortunately, these people were able to prove their innocence later.

KCSA has routinely used alpha-amylase but has not added invertase. By letting several days pass between cutting and milling, natural invertase in the stalks appears to invert enough sugar to prevent crystallization. Excessive inversion is stopped once the juice is heated, leaving sufficient sucrose in the syrup to satisfy the regulators.

While delayed milling of cut sorghum stalks starts the action of natural invertase, it does not affect the breakdown of starch through amylase activity. Starch granules must first be ruptured by heat.

The lower the temperature, the more likely sorghum will crystallize or "sugar." We were told to put the phrase, Refrigerate after opening, on our label (see p. 42). This was false advice. Refrigeration of sorghum is not necessary and actually enhances crystallization.

Labeling Requirements

Processors are not required to list enzymes on the label, because they are protein catalysts and used in such small amounts.

Sources and Storage

One of the members of the NSSPPA has sold small quantities of enzymes to other members. Most commercial suppliers sell in large quantities that are too costly and wasteful for small producers. Manufacturers of enzymes are listed in Appendix 2.

Enzymes are not stable over long periods of time. Unless refrigerated, liquid enzymes will last only six months and dry enzymes about one year. Refrigerated enzymes will keep up to four years, but a loss of at least 25 percent potency is expected (Fox, 1987).
PACKAGING, LABELING, AND PRICING

Attractive packaging and promotion is vitally important to marketing sorghum outside the immediate community. Sorghum is traditionally sold in four-pound cans. In many rural communities this is still preferred. However, cans have limited appeal to the wider, contemporary market. Decorative, plastic containers are currently the rage among producers. Plastic is probably the most marketable packaging, followed by glass.

Labels for sorghum must meet minimum requirements for information displayed. Contact the State Department of Agriculture for specifics.

In some cases weight is presented in terms of liquid ounces only. When actual weight is required, Table 3 will help in making conversions.

| Table 3. Net Weights: Pounds of Sorghum Syrup Versus Liquid Ounce Capacity. |
|-------------------------------|--------|--------|
| 1.0 lb                        | 11.5 oz| (to bottom of neck ring) |
| 1.5 lb                        | 17.2 oz|
| 2.0 lb                        | 22.9 oz|
| 2.5 lb                        | 28.7 oz|
| 4.0 lb                        | 45.8 oz|
| 5.0 lb                        | 57.3 oz|

If a large volume of production and eventual sales to supermarkets are anticipated, consider getting a Uniform Product Code (UPC). For more information contact: Uniform Code Council, Inc., 8163 Old Yankee Rd., Suite J, Dayton, OH 45458.

Sorghum is one of the few, farm-produced commodities that does not leave the farmer a hapless victim of the marketplace. As long as supply continues to lag well behind demand, farmers can continue to charge profitable prices on both retail and wholesale levels.

Small- and intermediate-scale processors, selling in one-gallon containers or smaller, should expect a retail price of at least $18.00 per gallon. If selling to a tourist or specialty market and concentrating on smaller containers, one might get closer to $22.00 per gallon. Wholesale prices will, of course, be lower but should not be less than $13.00 per gallon. These are ballpark figures and are presented only to give the new producer a starting point.
Other Methods of Production and Processing

A recent survey of producers in Tennessee showed that retail prices averaged $16.62 per gallon in 1988 and $17.35 per gallon in 1989 (Jenkins et al., 1991). Wholesale prices received were $12.93 per gallon and $13.21 per gallon in the same years, respectively.

There are many good reasons not to cut prices once they are set. Reducing price and increasing volume seldom increase income. It may actually reduce it, especially if one fails to meet costs. Price cutting also suggests lower quality or desperation of the seller. It encourages buyers to hold out for even more discounts. It is better to spend time and money establishing new markets where a quality product will be appreciated or to spend more on promotion.

Farmers should be among the last individuals in American society to be shy about demanding maximum fair prices for their products, considering the small percentage of income spent by citizens for food.
ECONOMICS

Good economic information on starting and operating a sorghum enterprise is difficult to find. Being a specialty crop grown on limited acreage, little support is available for budget updates as commonly done on most major crops.

KCSA has developed one of the most recent budgets for sorghum production. Table 4 is adapted from The 1986 to 1989 Project Summary of The Kerr Center for Sustainable Agriculture, Inc. The low yield of 109 gallons per acre is due to KCSA's commitment to evaluate traditional varieties, such as Sugar Drip and White African, which are very low yielding. Improved varieties, such as Dale and M81E, have yielded from 130 to 150 gallons per acre.

<table>
<thead>
<tr>
<th>Table 4. Variable Costs and Returns Per Acre of Sweet Sorghum at Poteau Mountain Farm in 1989.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
</tr>
<tr>
<td>Sweet Sorghum Sales (109 gal @ $18/gal)</td>
</tr>
<tr>
<td>Variable Costs</td>
</tr>
<tr>
<td>Land Preparation</td>
</tr>
<tr>
<td>Seed and Planting</td>
</tr>
<tr>
<td>Fertilizer and Application</td>
</tr>
<tr>
<td>Cultivation</td>
</tr>
<tr>
<td>Harvest (labor and machinery)</td>
</tr>
<tr>
<td>Milling (labor and machinery)</td>
</tr>
<tr>
<td>Cooking (fuel, labor, supplies)</td>
</tr>
<tr>
<td>Supplies and Miscellaneous</td>
</tr>
<tr>
<td>Repairs and Maintenance</td>
</tr>
<tr>
<td>Interest on Operating Capital at 12% for 6 months</td>
</tr>
<tr>
<td>Total Variable Costs</td>
</tr>
<tr>
<td>Return to Land, Capital, and Management</td>
</tr>
</tbody>
</table>

The high costs of milling reflect the use of a low-capacity mill. This expense was considerably reduced in 1990 with the introduction of a new, portable field mill.

Another budget in wide circulation among producers was introduced at the 1985 NSSPPA meeting (Table 5). The source of the budget is unknown. It is an optimistic budget but not unreasonable. Propazine herbicide shown in Table 5 is not currently labeled for sweet sorghum.
### Table 5. Estimated Costs and Returns of Sweet Sorghum Syrup Production.

<table>
<thead>
<tr>
<th>Cost/Acre</th>
</tr>
</thead>
</table>

#### Production

- Seed: 3 lb @ $3/lb
- Fertilizer: 400 lb/acre (10-10-10) @ $135/ton
- Weed Control — Propazine (Milogard): 2.5 lb active ingredient/acre @ $5/lb
- (3 cultivations substitute for herbicide)
- Plow and Double Disc: 2 acres/hour @ $7.30/acre
- Planting: 5.00
  - (2 rows) — 1 acre/hour @ $5/acre
  - **Total Production Cost** $60.00

#### Harvesting

- Strip and Top Cut: 2.5 hours/ton @ $5/hour, 15 tons/acre
- Hauling: 15 tons/8 hour day @ $5/hour plus $10 for tractor
- Milling: 1 ton/hour, 7.5 tons/day @ $5/hour plus $12 power, 2 days/acre
  - **Total Harvesting Cost** $341.50

#### Cooking and Canning

- Cooker and Cleaning: 8 hours/day, 7.5 tons @ 15 gal/ton @ $5/hour, 2 days/acre
- Canning and Cleaning: 8 hours/day @ $5/hour, 2 days
- Cans: 200 gal/acre at $35/hundred
- Liquid Propane Gas: 1 gal/gal syrup @ $1/gal
  - **Total Cooking and Canning Cost** $430.00
  - **Total Per Acre Cost** $832.30
  - **Gross Income (200 gal/acre @ $15/gal)** $3,000.00
  - **Less Total Per Acre Cost** $832.30
  - **Net Income** $2,167.70

#### Purchases for New Producer

- Mill: $1,000.00
- Evaporator Pan and Supplies: 400.00
- Furnace: 200.00
  - **$1,600.00**

Source: 1985 NSSPPA meeting.
During the 1985 NSSPPA meeting, Victor Stoll of Finger, Tennessee, reported that his family invested 108.5 hours of labor in growing and processing each acre of sorghum. Another $798.00 per acre was needed to cover other variable expenses. They had a high average of 250 gallons per acre. Selling at a wholesale price of $9.00 per gallon provided a net return to labor, land, management, and fixed costs of $1,452.00 per acre.

In planning budgets developed by the University of Tennessee, a net return to land and management of $590.84 was calculated based on 137 gallons per acre yield and a retail price of $13.90 per gallon (Walch et al., 1984).

Budgets developed in Georgia presented figures in terms of return per hour of labor (Given, 1980). At a yield of 100 gallons per acre, returns per hour of labor were $3.55 for a sale price of $10.00 per gallon and $4.86 for $12.00 per gallon. At a yield of 200 gallons per acre, returns per hour of labor were $8.42 for a sale price of $10.00 per gallon and $10.88 for $12.00 per gallon.
SORGHUM AND SUSTAINABLE AGRICULTURE

Stewardship of the Land

The history of man and agriculture is a checkered one. While agriculture is cited as the foundation for the great civilizations of the world, its consequences have also been the downfall of many of those civilizations, through destruction of the natural resources of soil and water (Lowdermilk). Whether our own modern society can learn from history remains to be seen. Public attention displayed during the 1990 Earth Day suggests that we are starting to wake up.

Developing a truly sustainable agriculture will be a long journey. It can begin immediately by taking steps we already know will move us in the right direction:

- Implementing soil conservation practices, such as contour cropping, grass waterways, conservation tillage, terracing, windbreaks, etc.
- Avoiding tillage on highly erodible soils.
- Planting winter cover crops to prevent erosion and leaching and to increase soil organic matter.
- Planting crop rotations (including legumes) to build the soil thereby decreasing synthetic nitrogen needs and to break pest cycles consequently reducing the application of pesticides.
- Managing manures and crop residues as fertility resources rather than wastes.
- Using pesticides sparingly, cautiously, and always within the guidelines and limitations of the label.

In SWEET SORGHUM Production and Processing an effort has been made to emphasize methods and practices that KCSA staff consider more resource conserving and environmentally sound. Since sorghum is a clean-cultured row crop, extra attention must be paid to preventing soil depletion and surface water contamination. Special care should also be given to field-milling and the return of cane wastes to the land. Sorghum has a reputation as a crop that is "hard on the land." This is true but only if we fail to manage it properly.

Fuel Usage

Sorghum syrup can only be made by applying large amounts of heat to accomplish the necessary evaporation. The producer can choose among a number of fuels. Steam heat offers the best combination of efficiency and control. Boilers can be fired using renewable resources, such as wood or sorghum cane waste. Small- and intermediate-scale processors can also burn these renewable resources. The use of cane wastes as fuel must be weighed against their value as residue returned to the soil, which can reduce erosion and increase long-term fertility.
Other Methods of Production and Processing

From a resource perspective, liquid propane (LP) gas and other petroleum-based fuels may be the least desirable fuel sources. An efficient, gas-fired sorghum pan will use about one gallon of LP gas for each gallon of pure sorghum produced. Most operations probably consume closer to one and a half gallons. However, LP gas has been heavily promoted as an alternative motor fuel because of its relative abundance and clean burn. For small- and intermediate-scale facilities, it may be the fuel of choice, because capital costs for the initial setup are reasonable when compared to steam. It is relatively easy to incorporate modifications that let the processor switch between wood heat and gas.

Integration with Other Farm Enterprises

Sweet sorghum integrates well with many other farm enterprises, particularly livestock. Sorgo is a good fodder or silage crop. Most carbohydrates in sorghum are in the form of sugars, so acetic rather than lactic acid is generated during ensiling, making it somewhat less nutritious than corn silage. Some specialists do not recommend it for dairy animals (Craigmiles et al., 1958).

Waste cane is often ensilled or otherwise fed to livestock. After removal of seed heads and juice, it is not a high-quality feed. Harvested seed heads can be a suitable feed but are not highly digestible unless cracked or ground.

Many livestock farms already have crop rotations including forage legumes and a supply of manure. The modest nitrogen needs of sorgo can be met with limited purchases of commercial fertilizer.

At KCSA we attempted to integrate sorghum into a u-pick fruit and vegetable farm. Sorghum provided us with an enterprise that fit well into the fall season. It was intended to be a drawing card for supporting sales of pumpkins, decorative corn, sweet potatoes, and other fall vegetables.

Production of a Whole Food Product

Those who take a truly holistic view of what sustainability means recognize that it includes the health of the farmer and the consumer. We believe the consumption of whole foods or those that have been minimally refined and processed is one of the keys to improved health.

Pure sorghum is a whole food. Producers should consider this in designing their label and promotions. Table 6 lists the nutritional content of pure sorghum syrup.

Small Farms, Family Farms

KCSA was primarily interested in sorghum syrup production because it appeared a viable enterprise for small and family-sized farms. We still believe this is true.

Currently, demand for quality syrup far exceeds the supply. Also, the demand seems to be expanding faster than production. These factors contribute to the high potential profitability of this enterprise and the opportunities for the small-scale processor. The market is quite capable of absorbing a large number of small-scale producers for some time into the future.

A mystique is associated with sorghum. It conjures the images of tradition, simpler lifestyles, and country living. The small producer can capitalize on this, especially in the promotion of mail-order and other forms of high-return retail sales.

It is not simply nostalgia to cling to the Jeffersonian vision of America as a country dominated by many small landholders and farmers. The present trend that concentrates food production into
Table 6. Nutritional Content of Pure Sorghum Syrup in a One Tablespoon Serving (Bitzer, 1987). *

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>20.00 g</td>
</tr>
<tr>
<td>Calories</td>
<td>52.00</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>13.40 g</td>
</tr>
<tr>
<td>Calcium</td>
<td>30.00 mg</td>
</tr>
<tr>
<td>Iron</td>
<td>2.40 mg</td>
</tr>
<tr>
<td>Sodium</td>
<td>4.00 mg</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.00 mg</td>
</tr>
<tr>
<td>Potassium</td>
<td>120.00 mg</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.02 mg</td>
</tr>
<tr>
<td>Niacin</td>
<td>Trace</td>
</tr>
</tbody>
</table>

* Values will vary from sample to sample.

fewer and fewer hands leaves the decisions of how food is grown, what is grown, and how it will be processed and marketed in the same few hands. It also ensures that fewer individuals will experience growth associated with self-employment, stewardship, and direct interaction with nature.

Democracy is more than simply the right to vote for representation in government. It extends to control of the resources that hold body and soul together. To surrender control of a critical resource such as food to a few is an erosion of democracy disguised as "efficiency."
REFERENCES


APPENDIX 1. READING LIST


Kerr Center For Sustainable Agriculture Newsletter. Kerr Center for Sustainable Agriculture, Poteau, OK.


Oliver Farm Equipment, Co. 1941. Instructions for setting up and operating cockshutt no. 2 long and short corn or row binder. Pamphlet 104. Small Farmer’s Journal, Eugene, OR.


APPENDIX 2. SPECIALIZED EQUIPMENT AND SUPPLIES

Containers, Labels

Dadant & Sons, Inc.
Hamilton, IL  62341
217-847-3324
Jars, honey supplies

Scottsboro Wholesale Co.
633 W. Willow St.
Scottsboro, AL  35768
205-574-3690
Cans

Smith Container Corp.
P.O. Box 18551
Memphis, TN  38181
901-794-0597
Cans, plastic containers, jars

Sugarhill Containers
Main Street
Sunderland, MA  01375
413-665-2111
Plastic containers

Tennessee Tape & Label Corp.
10635 Dutchtown Road, N.W.
Knoxville, TN  37932-3206
615-966-8711
Labels

U.S. Can
100 Stoffel Dr.
Tallapoosa, GA  30176
404-574-2313
Half gallon cans, other sizes
Enzymes

Biocon (US)
518 Codell Dr.
Lexington, KY  40509
606-269-6351
  Hi-tempase (amylase) — Temperature range 150 to 220°F
  Canarelase (amylase) — Temperature range 160 to 175°F
  Bioinvert (invertase) — Temperature range 70 to 140°F

Miles Laboratories, Inc.
Biotech Products Division
Box 932
Elkart, IN  46515
800-348-7414
  Tak-a-therm L-340 (amylase) — Temperature range 176 to 203°F

Novo Laboratories, Inc.
59 Danbury Road
Wilton, CT  06897
203-762-2401
  Termamyl (amylase) — Temperature range 150 to 220°F

Rohm Tech, Inc.
195 Canal St.
Malden, MA  02148
  Rohhalase A, A3, AR, AL (amylase) — Temperature range 120 to 175°F
  Rohhalase 13X (invertase) — Temperature range 120 to 150°F

Gas Burners

Maxon Corporation
P.O. Box 2068
Muncie, IN  47302
317-294-3304

Instruments for Processing—Thermometers, Hydrometers, Refractometers, Etc.

American Scientific Products
2340 McGaw Road
Obetz, OH  43207
800-848-9670
Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007-1380
609-573-6259

K. Retay
P.O. Box 22
Tennent, NJ 07763
231-431-5791

Markson
7815 S. 46th Street
Phoenix, AZ 85044-5399
800-528-5114

**Pan Manufacturers**

Bill DeRosett
Rt. 4, Box 236A
Livingston, TN 38570
615-498-2182

Paintsville Heating and Roofing
Paintsville, KY 41240
606-789-3621

**Seed Companies**

Kentucky Seed Improvement Assn.
P.O. Box 12008
Lexington, KY 40579-2008
606-257-2971
Dale

MAFES Auxiliary Units
Foundation Seed
P.O. Box 6311
Mississippi State, MS 39762
601-325-2390
Dale, M81E, Theis, Brandes

R.H. Shumway Seedsman
P.O. Box 1
Graniteville, SC 29829
Sugar Drip
GLOSSARY

Alpha-Amylase
An enzyme capable of speeding the breakdown of starch into glucose, maltose, and dextrins.

Baffle
In a sorghum pan, partitions placed to force the flow of juice, semisyrup, and syrup from the lower to the upper end of the pan.

Barometer
An instrument for measuring atmospheric pressure.

Basic Slag
A by-product of steel manufacture, containing lime, phosphate, and trace minerals.

Baume
A scale of liquid density used on hydrometers. Similar to Brix.

Brassica
Any plant of the Mustard (cabbage) family, including rape or yellow mustard used as cover crops or green manures.

Brix
A scale of dissolved solids in a liquid used on refractometers. Similar to Baume.

Cane
The stems or stalks of sweet sorghum and sugarcane.

Catalyst
A substance that alters the rate of a chemical change but remains unchanged at the end of the reaction.

Certified Seed
Used for commercial crop production. Grown from Foundation, Registered, or Certified seed under the regulation of a legally constituted agency.

Coagulate
To change from a liquid to a gel. To curdle.
Colloidal Clay Phosphate
   A fine clay material impregnated with phosphates. A by-product of hydraulic processes used in mining phosphates.

Compost
   A soil amendment and fertilizer consisting of decomposed organic materials.

Crop Rotation
   A system of growing different kinds of crops in recurrent succession on the same land.

Crystallization
   The formation of sugar granules in sorghum syrup.

Decant
   To pour or draw off a liquid without disturbing any sediment.

Denature
   To alter or destroy a protein.

Dextrin
   A short-chain polysaccharide.

Diatomaceous Earth
   Made from the skeletal remains of plankton and other minute marine life by fine grinding and drying. Has special use in filtration of liquids.

Disaccharide
   A compound sugar consisting of two simple (monosaccharide) sugars, e.g. sucrose.

Dolomite
   A liming material containing both calcium and magnesium carbonates.

Enzyme
   A protein naturally produced by living organisms having catalytic properties.

Fodder
   The entire plant of grasses, such as corn or sorghum, including the grain that is harvested, cured, and fed.

Foundation Seed
   Seed stock grown from Breeder seed under the control of an agricultural experiment station.

Fructose
   A monosaccharide sugar. Fruit sugar.

Glucose
   A monosaccharide sugar. Blood sugar.
Green Manure
Any crop or plant grown and plowed under to improve the soil, especially by adding organic matter.

Holistic
Relating to or concerned with wholes or with complete systems rather than with the analysis of, treatment of, or dissection into parts.

Humate
A mixed material similar to lignite coal high in natural humic acids and containing a wide range of trace elements.

Hybrid Variety
Results from the controlled crossing of two parent plants that are genetically different. Hybrid seed must be purchased each year. Seed saved from a hybrid crop produces a variable and generally disappointing crop.

Hydrometer
An instrument designed to measure the density or specific gravity of liquids.

Internode
The part of the stem or branch of a plant between two nodes.

Invertase
An enzyme capable of speeding the breakdown of sucrose into glucose and fructose.

Legume
Any plant or crop that produces seed in pods and is characterized by root nodules capable of fixing nitrogen from the atmosphere when inoculated with the proper bacteria. Legumes include peas, beans, soybeans, vetch, clover, sweetclover, lespedeza, and alfalfa.

Lister
An implement for furrowing the land, leaving it in a rough-bedded state.

Lodging
Crop plants with broken or bent stems.

Monosaccharide
A simple sugar. Glucose and fructose are monosaccharides.

Node
The joint of a stem where a leaf is attached.
Nitrogen Tie-up
Microbial decomposition of plant litter or other organic matter in the soil or in a compost pile requires a supply of nitrogen. If the organic material is relatively low in nitrogen, microbes draw on nitrogen present in the soil. This results in nitrogen-starvation to any crops growing at that time.

Open-Pollinated Variety
A variety from which the seed may be harvested and regrown annually. The seed produces a population of plants genetically similar to the parent crop.

Organic Agriculture
Farming systems that do not use synthetic pesticides or processed commercial fertilizers.

Peduncle
The top section of a stalk that supports a seed head.

pH
A numerical designation for acidity and alkalinity. A pH of 7 is considered neutral. Greater than 7 is alkaline, and less than 7 is acidic.

Polysaccharide
A compound sugar consisting of two or more simple sugars.

Potable
Suitable for drinking.

Propazine
A selective, preemergence herbicide used to control annual weeds in grain sorghum.

psi — pounds per square inch
A measure used for the pressure of gases and liquids.

pto — power take-off
A shaft extending from a tractor enabling the engine power to be used to operate towed or stationary equipment.

Refraction
The bending of light rays as they pass through substances of different densities. Light rays are refracted to a greater degree as they pass through a dense syrup compared to a less dense semisyrup.

Refractometer
An optical instrument for measuring refraction used in juice, wine, and syrup production.

Semisyrup
Sorghum juice that has been evaporated to a significant degree, within a range of 42 to 45°Brix.
Starch
A long-chain polysaccharide consisting of many units of sugars.

Stewardship
Responsible management of a farm or other natural resources for which one is accountable.

Sucrose
A disaccharide sugar found in sorghum juice.

Sustainable Agriculture
Farming systems, methods, and policies that do not deplete the soil, environment, or people while promoting physical and economic health.

Syrup
A solution of water and sugars concentrated to a desired consistency. By legal definition, sorghum syrup is equal to or greater than 74°Brix.

Thermocouple
A temperature sensing and measuring device. Provides a digital, temperature readout that is both rapid and precise.