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SORGHUM SIRUP MANUFACTURE.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Chemistry,
Washington, D. C., September 28, 1911.

Sir: I submit herewith, for your inspection and approval, the manuscript of Farmers' Bulletin No. 477, prepared by A. H. Bryan, Chief of the Sugar Laboratory. This bulletin is to take the place of Farmers' Bulletin No. 135, by A. A. Denton, which was published about ten years ago, and which in turn superseded No. 90.

The text has been drawn in part from the former bulletins and from those of C. R. Ball, of the Bureau of Plant Industry, also in part from experiences of old makers of this sirup. The material under the heading Culture of Sorghum has been supplied by Mr. A. B. Connor, of the Bureau of Plant Industry, who has had much experience in recent years with this crop in the West.

It is hoped that the bulletin, in its revised form, may prove as useful as its predecessors to those interested in the extension of this industry, the demand for this information having continued during the past ten years.

Respectfully,

F. L. Dunlap,
Acting Chief, Bureau of Chemistry.

Hon. James Wilson,
Secretary of Agriculture.

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SORGHUM SIRUP MANUFACTURE.

INTRODUCTION.

When the extension of the sorghum industry was first advocated it was thought that this crop would play a notable part in supplying the nation's sugar on account of its wider distribution than sugar cane or sugar beets, its large yield per acre and ease of cultivation, and its rather high sucrose content. After many trials, however, it was found that the juices, although rich in sucrose, contained some reducing sugars and also quite a large percentage of gums and gummy material which on concentration prevented crystallization. After these experiments were made the question of using sorghum for sugar and sirup manufacture was dropped to a great extent until more recently, when the manufacture of sorghum sirup has been in a measure revived. This is true particularly in the regions where maple sirup was formerly made in notable quantities as well as in the old sorghum States, and has been brought about in part by the depletion of the maple forests, and by the scarcity of old-time cane sirup and molasses and also by the fact that with patent evaporators a good, light-colored sorghum sirup with a pleasing taste can be obtained.

Although the terms "sirup" and "molasses" are often used interchangeably in connection with sorghum, they refer to altogether different products. Sorghum sirup is the concentrated juice of the sorghum plant with or without the addition of the usual clarifiers, while sorghum molasses is the liquid residue coming from the draining or centrifugaling of sorghum sugar. As very little, if any, sorghum sugar is manufactured to-day, the product of farm manufacture could hardly be termed "sorghum molasses." This confusion of terms may be due in part to the fact that molasses is generally heavy and thick, while sirup is lighter and thinner and ordinary sorghum sirup is heavy in appearance, due to the gummy material present, resembling molasses more than it does a maple or cane sirup of equal density.

The manufacture of sorghum sirup is not a complicated process requiring special skill. It does not necessarily call for expensive apparatus or machinery nor are dangerous chemicals employed. The processes to be described are simple, but as in all sugar or sirup making cleanliness and dispatch are necessary, and unless one is very careful, numerous unsuccessful trials may be made before a fine sirup is produced.

HISTORY OF SORGHUM.

Under sorghum, in the broad sense of the word, are included all the groups popularly known in this country as sorgo, sweet sorghum or saccharine sorghum, kafir, broom corn, shallu, kowliang, durra, and milo, but only the first group is of practical interest. Carleton R. Ball has given an extensive account of The History and Distribution of Sorghum in Bulletin No. 175 of the Bureau of Plant Industry, United States Department of Agriculture. It appears that sorghum originally grew wild in all tropical and subtropical parts of the Old World. In Beni-Hassan, Egypt, on the tomb of Amenembes, belonging to the dynasty existing at least 2,200 years before Christ, is frescoed a harvest field which is said to represent sorghum. In the book of the prophet Ezekiel (600 B. C.) is found the word "dochan," translated "millet," which word is still used in Arabic for forms of sorghum. As civilization moved westward the sorghum was carried with it, but no statements are to be found in the literature showing that the ancient cultivators knew that sorghum was a sugar-producing plant and it was in this country that the first efforts to manufacture sugar and sirup were made.

The credit of first growing sweet sorghum in the United States belongs to a nurseryman, William R. Prince, of Flushing, N. Y., who, in 1853, grew a variety of Chinese sorgo which came from France.[1] In 1855 the United States Commissioner of Patents distributed a small quantity of seed secured in France and the next year the first wide distribution of seed was made by the United States Government. In 1857 about 16 varieties of African sorghum were introduced and grown in Georgia and South Carolina. As a class they were called "imphee," a name found in many of the older works on sorghum, and often applied to certain varieties by some of the older growers. In 1865 four more varieties were received from China and in 1880 a large number of varieties were imported, both from China and from Natal.

VARIETIES OF SORGHUM.[2]

Saccharine sorghums are recognized by their sweet sap or juice. They are, as a rule, tall with a leafy growth, branching only sparingly at the upper nodes or joints, and not stooling much at the base under ordinary cultivation. The seed head varies from the close compact "club" head of the Sumac sorghum through the rather more open

[1] U. S. Dept. Agr., Bureau of Plant Industry Bul. 175, p. 32.

[2] The notes and description of varieties are taken in part from Farmers' Bulletin No. 246, entitled "Saccharine Sorghums for Forage," by Carleton R. Ball.

heads of Orange and Gooseneck, to the loose and often widely spreading heads of the Amber and Honey varieties.

Beginning with the original importation of a single variety of Chinese origin in 1853, there were in 1906 probably no less than 200 so-called varieties in cultivation. Most of them, however, never attained any prominence outside of the locality where they originated. Ball has divided the sweet-sorghum varieties into three or four groups, each consisting of a single well-marked variety and a number of forms derived from it. Such groups are the Amber, Orange, Sumac, and Gooseneck sorghums.

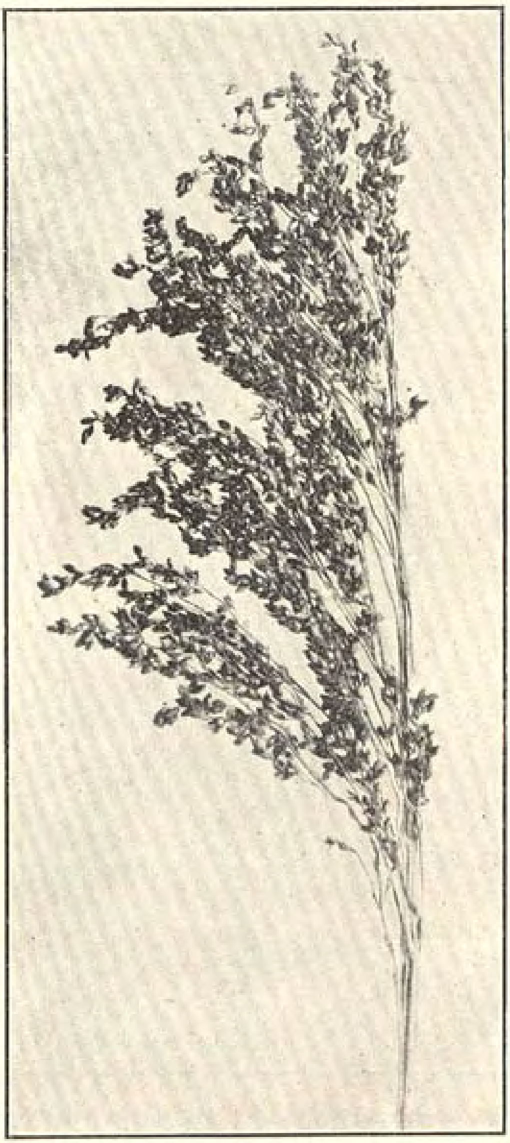


FIG. 1.—A head of Amber sorghum (about one-fourth natural size).

AMBER SORGHUM.

Amber sorghum is said to have developed in Indiana from the original Chinese sorghum. It is an early variety and is sought for that reason. It soon was called Early Amber, and when the seed came from Minnesota was known as Minnesota Early Amber. In Bailey's Encyclopedia of American Agriculture, the latter variety is said to have originated through selection by Seth H. Kenney. From 70 to 100 days are necessary for the Amber sorghum to reach maturity, the time varying according to the latitude, season, and soil. It is characterized by the rather slender stalks and comparatively few and narrow leaves; the seed heads are generally black in color, varying considerably in shape and size, and rather loose, as is shown in the cut (fig. 1). One variety of this Early Amber is known as Folger and is a strain originated as an improved sirup variety having all the characteristics of Amber sorghum. Other varieties of some prominence are the Red Amber and the Minnesota Amber.

ORANGE SORGHUM.

Orange sorghum is of South African origin and differs from the Amber variety in having larger and heavier stalks, larger and more abundant leaves, and heavier and more compact seed heads (fig. 2). The seeds just before ripening are almost white. The Early Orange, as this standard variety is usually called, requires about two or three weeks longer than the Amber to reach maturity. On account of its growing taller and the stalks larger, it gives a slightly heavier yield per acre. Various forms of this variety are offered on the market, including Kansas Orange and Late Orange.

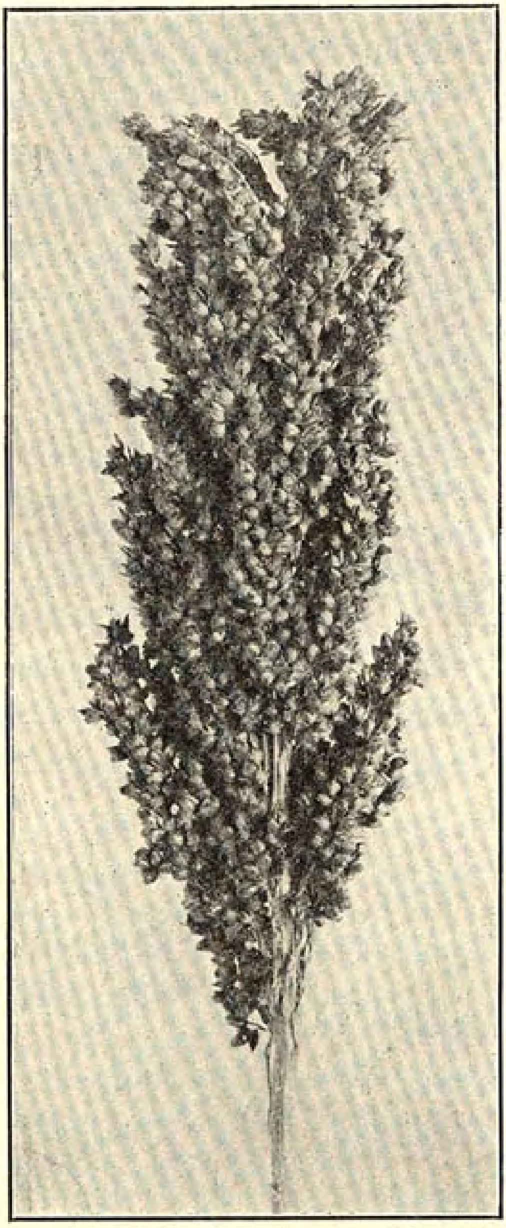


FIG. 2.—A head of Orange sorghum (one-half natural size).

The Colman variety, which is said to have originated as a hybrid between Early Amber and Orange sorghum, is used by many for sirup making and has been shown at times to give a juice richer in sugar than any other (see p. 40 for analyses of this variety). In size, character of the seed head, and time required for maturity it is almost identical with Orange sorghum.

Another variety that was formerly grown extensively for sirup was the Collier, which when first introduced and given its name was a distinct variety, quite different from Orange, but the pure Collier seems to be no longer grown (see p. 40 for analyses).

SUMAC OR RED-TOP SORGHUM.

Sumac or Red-Top sorghum may quite certainly be identified with the varieties brought from Natal. It is a stout, stocky variety with an abundance of large, broad leaves; the seed heads are stout, thick, cylindrical and erect, and the reddish-brown seeds are the smallest of any (fig. 3). This variety grows from 7 to 10 feet high, according to its environment, is usually of a very even growth throughout a field, and matures rather early, requiring from 90 to 120 days. It is cultivated quite extensively in the South.

GOOSENECK SORGHUM.

Gooseneck sorghum is distinct from any of the others grown in this country and is thought to be a direct descendant from one of the original African varieties. Its name is probably derived from the recurved and pendent stems, reddish in color (fig. 4). It grows commonly from 10 to 12 feet high and when thinly sown, for sirup making, the stalks are from 1 to $1\frac{1}{2}$ to 2 inches in diameter at the butt. This variety was extensively grown in the South, especially Texas, but being a much later ripener than Amber and a week or 10 days later than Orange and Sumac, it can not be grown in the Northern States.

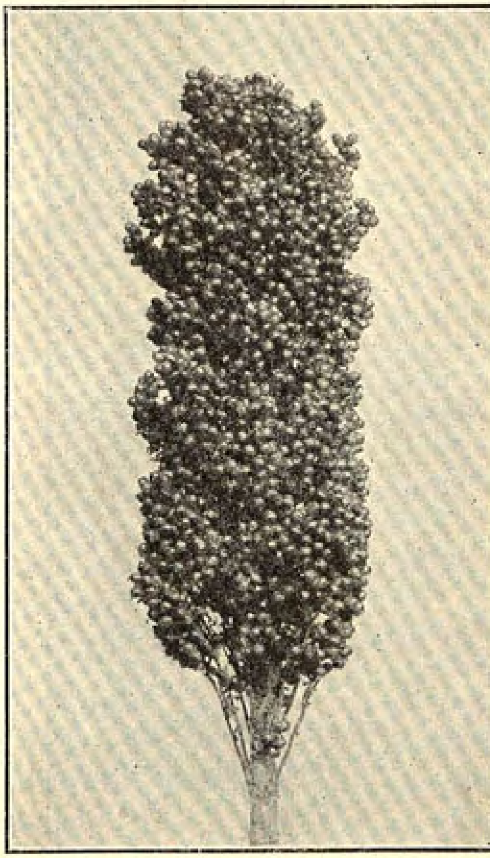


FIG. 3.—A head of Sumac sorghum (one-third natural size).

HONEY SORGHUM.

Another variety of some prominence is the Honey. Its origin can not be definitely traced, but no doubt it came from an African importation. The stalks are from 7 to 10 feet high, averaging 13 to 18 nodes in different localities, are stout, from 1 to $1\frac{1}{2}$ inches in diameter at the base, and very sweet. The stems are markedly tender in comparison with other stout varieties. It is, however, a very late ripener, requiring from 130 to 140 days to mature, and therefore is best adapted to the South.

SELECTION OF A VARIETY.

From the preceding discussion it is seen that for northern regions, where the growing season is short, some form of Early Amber or of Early Orange, preferably the former, must be selected, while farther south all the varieties may be used. A variety grown one season may produce a good sirup, but under different climatic conditions another year may not yield so good a product. The nature of the season seems to exert a marked influence on the composition of the plant, as has been definitely determined in the case of other sugar-bearing crops. It is to be regretted that the systematic work in the selection of a sorghum for sirup and sugar making, begun about 1890, was not carried out, as many facts were being brought forth and a strain of sorghum rich in sucrose and low in reducing sugars was being propagated.[1] However, this subject is being revived and it is hoped that valuable data may be obtained.

When a variety has repeatedly given good yields and a good quality of sirup, the seed should be carefully selected for replanting. To do this, place several typical canes[2] in shock, cover them with a net or other protection from birds, and when quite dry cut the seed heads and place them in a stout grain bag. The seed can be thrashed by pounding with a club and cleaned by pouring from one pan to another in a gentle breeze. Stems and trash can be removed from the seed by shaking the pan and picking them out as they come to the surface. In this way an unmixed seed of good quality can be obtained by the sirup maker.

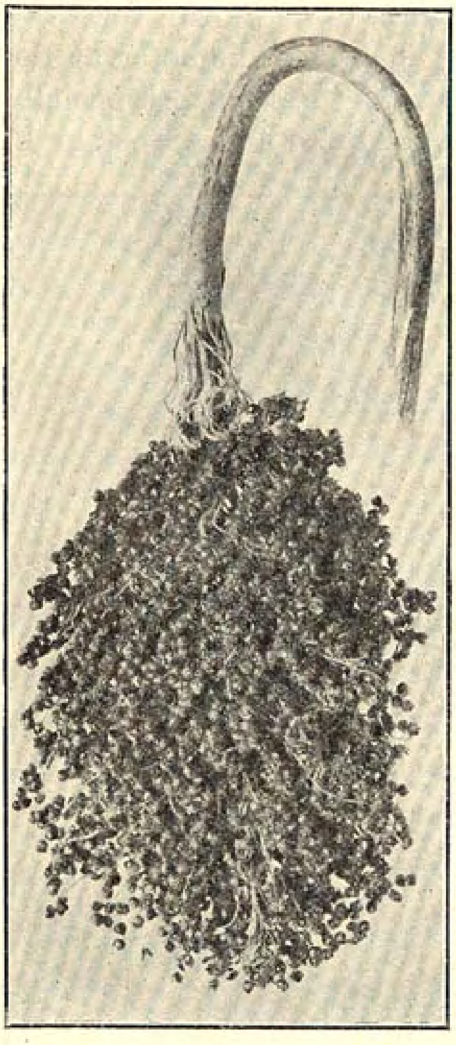


FIG. 4.—A head of Gooseneck sorghum (one-third natural size).

CULTURE OF SORGHUM.[3]

While sorghum is a crop that is generally thought to require little attention, its yield and value can be materially increased by using care in its culture. Good seed of the right variety is necessary for the best yields, but there are other equally important factors that must not be neglected, such as preparation of the soil, time and rate of seeding, and manner of planting. Perhaps more failures to get satisfactory crops are due to improper seeding than to any other cause, and too great care can not be given to planning for and planting the crop.

PREPARING THE SEED BED.

Although a large portion of the land planted to sorghum is left unplowed until a short time before seeding, this practice is by no

[1] U. S. Dept. Agr., Bureau of Chemistry Bul. 40 contains a summary of this work.

[2] Comparison of the size of seed head and sugar content of stalk has led to the generalization that individual cane with larger seed heads than their fellows have a lower content of sugar. (A. A. Denton) U. S. Dept. Agr., Bureau of Chemistry Bul. 26, p. 94.

[3] This section was prepared by A. B. Connor, Bureau of Plant Industry.

means advisable. For the best yields there must be a firm seed bed, obtained by plowing the land early in the fall and harrowing or disking to keep down weeds until seeding time. Such preparation allows whatever vegetation there may be in the soil to decay and leaves it in the best tillable condition. In the drier regions this treatment serves to take in and retain any moisture that may come during the winter season and to decrease the chance of failure from drought. In the same manner it increases the yield in more favorable seasons. In the more humid sections early preparation is preferable, though not so necessary as in the drier regions. The land is sometimes prepared by "bedding" or listing with a middle buster or a turning plow.

PLANTING.

The planting of sorghum deserves more careful attention than any other operation entering into the production of the crop. The time, method, and rate of seeding mean success or failure in the degree in which it has been properly or improperly done. It is therefore of vital importance that the farmer attend carefully to the planting of his crop.

Time of planting.—The sorghums are usually planted soon after corn, when the ground is thoroughly warm. They may be planted at any time after that date until as late as will permit the crop to mature safely. In the Southern States the first of April is considered early planting. Northward, using the northern line of Louisiana as a base, the season gets later at the rate of about one week for every 2 degrees, or 150 miles. Early seeding is preferable for the reason that it may produce a second crop which can be used for forage. It is usually well to make two or three different plantings at intervals of about ten days or two weeks so as not to have all the crop mature at the same time.

Method of planting.—For sirup production sorghum should always be planted in rows 3 or 3½ feet apart. This may be done with a single or double row planter either on a bed, on the surface, or in a lister furrow, as is most advisable, depending on the section where the crop is grown. Furrow planting is most common in the drier regions, but it is practiced to some extent in the humid sections. In some of the lower and poorly drained lands planting is made on a bed, but only under such conditions should this method be used.

Rate of seeding.—The rate and regularity of seeding largely influence the yield of sirup regardless of the method used. Seeding should be done so that the plants will be very evenly distributed and average a distance of 4 to 6 inches in the row, or even thinner in the drier regions. A special plate for the drill can be made that will plant the crop very satisfactorily and thus avoid a great deal of labor in thinning. A very small quantity of seed is required to plant an acre, at most not more than 1 or 2 pounds.

CULTIVATION.

While sorghum will grow and give fair yields with little or no cultivation, this is by no means the most profitable method of producing the crop. Careful cultivation has repeatedly been known to increase materially the yield per acre. The first cultivation can be given with a spike-toothed harrow, and as soon as possible afterward it should be cultivated deeply with sweeps or shovels. Later in the season at least two additional shallower cultivatings should be given for the best results. Sorghum can be cultivated to advantage until it begins to put out heads, provided care is taken not to destroy the surface feeding roots.

HARVESTING.

The stage at which the sorghum contains its greatest sugar content, a matter of the greatest importance to the sirup maker, has been the subject of much investigation in former years. Collier gave the following figures as a result of about 2,740 analyses of sorghum canes made at different stages of growth:

Sugar content of sorghum at different stages of growth. (*Peter Collier.*)

Stage of cutting.	Sucrose.	Invert sugar.
	Per cent.	*Per cent.*
Panicles just appearing	1.76	4.29
Panicles entirely out	3.51	4.50
Flowers all out	5.13	4.15
Seed:		
In milk stage	7.38	3.86
Doughy, becoming dry	8.95	3.19
Dry, easily split	10.66	2.35
Hard	11.69	1.81

From these figures it appears that from the time the seed is in the late milk stage until it is becoming dry, the cane is in the best condition for sirup making. Some prefer to wait until the seed is hard before cutting, as the sugar content is still higher then, but they run the danger of a frost before all of the cane is worked up.

Cutting can be done by hand or by a harvester. When harvested by hand, the individual canes are cut about 6 or 8 inches above ground and laid across the rows with the heads all in the same direction. With a harvester and binder the cutting and binding in bundles forms one operation, and the seed heads are all at one end of the bundle. It is customary among some makers to leave the hand-cut cane in the field for a day or two to wilt the leaves, which is said to improve the quality of the sirup. The seed heads are removed and left in the field to be collected after the harvest. In making a good grade of sorghum sirup it is necessary to remove all leaves and seed heads from the cane, as these on passing through the mill give the juice and the resulting sirup a bad flavor and also make clarification more difficult. In removing the seed heads, about 6 to 18 inches of the upper cane should be cut off, as this part contains little sucrose and many impurities; suckers should also be discarded for the same reason.

The harvesting should progress in proportion to the mill work, no more being cut at one time than can be worked in two days. When the weather is cold the cane may be cut and shocked. Some makers have kept it in shock for four weeks with no appreciable loss in sirup-making properties. Like other sugar-producing plants, however, a freeze does not hurt the crop, provided the cane can be worked up just as soon as it thaws. On freezing, the cells of the cane are broken; and on thawing, decomposition quickly sets in. A frost will not hurt a ripe cane materially, but if the cane is immature it will be spoiled. Frosted cane, like frozen cane, should be worked up as soon as possible. In Louisiana the sugar cane is "windrowed" when a frost or freeze is expected—that is, the cane is cut and laid on the ground between the rows, the leaves serving as a protection. In the case of sorghum, under such conditions, if the weather is warm during the middle of the day, the leaves on the stalk soon produce a "heating" of the pile and decomposition sets in. "Heated cane" and frosted cane do affect the flavor of the sirup. One of the large makers states that by shocking the cane with leaves and heads on, he has kept it in good condition for many weeks. This, of course, was during cool weather, for even when standing in shocks the cane is liable to "heat."

As stated before, for sirup making the best stage for cutting is just before hardening of the seed. Earlier than this the cane is too green and the resulting sirup will have an unripe taste. If cut when the seeds are very hard, the juice is said to be difficult to clarify, and the flavor of the sirup is not good.

On the subject of yield, but few definite data can be given, as so many factors influence it. Sorghum may yield as high as 15 tons to the acre or as low as 4 or 5 tons; an average crop is about 8 or 10 tons. The gallons of sirup per ton of sorghum depends on the kind of mill and on the care in manufacture, also the ripeness and kind of cane. A ton of cane with a 3-roller mill should yield anywhere from 700 to 1,200 pounds of juice, giving 8 to 30 gallons of finished sirup, depending upon the richness of the juice. Or, in other words, one should obtain from 60 to 300 gallons of sirup per acre, a fair average figure being between 100 and 150 gallons. There are large losses of juice in the mills and again in skimming.

MANUFACTURE OF SORGHUM SIRUP.

A few well-defined steps in the manufacture of sorghum sirup will be considered under the following heads: (1) Extraction of the juice; (2) Clarification of the raw juice; (3) Evaporation of the juice; (4) Bottling or canning of the sirup; (5) Utilization of the waste. Under these different headings many subheads are made for a clearer understanding of the procedure. At this point it might be well to say that the discussions entered into are more for the benefit of the small makers of sirup than for those having large, well-equipped plants.

EXTRACTION OF THE JUICE.

The ordinary method of obtaining juice from sorghum cane is by pressure—that is, running the cane between iron rollers set at a certain distance apart. Another method is by diffusion, a process in which the cane is first finely shredded and placed under pressure with water in large tanks, the water removing the sugar and soluble material. This method requires very expensive machinery and much experience, and is not used now by any sorghum-sirup makers, although it is the ordinary process used for extracting the sugar from beets.

The primitive mills were made by placing two logs upright side by side in a heavy frame. To one of the logs, extending above the frame, was attached a large sweep. On turning this and feeding the cane between the rollers, the juice was squeezed out. This kind of mill is used now to a very limited extent. It does not extract more than 25 or 30 per cent of the juice, and hence has little commercial value. The wooden rollers of this form have been replaced by iron rolls, and to-day many makes of 2-roller mills are found on the market. The extraction with these is better than with the wooden rollers, but does not equal that of the 3-roller mill. The latter can be obtained with the rolls upright or horizontal. The smaller mills are operated by horses or mules, the larger ones by steam or water power. Figure 5 gives a view of a 3-roller upright mill with a shaft for a sweep operated by horsepower. Figure 6 shows a 3-roller horizontal mill for horsepower. These mills can be provided with smooth or serrated rolls. In the upright position the serrated rolls prevent the cane from twisting to one side. A good mill should be easily taken apart and new pieces substituted when breaks occur; it must run smoothly and true for good results. The rolls must be capable of being adjusted to any distance from each other. In setting up such mills, care should be exercised to have the mill level and rigid on the frame or upright supports, which should be carefully braced. Without these precautions, imperfect pressing will result and a break in the mill be caused. Figure 7 shows a power mill. These are made either single or double geared, so that they can be connected direct with some form of farm engine. Figure 21 (p. 35) shows a power mill driven by a traction engine. Power mills are certainly to be preferred to the horse mills, as the crop can be worked up more easily and quickly. Figure 8 shows a power mill fitted with a feed table and a bagasse carrier. The former is an important adjunct to a milling outfit, especially for a power mill, as it allows the cane to be arranged in some order before entering the rolls, thereby assuring a more even feed. A bagasse carrier geared to the rolls delivers the bagasse some distance from the mill.

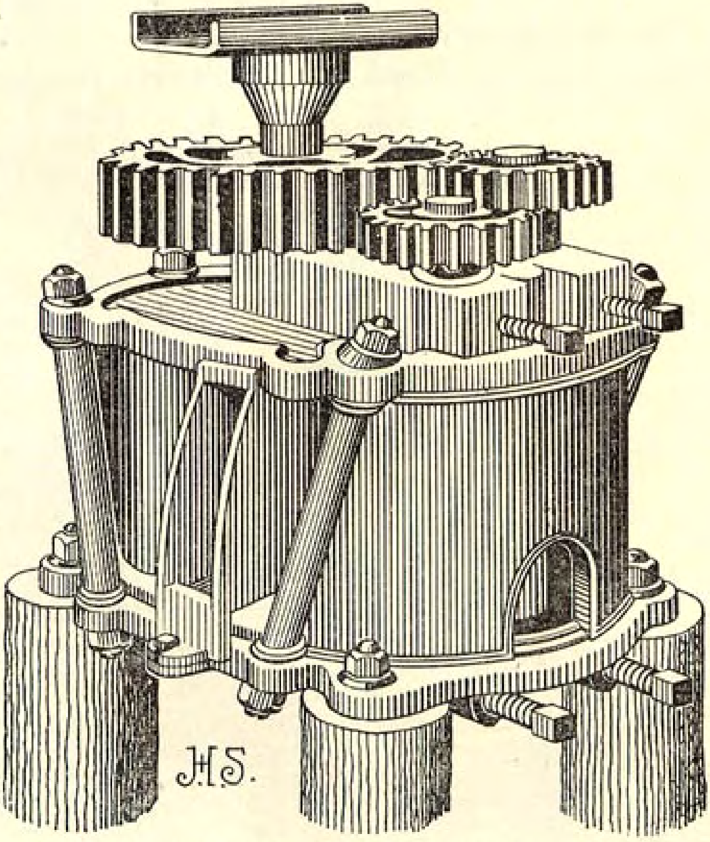


FIG. 5.—Heavy three-roller vertical horsepower cane mill.

In making sorghum on a large scale, two 3-roller mills may be used, one following the other. In this case, the crushed cane (bagasse) as it comes from the first 3-roller mill is often moistened slightly with water and then passed immediately into the second mill. This method increases the extraction considerably.

Having selected a mill and set the rolls, the next point to consider is how to feed the mill so as to obtain the best results from the cane. Sorghum ordinarily contains from 70 to 80 per cent of water and about 10 to 12 per cent of fiber, but it is not possible to obtain all of the water as juice. With a 3-roller mill, at least 50 per cent of the weight of the cane should be obtained as juice unless the cane is very hard and dry, and with a good mill and close setting 60 per cent is not too much to expect. The "feed," or amount of cane in the mill at one time, should be light or heavy according to the adjustment of rolls. When the rolls are set "open" or apart the feed should be heavy; when they are set close together the feed should be light; but in all cases it should be regular and uniform. It is evident that when the rolls are set "open" there is a waste of juice when the feed is light; with a close-set roll there is also a loss of juice when the feed is irregular and not even over the roll.

Juice obtained by moderate pressing is purer than that obtained by extreme pressure, for under the latter condition not only more juice but also more impurities from the rind and joints of the cane are extracted. Sirup made from moderate pressing is generally better flavored than that from the heavy pressing. Where cane is cheap and abundant it is inadvisable to increase the extraction of the juice greatly by excessive pressure.

SETTLING TANKS.

The raw juice coming from the mills should pass into collection or storage tanks. These may be merely rough barrels or metal or concrete tanks. The raw juice before entering these should pass through a fine sieve or mesh screen to remove particles of cane, dirt, etc. There should be at least two tanks, one being filled while the other is emptied. A third tank is almost a necessity as it allows time for the juice to settle. Raw sorghum juice holds mechanically in solution a number of impurities which on standing will slowly settle to the bottom and if not allowed to settle they will collect in the evaporator at the point of entrance of the raw juice and may burn on the bottom of the evaporator. It is necessary, therefore, to remove as much as possible of this material before evaporation is begun. Heating the raw sorghum juice tends to quicken the settling of the juices. Some makers use a small boiler or feed cooker (fig. 9) for this purpose; especially is this done when the evaporation is carried on by direct fire. Where steam evaporation is used, the exhaust may be used to heat the raw juice.

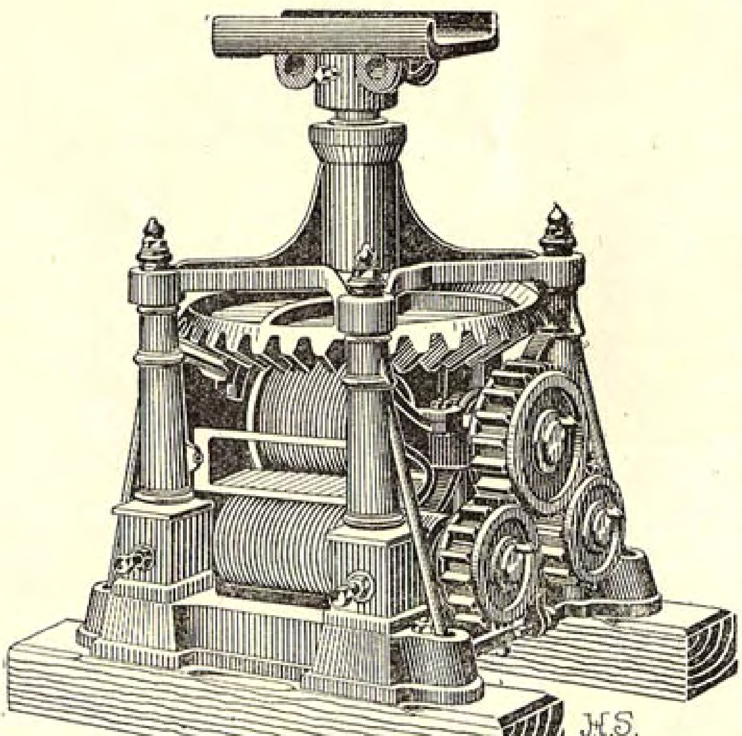
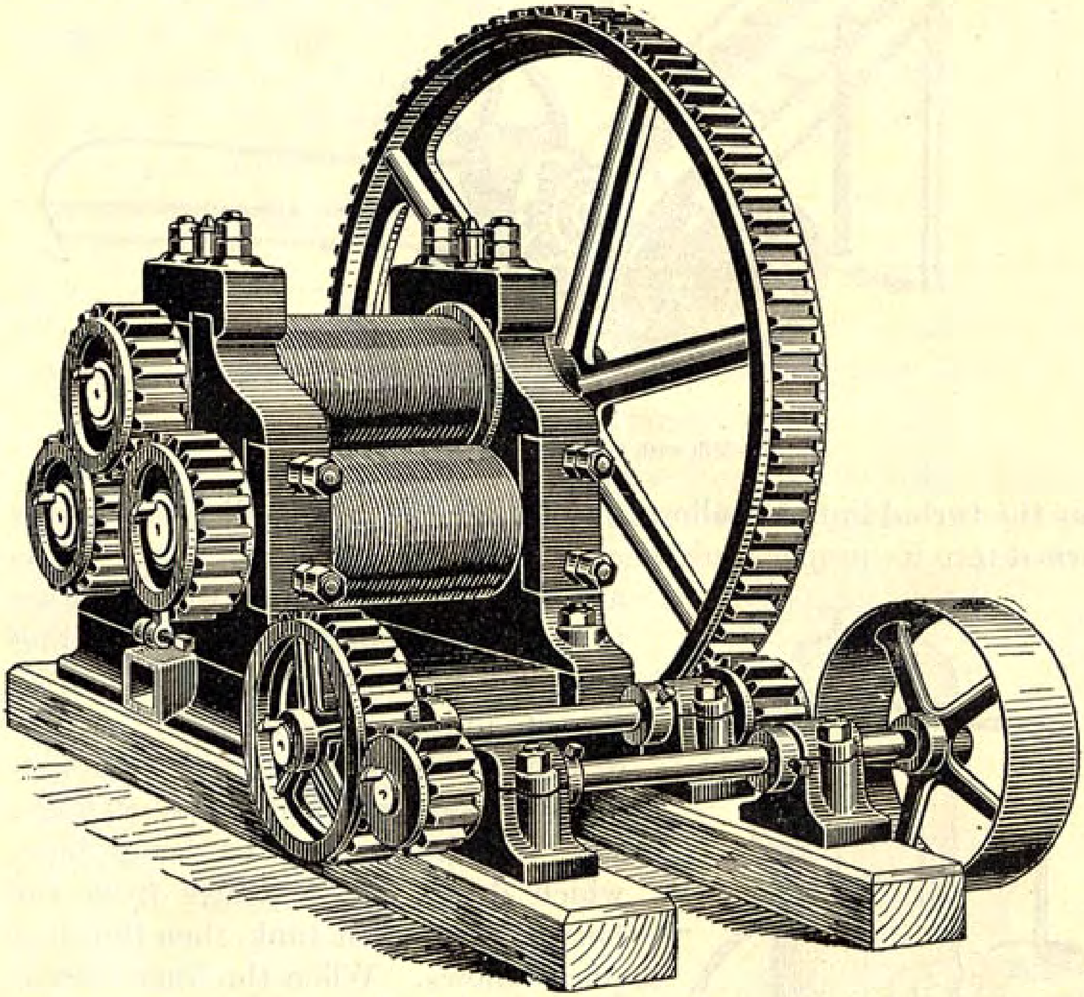


FIG. 6.—Three-roller horizontal horsepower cane mill.

Other makers settle this material by means of clay added to the cold or hot raw juice. A. A. Denton[1] proposed that a heavy, finely divided clay be stirred in with the juice. This tends to surround the floating sediment and carry it to the bottom, but it requires the use of a heavy, coarse-grained clay, which is often not easily obtainable. An examination of some 200 samples of clay,[2] collected from all over the country, showed in general: (1) That fire clays are too coarse grained and do not carry down the impurities; (2) that pure white clays are too fine grained and give bulky and indistinct settlings;



F G. 7.—Three-roller power mill.

(3) that blue clays, gumbo, or waxy clays are not suitable; and (4) that yellow or brown plastic clays are best. Still other makers pass the raw juice through filtering bags to remove the sediment, but this is rather tedious and does not always accomplish the purpose.

Settling tanks should be equipped with some arrangement for drawing off the clear juice without disturbing the settlings, or for drawing off first the settlings and then the clear juice. Figures 10 and 11 show such devices. Figure 10 shows a swinging barrel which

[1] U. S. Dept. Agr., Farmers' Bulletin 90. [2] U. S. Dept. Agr., Bureau of Chemistry Bul. 37, p. 85.

can be used by manufacturers working on a very small scale. Connections suitable for tanks are shown in figure 11. Cut "A" shows an opening near the bottom fitted with a cock. By carefully opening

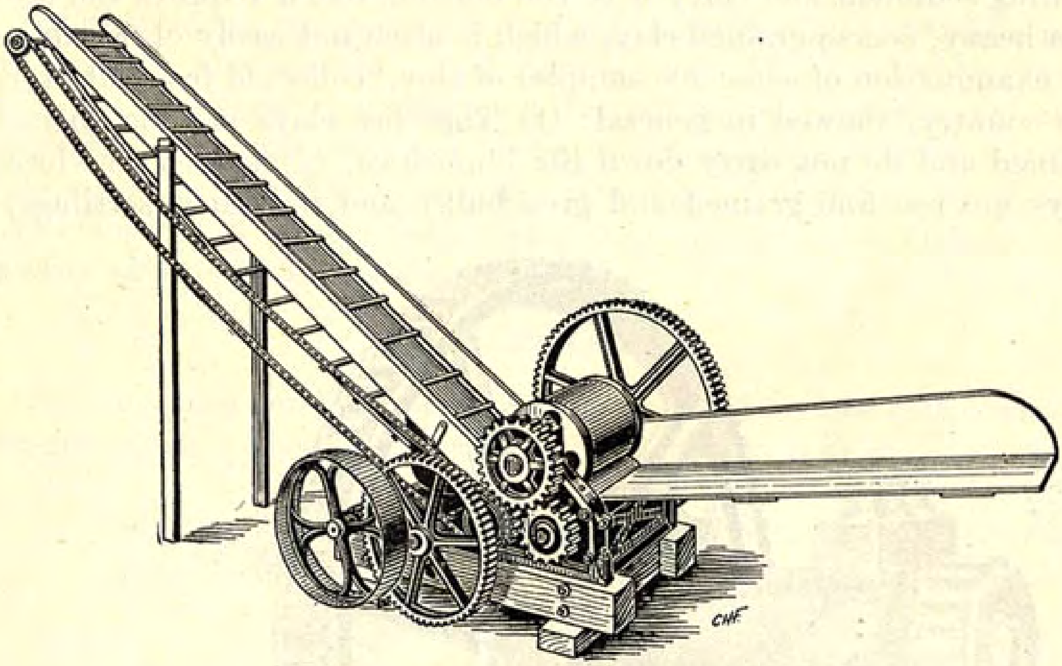


FIG. 8.—Mill with feed table and bagasse carrier.

this the turbid liquid is allowed to flow out into a small vessel and is turned into its proper tank when it begins to run clear. Cut "B" is a sliding overflow pipe, which passes through the bottom of the settling tank; by pushing the pipe down, so that its upper end is below the surface of the liquid, the clear juice is drawn from the surface down to the settlings. Cut "C" is an outside swing pipe, which draws the settlings from the bottom of the first tank, then the clear juice follows. When the long arm is turned down, the liquid flows out; when it is turned up, the flow ceases.

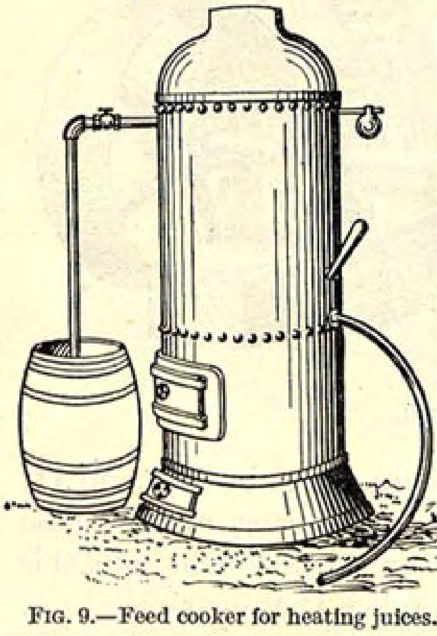


FIG. 9.—Feed cooker for heating juices.

Cut "D" represents possibly the best form for tanks. The swing pipe is placed inside of the tank and by keeping the upper end of the long arm just below the surface of the liquid, the sediment is left behind. A float may be connected with the long arm, keeping it just below the surface of the liquid, and arranged so as not to draw the settlings. The arm when standing erect must be long enough to reach above the surface of the liquid in the settling tank, and the swing pipe should be placed close to the bottom of the tank, far enough from the side to allow the long arm, when turned down entirely, to lie flat upon the bottom, so as to draw all the liquid, as well as the sediment, from the tank; the long arm of the nipple should fit the threads tightly enough to hold the weight of the pipe in any position and not allow it to drop down under any conditions. The settlings or sludge can be used for feeding hogs; but when the settling has been done hastily it should be drawn off to another tank and allowed to settle more slowly, thereby saving more of the juice.

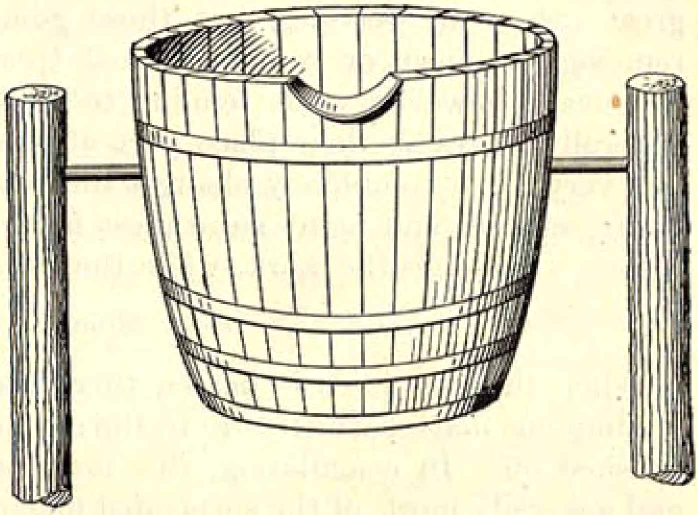


FIG. 10.—A swinging barrel for easily pouring off settled juice.

CLARIFICATION.

The object of clarification is to remove the objectionable substances from the raw juice so that a better grade of sirup may be obtained.

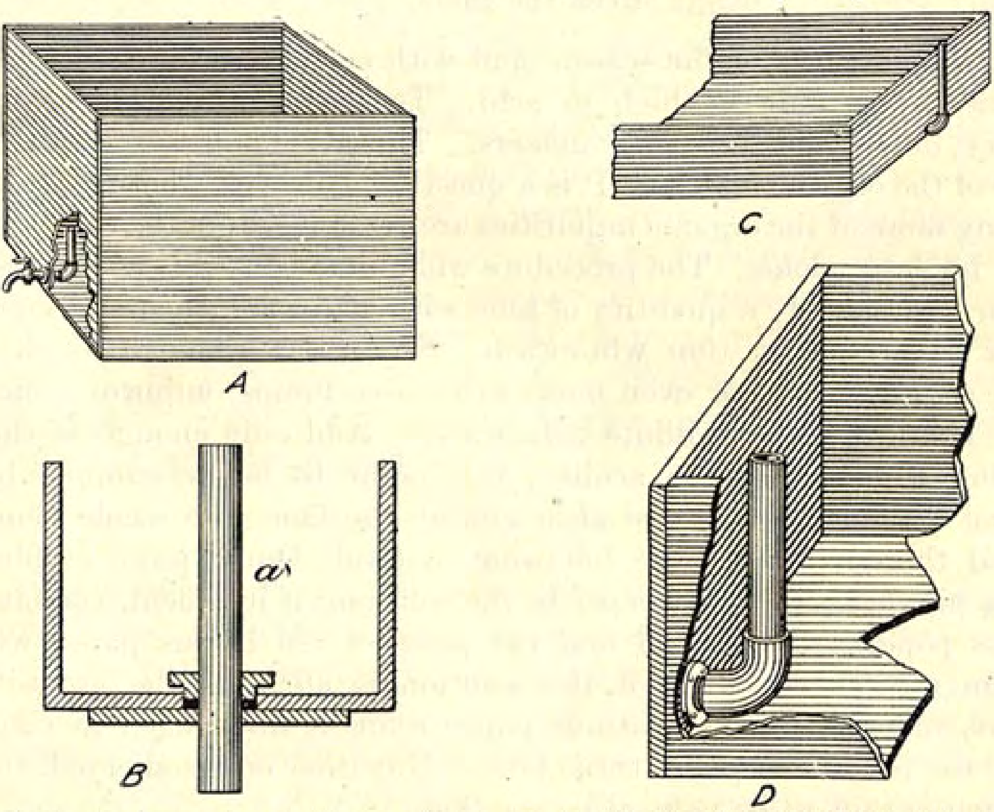


FIG. 11.—Tank connections for drawing off juice. *A*—A settling tank from which the clear liquid is drawn by an upright nipple near the bottom *B*—A sliding overflow pipe for decanting liquids. *C*—An outside swing pipe for drawing liquid from the bottom. *D*—An inside swing pipe for decanting liquids from near the surface.

The impurities in sorghum juice vary, depending on the season, variety of cane, pressure used in extraction, and the ripeness or condition of the cane. The undissolved impurities are removed to a great extent by settling, but those going into solution must be removed by heat or some chemical treatment. The addition of chemicals, however, while tending to throw certain impurities out, generally leaves in their place part of the foreign substance added and very often completely changes the flavor of the resulting sirup. Many schemes and many substances have been proposed for clarification. Some do the work, while the use of others is questionable.

Heat Alone.

When the raw juice is heated there occurs a coagulation of the albuminous matter which rises to the surface and can be skimmed or brushed off. In coagulating, this material tends to remove some, and generally most, of the suspended matter. Some makers provide special pans or tanks for this heating or clarification; the temperature of the juice is brought nearly to the boiling point and then the heat is turned off and the juice is allowed to stand; the clear layer is then drawn off for evaporation. This process, which is to be preferred especially in the manufacture on a small scale, is also commonly used in cane sirup manufacture.

Heat and Lime.

At certain times of the season, and with certain varieties of cane, the raw juice may be high in acid. To partially neutralize this acidity, lime is added by some makers. This also tends to precipitate some of the organic matter. It is a question, however, whether by its use any more of the organic impurities are removed from the raw juice than by heat alone. The procedure when lime is used is as follows:

Slack completely a quantity of lime with water and then add more water to produce a thin whitewash. Strain the whole through a mesh screen, ⅛ inch or even finer, to remove lumps, unburnt stone, etc. If still too thick, dilute with water. Add only enough of this to almost neutralize the acidity, this point to be determined by testing the juice before and after adding the lime (the whole being stirred thoroughly) by the following method: Dip a piece of blue and a piece of red litmus paper in the solution; if it is acid, the blue litmus paper will turn red and the piece of red litmus paper will remain unchanged, while if the solution is alkaline, the opposite occurs, namely, the blue litmus paper remains unchanged in color while the red litmus paper turns blue. If neither one is affected, the solution is said to be neutral in reaction.

It is far better to lime lightly at first, noticing the color of the juice after the addition of lime, the tint of the blue litmus paper after wetting it in the thoroughly stirred limed juice, and the quality of the sirup produced; then add more or less lime to the next lot of juice, keeping always on the safe side—that is, the acid side. Liming should cease when the juice gives only a faint red to litmus. If it does not change the color at all, too much lime has been used, and fresh unlimed juice should be added.

Litmus paper can be obtained in "books" or in sheets. The former is a little more expensive but is easier to use. If sheet litmus is used, a piece should be cut for immediate use, clipped into small oblong pieces, and put into a small bottle, which may be corked and carried in the pocket. The rest of the sheet should be put away in a corked bottle for future use. Acid vapors in the air and fingers moist with acid juices redden and spoil blue litmus. By moistening the tip of the finger and touching one of the pieces of the blue paper it may be picked up without handling the others. The greatest care must be exercised in using lime for clarification, as an excess will spoil the flavor of the sirup.

Other Methods of Clarification.

Use of phosphoric acid compounds.—In this treatment two methods of procedure have been used. In one the phosphoric acid is added to the raw juice and then limed before heating. In the other, lime is added to alkalinity, then phosphoric acid is added to a slight acidity, and the juice is heated. This procedure greatly changes the flavor of the resulting sirup, and its use is very questionable.

Use of lime carbonate or whiting.—Ordinary slacked lime is strongly caustic while the carbonate of lime or whiting is not, so less care is necessary when using whiting to avoid an excess. The method of using this material is to heat the juice and sprinkle the carbonate over the surface, reheat and sprinkle again, noting the reaction to litmus of the resulting solution. Much more whiting than lime is necessary to neutralize the acidity. Whiting can be added to settling juice to cause a better and quicker separation of the precipitated and suspended material.

Test Glass and Its Use.

As a means of watching the progress of clarification, a test glass may be used to withdraw samples and examine them by transmitted light. Prepare a handle from a ½ to ¾ inch board about 2 feet in length and notch it as shown in figure 12. Obtain a 2 or 4 ounce salt-mouth glass bottle from a drug store and place it in the notch, then by means of a strip of sheet iron bind the bottle in place. This will be found very convenient at various stages of sorghum sirup manufacture.

EVAPORATION OR CONCENTRATION.

The object of the process of evaporation is to remove the water from the raw juice and thereby thicken it to a sirup. This thickening may be carried to a half concentration, filtered, and the concentration completed. This procedure is quite often followed in manufacturing on a large scale, in making a sirup from overripe or underripe cane, or when much lime has been used in clarification.

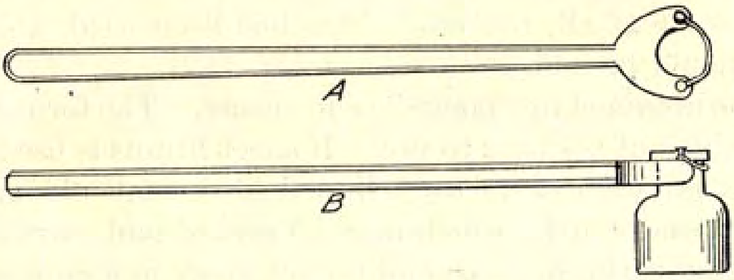


FIG. 12.—Test glass with cut of handle.

Use of Kettles.

The simplest form of boiling apparatus is the old iron kettle. There may be one of these swung from a chain or pole or several may be arranged in a row as a battery, generally called a "Jamaica train," as shown in figure 13. The fresh juice is placed in the kettle next to the chimney and as it heats it is ladled into the next one. The finished sirup is taken from the kettle immediately back of or over the fire box. When a single kettle is used a fire is built around the outside of it, the raw juice is poured in, and the kettle is swung in to the fire. Concentration in this form of apparatus seldom yields light-colored, good-flavored sirup. The greatest care must be used not to allow the flame to get above the level of the juice in the kettle, otherwise it will burn and have a scorched taste. Another precaution necessary when making sirup in this kind of an apparatus is to concentrate a single charge and not to add fresh juice to the boiling sirup. The

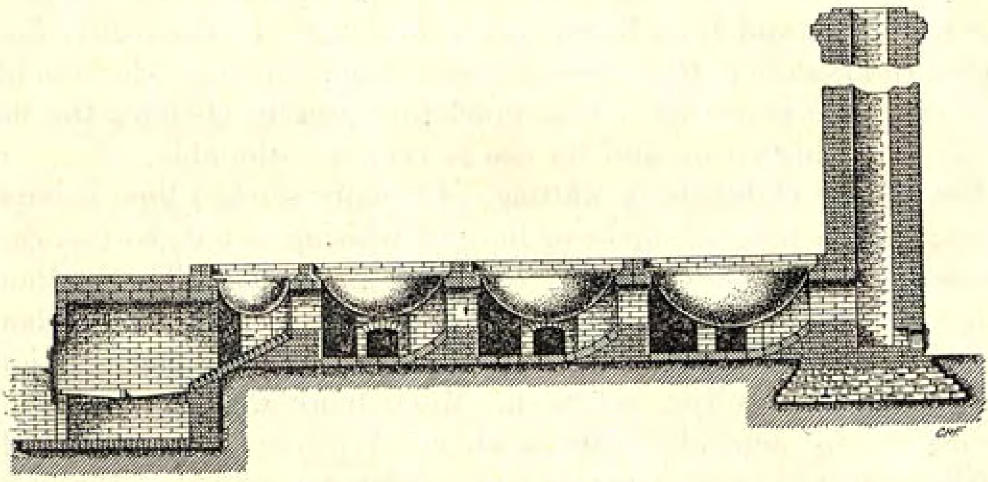


FIG. 13.—Jamaica train of kettles.

latter procedure always gives a dark-colored sirup with a strong burnt flavor. After a charge has been concentrated, the kettle should be swung from the fire and the sediment washed out before it has had time to burn. If the kettle can not be removed from the fire, then after two or three charges, remove the fire and clean the kettle. Any scum collecting on the surface of the boiling liquid should be removed as it forms, which is easily done with a skimmer.

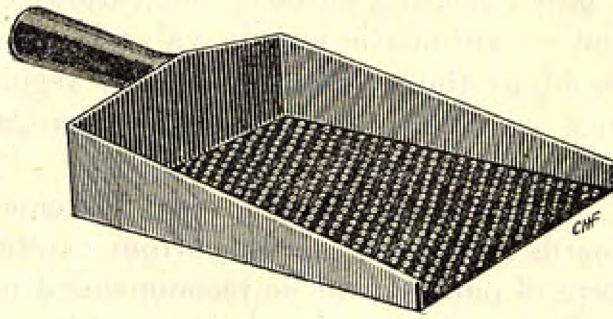


FIG. 14.—A sirup skimmer.

A sirup skimmer is made of metal, and resembles an ordinary dust-pan, with the bottom perforated. It may have a short handle, as shown in figure 14, or a long wooden pole may be attached to it. Another form of skimmer often used is a pole with a narrow piece of metal fastened on to it toward the end. By means of this the scum can be raked to the near edge of the pan and then be lifted off by the regular skimmer.

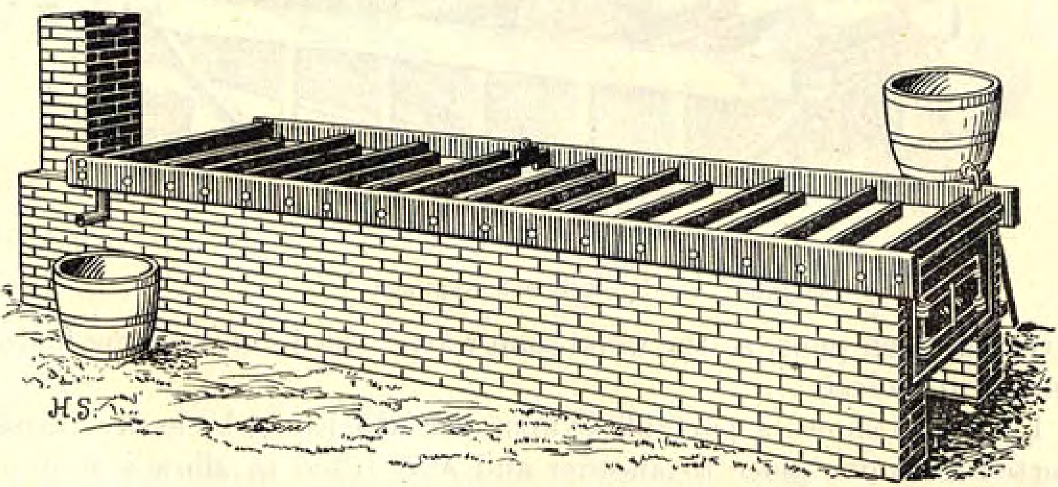


FIG. 15.—A pan evaporator.

Use of Pans and Patent Evaporators.

Instead of kettles many makers use shallow pans (not over 4 to 6 inches deep) made of sheet iron, galvanized iron, or heavy tin. In this case, a single pan covers the whole space occupied by the kettles or there may be two or three pans used, one back of the other. These may or may not be connected so that the juice can flow from one to another. Figure 15 shows a single pan with strips to guide the juice so that it may have a zig-zag course in boiling. The raw clarified juice comes in at the fire end and the finished sirup runs out at the chimney end. In most cases these pans are lifted from the fire for removing the sirup and cleaning at the end of the day.

Many improvements have been made in late years in the evaporation apparatus. Patent evaporators have many points of superiority to recommend them. The bottoms are usually corrugated to give a larger heating surface, the various compartments are connected, and an automatic supply valve is placed so that the depth of the liquid in the evaporator can be regulated. Their construction is such as to produce a quick concentration without the danger of burning or scorching the sirup.

Some makers prefer and use a homemade pan constructed of 1½-inch boards with a sheet-iron bottom carefully luted to the sides. This form of pan can not be recommended under the usual conditions for making a good grade of sirup. After once using the wood becomes soaked with the juice and if allowed to stand empty this juice sours and taints the next boiling. In the long run they are more expensive than iron pans, as the wood soon warps, the joints become loose, and sirup is lost.

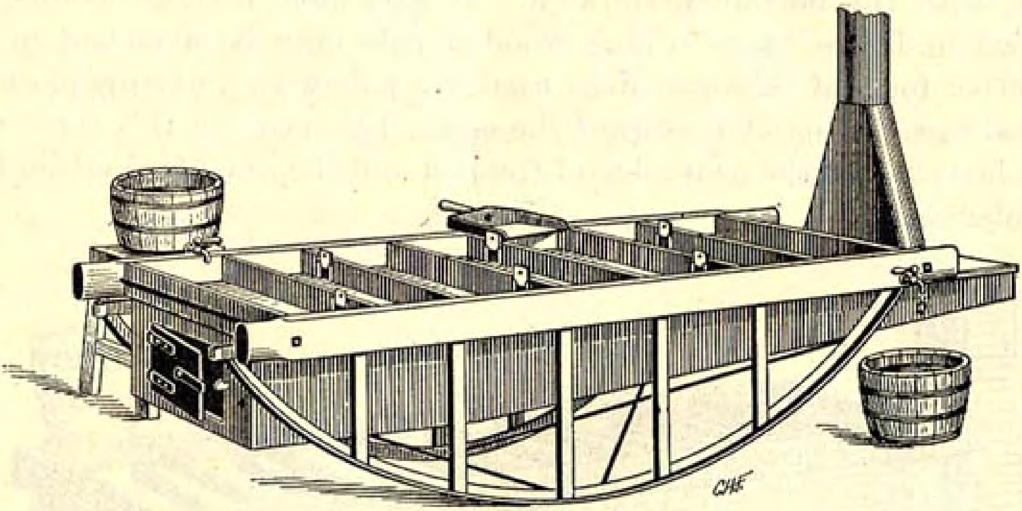


FIG. 16.—A portable evaporator.

Figure 16 shows a portable evaporator which can be easily transported from one place to another and also tilted to allow a flow of juice and sirup. It is used quite extensively in some sections of the country.

To obtain the best grades of sirup when using these forms of evaporators only a thin layer of sirup should be boiled. Not more than a 1½ to 2 inch layer of juice should be in the pans or evaporator at any time, and with care even a thinner layer might be successfully carried. A thin layer makes a quick evaporation and, as a consequence, less color is developed when concentrating to a sirup. Also when boiling a thin layer the impurities reach the surface more easily, and by constant skimming a clear finished product is obtained. Deep boiling in such an apparatus produces the same effect as in iron kettles, namely, a dark, bad-tasting sirup. If an ordinary gutter is placed along each side of the pans when installed the scum can be raked off into this and then caught at the end in a bucket or tub. These skimmings make good food for hogs unless much lime has been added in clarification.

Some makers prefer to boil to a comparatively thin sirup, pass this through a filtering medium to remove the sediment, and then reboil to a proper density. If much lime has been used in clarifying, or if the juice contains much mineral salts, there will be some deposit of salts on concentration. Maple-sirup makers bring much of the floating mineral sediment to the top by adding to the boiling liquid the white of an egg or some whole, fresh, sweet milk, which produces a gelatinous precipitate around the small particles and brings them

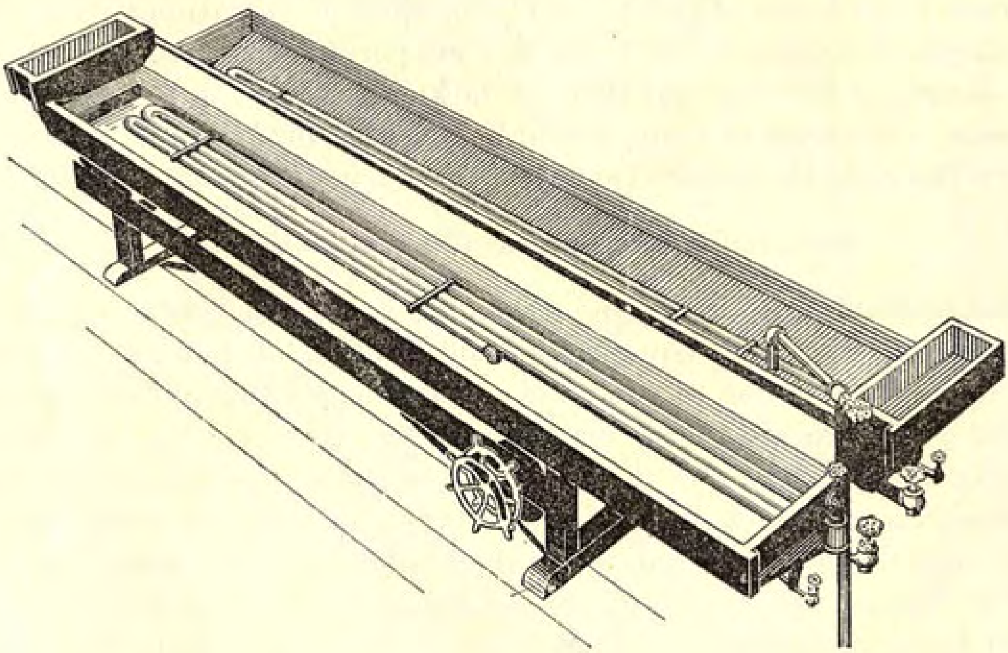


FIG. 17.—A steam evaporator.

to the top, where they are removed by skimming. Some sorghum makers do likewise. Under most conditions this material can be removed easily by filtering through flannel or by simply allowing it to settle. Filtering is rather difficult if the sirup is thick and gets cold; a hot liquid filters faster.

In starting a patent evaporator always have water in all the parts and boil this until the raw juice enters. Never heat kettles or pans without water unless it is desired to burn the scale loose. Even this can generally be done in other ways, namely, by boiling water in the pans, either alone or with some acid, as muriatic acid. The acid, however, must be used with the greatest care, as it dissolves the metal of the evaporator. Scraping with an iron removes the scale but it often spoils the evaporator, causing a leak at the place scraped.

Use of Steam Evaporators.

In the steam evaporator the heating is accomplished by means of steam coils. The most common form of such evaporators is a heavy wooden box lined with some metal, as iron, tin, or copper and containing a coil of iron or copper pipe. The coil is removable so that it can be cleaned. Figure 17 shows a form of steam evaporator that is used to some extent; one side is for heating the juice, thereby clarifying it, and the other for the concentration. When working on a large scale, copper tanks with copper coils are used. For the small maker it is a question whether steam evaporation pays or not. When the farmer intends to manufacture sirup for others and make it on a large scale, it might pay to use steam evaporators, but fire evaporators can be purchased that will produce 200 gallons of sirup or more in 10 hours of boiling. The method of operation with steam heating is the same as with the fire evaporators, but there is much less danger of burning and thereby darkening the sirup by the former process. The level of sirup should be not over half an inch to an inch above the coils for quick evaporation and a good-flavored product.

Methods of Determining the Finishing Point.

The finished sirup upon cooling should have a moisture content of not over 30 per cent, equaling a solid content of not less than 70 per cent. One gallon of such a sirup would not weigh less than $11\frac{1}{4}$ pounds. Commercial practice recognizes this as the minimum density for a sirup. As the sirup comes from the evaporator it is rather difficult to fill and weigh a gallon measure, and again such a weight would be correct only when the whole was cooled down to about 60° F. before the weighing. Some makers determine the finishing point by pouring the sirup from a spoon and watching the last drops fall, but there are two methods which are superior and yet easy to perform. The first is noting the temperature at which the sirup is boiling and the other is to measure the density by means of a Baumé hydrometer.

By thermometer.—As a liquid thickens, the boiling point is raised. Water at ordinary pressure or at sea level boils at 212° F., while a sugar solution with 70 per cent of solids boils at 223.7° F. If, now, a thermometer is placed in the boiling sirup one can roughly judge of the density of the product. In testing a sirup for its density by this manner it would be well to test the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Then finish the sirup at a point 12° to 13° higher than the boiling point of water. Altitude affects the boiling point of liquids. For every 500 feet above sea level, roughly speaking, the boiling point is lowered

1° F., so that water at a point 2,000 feet above sea level would boil at 208° F. and a finished sirup at 220° F. In taking the temperature one must be careful not to allow the bulb of the thermometer to touch the bottom or sides of the evaporator or be exposed above the surface of the liquid, otherwise the reading will not represent the true temperature.

By hydrometer.—A hydrometer or spindle is an instrument for showing the density of a liquid. Hydrometers are graduated to various scales and for various purposes. The one generally used for rough sugar work is the Baumé. The standard of graduation is an arbitrary one and varies somewhat with different makes. The usual Baumé hydrometer shows a graduation of zero to 50 divided into degrees, as shown in figure 18. The instrument being of glass is rather perishable. The density is measured by floating the hydrometer freely in the liquid, which is generally held in a tall cylinder, as shown in the illustration. The point on the scale where the instrument comes to rest is considered the density. With a raw juice this varies from 4° to 8°, while for a finished sirup it should be 38° and over.

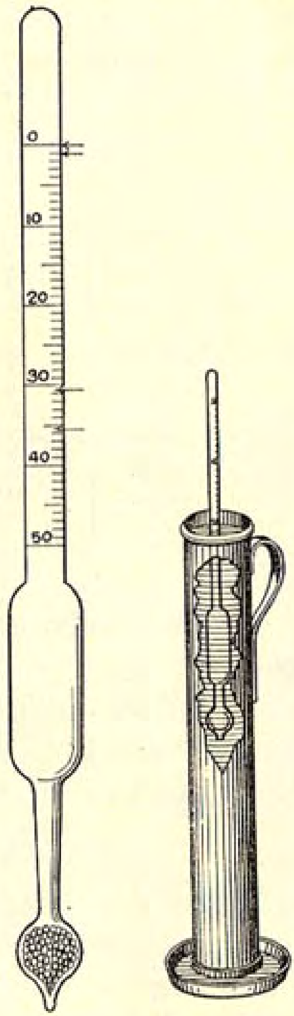


FIG. 18.—Hydrometer and its position in the liquid.

The temperature of standardization is 60° F., so for correct readings the sirup under examination should be cooled to that temperature. A boiling sirup that gives a reading of from 35° to 36° when cooled will generally read over 38°. The accuracy of these glass hydrometers is very much affected by using them in hot liquids, hence it is not good practice to use your accurate instrument in the hot sirup. The following table shows the solid content and the water content for different degrees Baumé. These figures are only approximate.

Dry substance and water corresponding to each degree Baumé.

Degrees Baumé.[1]	Dry substance.	Water.	Degrees Baumé.[1]	Dry substance.	Water.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1	1.7	98.3	26	46.8	53.2
2	3.5	96.5	27	48.6	51.4
3	5.3	94.7	28	50.5	49.5
4	7.0	93.0	29	52.4	47.6
5	8.8	91.2	30	54.3	45.7
6	10.6	89.4	31	56.2	43.8
7	12.3	87.7	32	58.1	41.9
8	14.1	85.9	33	60.0	40.0
9	16.0	84.0	34	61.9	38.1
10	17.7	82.3	35	63.9	36.1
11	19.5	80.5	36	65.8	34.2
12	21.3	78.7	37	67.8	32.2
13	23.0	77.0	38	69.7	30.3
14	24.8	75.2	39	71.7	28.3
15	26.6	73.4	40	73.7	26.3
16	28.4	71.6	41	75.7	24.3
17	30.3	69.7	42	77.7	22.3
18	32.1	67.9	43	79.7	20.3
19	33.9	66.1	44	81.8	18.2
20	35.7	64.3	45	83.8	16.2
21	37.5	62.5	46	85.9	14.1
22	39.4	60.6	47	88.0	12.0
23	41.2	58.8	48	90.1	9.9
24	43.1	56.9	49	92.2	7.8
25	44.9	55.1	50	94.4	5.6

[1] Taken at 60° F.

It is not to be understood that a degree Baumé corresponds to 1.7 per cent of sugar, for the hydrometer measures other dissolved solids also. When determining the density of the raw juice, a reading should not be made for about twenty minutes or until after the hydrometer has come to rest, when all the air in the juice has escaped.

TREATMENT OF FINISHED SIRUP.

When the sirup has reached the desired density it should be quickly removed from the fire and rapidly cooled. If no care in skimming has been exercised during the concentration, the sirup will have a dirty appearance and even though carefully skimmed, there may be more or less turbidity due to suspended matter. To completely remove this in many cases is a difficult task, but allowing it to remain in the sirup spoils the appearance and to a less degree the flavor. Many methods have been proposed for removing this material. Some makers filter the sirup, some give it an extra treatment, while others allow the sirup to stand to settle the sediment. A filtration of the semisirup during concentration renders a filtration of the finished sirup unnecessary under most conditions. The greater portion of the sediment is thus removed, leaving only the mineral sediment which is thrown down by concentrating to a higher density. Again, upon boiling a thin layer in an evaporator and carefully skimming there is little suspended material left in the sirup.

Sorghum sirup being particularly viscous at high concentrations does not filter easily through flannel or felt, although when worked hot it can be done. A rather coarse, sharp sand makes a good filter bed. The sand should be carefully cleaned, all organic and soluble material and clay being removed. A bed about 6 inches thick makes a filter that will generally remove the sediment. Some makers use 6 to 8 inches of excelsior or wood straw as a filtering medium. The excelsior should be soaked in hot water to remove all soluble matter before using it for this purpose. Sand or asbestos filters, or in fact any filters, should be carefully cleaned after using. All the remaining sugar solution should be washed out and the bed thoroughly sterilized with hot water or steam. When operating on a large scale, sorghum sirup can be forced through filters under pressure and the maximum cleaning in the minimum time obtained.

If the sirup is not too heavy, standing will cause the sediment to collect at the bottom and the clear sirup can be drawn off. For this purpose, tall milk cans with one or two faucets placed 2 and 4 inches from the bottom serve well the purpose. Figure 19 shows such a can with three faucets. The sirup coming from the cooler can be placed in this and allowed to settle. A very heavy sirup, however, or one that is particularly viscous, may stand for as long as a week without any appreciable sedimentation taking place. If the cleansing is carefully done during the process of manufacture the finished sirup will not need much treatment.

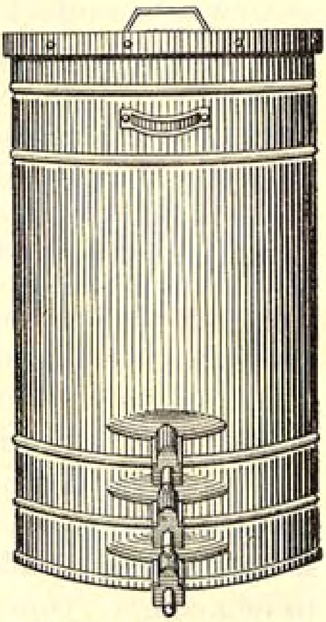


FIG. 19.—A settling can.

Sorghum sirup should be quickly cooled after finishing, so as to hold the color. Many makers run their sirup through a coil of pipe incased in cold water which can afterward be used advantageously for the boiler when a power mill or steam evaporator is used. Some makers have this coil in their raw-juice tank which serves the double purpose of heating the raw juice and cooling the finished sirup. Makers who cool their sirup quickly claim that the color is not darkened and a better grade is therefore produced.

CANNING SIRUP.

The form in which the makers offer their sirup for sale depends greatly upon the market conditions. It may be placed in tin containers with screw tops, holding one gallon, one quart, or half a quart, convenient sizes for local consumption. When packing in this form, the cans should be thoroughly scalded with hot water before filling. Wooden pails holding five gallons, or half and full barrels, can be used. When using wooden packages, they should be carefully washed out, and for the best after effects should receive a thorough steaming before filling. Fermentation can be long prevented by careful handling of the sirup. If the sirup goes directly from the evaporator into previously steamed barrels there should be no trouble from fermentation, nor should there be much danger of it when the sirup is carefully covered, cooled, and then canned in sterilized packages.

Sorghum sirup can be graded as to color and also flavor by establishing standards on these points and classifying the output. This is of extreme importance in supplying a local market, and it might be of value to the makers of sorghum sirup in a certain locality to unite and sell their product under such conditions. The usual purchaser of such a commodity desires two purchases of the same material to have the same color and flavor. They are not informed as to why manufacturing conditions affect these and why all sorghum sirup is not of the same appearance and taste. By having such an association of farmers and a system of standardization, different products can be classified. As maple-sirup makers have found this plan of value, it might be profitably applied to the sorghum-sirup industry.

PREVENTION OF CRYSTALLIZATION.

Crystallization results from making a supersaturated solution of a substance in a liquid. In the case of sirups the sucrose becomes concentrated to a point at which it is no longer soluble in the water present, and hence it crystallizes out. This is the fundamental principle of recovering or manufacturing sugar. In these processes every care is taken to prevent the destruction of sucrose during manufacture so that a greater yield of sugar will be obtained. If sirup is the product to be made, on concentration it would be natural for a crystallization to take place, and to prevent this crystallization as far as possible the following precautions are taken:

Sucrose, on being heated in the presence of an acid or on long and high heating in water, becomes broken down into two sugars. One of these is crystalline in form; the other is liquid under most conditions. These two sugars are known as invert sugar and possess a sweet taste. The modification of the process referred to is to leave the juice after clarification more acid than in ordinary work. In other words, to use less lime or none at all for clarification. On concentrating such a juice a natural inversion of the sucrose will take place, and hence there will be less crystallization. This may and does suffice in most cases, but when the sorghum is very ripe (has a high sucrose content) the sirup may still crystallize. Some makers accomplish the desired inversion by allowing the cane to remain in the field for 24 hours or more after cutting. This practice will certainly reduce the amount of sucrose in the cane, but its effect on the flavor of the resulting sirup is a matter of conjecture. However, it is done extensively in sorghum sirup manufacture. Sorghum juice, as expressed from the cane, contains some little starch and gummy materials. If these are not removed in the process of settling and clarification, they will tend to keep a sirup from crystallization, especially if the starch becomes soluble by boiling. It is not the usual policy, however, to allow them to remain in the juice for this purpose (though they are sometimes present, due to poor settling and skimming), as they do influence the flavor of the sirup. The danger of crystallization in sorghum sirup is much less than in cane or maple sirup. Long standing, however, in a cool place may cause crystals of sugar to form.

COMMENTS BY REPRESENTATIVE SIRUP MAKERS.

Mr. Seth H. Kenney, of Minnesota, a sorghum maker of 50 years' experience, states:

I grow Minnesota Early Amber cane and make 10,000 to 15,000 gallons of sirup yearly. I also buy 1,000 to 1,200 tons yearly, at $2 per ton. The average cost of growing cane and hauling it half a mile to the mill is 10 cents per gallon of sirup manufactured. The average cost of making the sirup is 9 cents a gallon. Two pounds of seed are required for an acre. The planting should be done so that the cane will not all ripen at once. The plants should be thinned. It is important to cultivate cane well when small. When the seed heads begin to turn brown, I begin to grind. I cut cane 24 to 48 hours ahead of my wants. If there is an appearance of frost, I cut all standing cane and pile 6 hills in a pile. With cane cut 12 to 24 hours before a frost the juice cells shrink enough so that frost does not injure it. I know nothing better than lime for defecation and the steam pan for evaporation. The lime is about as thick as whitewash when used. About 1 quart of this milk of lime is used in each 100 gallons of raw juice. It is allowed to drip in the spout that contains the juice as it comes from the mill. A good sirup can be made without lime—and probably nineteen-twentieths is manufactured in this way—but the use of a quart of milk of lime in 100 gallons of juice is preferable. The use of lime at the right time, in the right place, and in the right quantity requires skill. It is necessary to bring the juice nearly to a boil, skim, draw off into the evaporator, boil rapidly, and cool the sirup quickly. The latter should weigh 11½ to 12 pounds per gallon. The pan should be well cleaned once a day. The tanks, etc., should be clean and sweet.

Mr. Conrad Munz, of Illinois, who has made sirup since 1889, writes as follows:

I have made as high as 29,000 gallons of sirup a season. My first attempts were with a small mill and fire evaporator, but am now using a mill crushing 5 tons of cane per hour and corresponding steam defecation and evaporation. I have discontinued the use of clarifiers, as lime and sulphur, and now use nothing but heat, and plenty of it, to make our sorghum sirup.

Densmore Bros., of Minnesota, say:

The best soil in which to grow sorghum is a light loam inclined to be sandy rather than rich in vegetable plant food. The best results follow the use of wood ashes as a fertilizer. Soil fertilized with barnyard manure or ground which has been used as a hog yard or pasture is to be avoided for sorghum, as it is a voracious and indiscriminate feeder from the soil. The yield of cane, seed, or sirup is a true index of the care bestowed in selection of the soil and cultivation. The ground must be kept free from grass and weeds, so the air can have free access between the rows and to all parts of the cane. The yield of sorghum cane is from 9 to 12 tons to the acre and of sorghum seed 10 to 20 bushels per acre. In a record of a hundred or more lots of cane, the lowest yield of sirup was 60 gallons per acre, and the highest 245 gallons, the average being 150 gallons. In manufacturing sirup from sorghum juice, it must be remembered that raw sorghum juice is a very unstable liquid—it soon begins to ferment and decay. To forestall this condition milk of lime and heat are necessary. Good defecation is important; evaporation affords no remedy for poor defecation. As it comes from the mill the juice is full of impurities, which, if allowed to remain in the sirup, affect its quality. Many substances have been tried in the defecation but the invariable conclusion is a return to lime. It neutralizes the acids and cuts the gummy matter. It is a necessity to remove impurities from the juice before evaporation begins. The juice after the lime is added is agitated by pumping and then heated to about 180° F. and finally to about 212° F., then the heat should be shut off and the impurities allowed to separate as scum and sediment. Three defecators should be used; one being filled, one settling, one being drawn from. An automatic swing pipe drains the juice from near the surface to the evaporator, where there is a valve for regulating the supply. When not in use the swing pipes are turned up to full height, so as not to act. The outlets from the defecators all connect with a pipe which conveys juice to the evaporator, where it is concentrated as quickly as possible. Boiling should be accomplished in as thin a film of juice as possible. The thicker the layer, the longer the time and the darker and stronger the sirup. The temperature for finishing an 11½-pound sirup at the altitude of St. Paul is about 225° F.

J. J. Bishop, of Indiana, writes:

I strip all of my cane before cutting and let it stand a few days, then top and cut. Trials of grinding cane without stripping produced a bad sirup as there was more filth and sediment than with stripped cane. The juice is allowed to settle in cement tanks and then siphoned two or three times. Boiling is accomplished in the ordinary form of patent evaporator, which in the winter is used for maple sirup.

J. T. Elliott, of North Carolina, writes:

I prefer Gooseneck to the other varieties used around here. When the cane is ripe, I go into the field, strip fodder, and scatter it on the land; then cut the heads and place in piles; then cut cane and haul to mill as soon as possible; if crowded it may be one or two days before it is ground. I always try to cut all cane before the frost; a light frost will not do much damage, but a heavy frost or freeze will ruin the cane for sirup making, and under such circumstances I cut and give it to the hogs. The cane is ground in a 3-roller mill and the juice strained through coarse cloth or sacking. All juice is worked up the day the cane is ground; allowing it to stand over night causes it to sour and become unfit for sirup making. My evaporator is a homemade one, 20 by 60 inches. I took dressed hardwood, 2 by 10 or 12 inches for sides, and bolted together at the ends; then nailed heavy sheet iron on for a bottom. The whole is placed on brick walls 15 inches high so as to admit of wood and fire under it. The evaporation is carried on as quickly as possible. The juice is brought to a boil and then allowed to concentrate, skimming off foam as soon as it begins to form, with perforated ladles and continuing to skim until nearly done, which is told by the way it drops on cooling. When finished the pan is removed from the fire by a man at each corner, cooled and measured. If a small crane is fixed on ceiling of shed, one man can remove the pan. The skimmings are good for hogs. Farmers in this section say the heads on a row of cane are worth as much to feed hogs as a row of corn of the same distance.

W. J. Maxwell, of Missouri, makes the following statement:

Hand harvesting of cane is the only satisfactory method we have found for a high grade sirup, as a harvester will cut all, and some canes are unfit for sirup of high quality. Stripping or removing the blades seems quite a task, but carefully testing quantity and quality we find ourselves from $5 to $7 per acre ahead by doing so and besides have a lot of good feed. The sooner the sirup is made after the cane is cut the better the grade, though a few days to a week does not materially damage the quality; if cut during dry weather, the quantity of sirup is decreased. In case of a heavy frost or freeze we cut and shock the cane. For manufacture of a good sirup one needs a heavy mill with greater capacity than the evaporator used. The juice as it comes from the mill is run through a strainer made of fine wire (same as used for milk strainer) into one of two tanks with valve between, about ½ inch from the bottom of the one that the juice runs into. This pipe with valve empties juice into the second one and from this one the juice goes to the evaporators. I always have these tanks full of juice or about so at least. The sediment settles in tank 1 and whenever the juice gets low enough the sediment is turned to the hogs, as it is a great deal better to get it out of the evaporators. I used to think clarifiers were necessary (such as lime and alum), but I have found out differently and my sirup now is better without their use. I use an evaporator with a good furnace under it, something that will start juice to boiling two minutes after lighting the fire. By allowing the raw juice to enter one end and taking the finished sirup off at the other, we have a continuous process. For juices rich in sugar and good in color, we have the layer of juice in the evaporator about 1 inch deep, but with poor juice we keep the level as low as possible to finish into sirup in 20 minutes. As the raw, cold juice enters the evaporators the sediment and impurities collect at this point and are skimmed off. My experience is that all changes in flavor and color of sirup take place while it is hot and this is why we shorten the time of evaporation and why we run our finished sirup from the evaporator immediately into a cooling tank.

Bieder Bros., of Minnesota, who have manufactured sorghum sirup for 16 years, write as follows:

We have recently put in an all-steam plant. Have a 5,000-pound mill, which furnishes bagasse dry enough to burn immediately. We use this under our boilers together with cord wood, and find a saving of about 35 per cent in fuel, besides saving the expense of hauling. The grates are hollow and air is forced through by means of a blower to make a more intense fire. The juice coming from mill is strained and pumped to one of three defecating tanks, where lime of 13° B. is added (1½ quarts to 100 gallons). The quantity of lime depends on the richness and greenness of the juice. Steam is slowly turned on in this tank and the temperature brought up to 210° F. If the right amount of lime is added the scum will come to the surface and the juice be clear. Three-fourths to one hour is necessary for settling, and then the clear juice is run off to the evaporator. A shallow boiling is practiced—not over one-half inch of juice above the steam coils at any time. When finished the sirup is allowed to run over pipes of cold water to quickly cool it.

ECONOMIC CONSIDERATIONS.

LOCATION AND ARRANGEMENT OF A SIRUP PLANT.

The small maker should consider carefully the location and arrangement before putting up a plant; as these points are most essential to economy in manufacture. It is impossible to enter into a very thorough discussion of this subject or to lay down hard and fast rules, as many circumstances might affect one's decision. It is certain that the boiling house, etc., should be located so that it is easily accessible for bringing in the cane and fuel and storing and taking care of the finished product. In a small plant it is not necessary to cover all the equipment. The mill should be placed on the highest level, the raw juice caught at a lower point, and the evaporator be placed lower. In this way gravity is made to play an important part. This same idea can be carried out with power mills. In manufacturing on a larger scale the mill is best placed on the ground, the raw juice is pumped into storage tanks placed higher up,

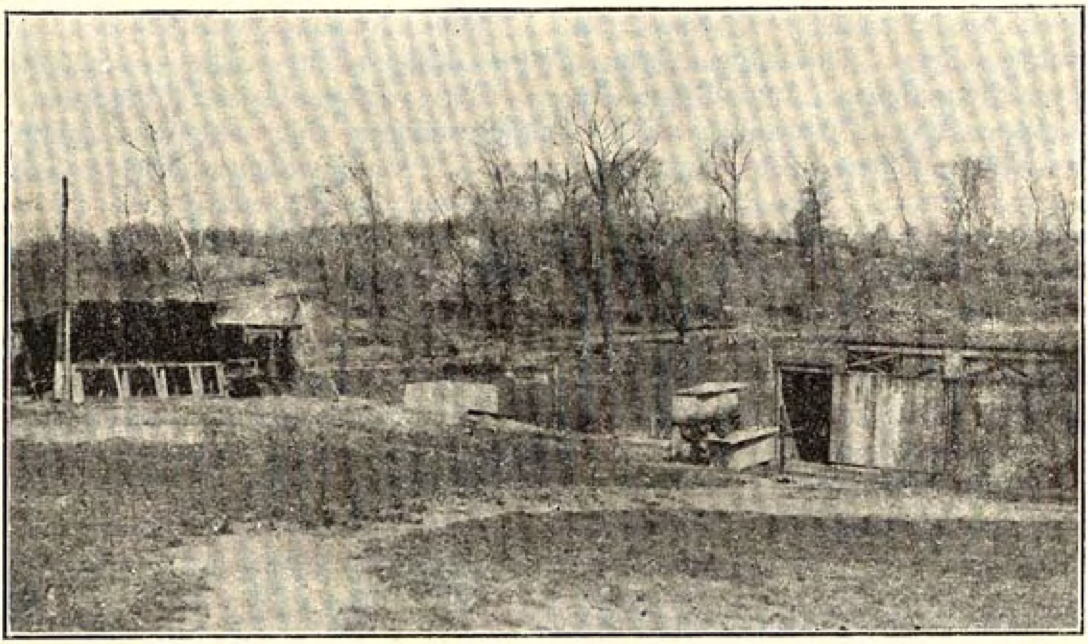


FIG. 20.—General view of sorghum sirup plant. At the extreme left are the cane mill and engine; in the center, the cement settling tanks; and at the right the oil tank and boiling sheds.

and from there it runs down through the clarifiers to the evaporators on the ground floor.

The boiling house under all conditions should be covered and provided with a good ventilator in the top so as to dissipate the steam. A good form for such a structure is shown in figure 22, one of the sides of the house being raised up to form an awning which when let down still allows for a passageway around the evaporator. If possible the floor of the boiling house should be paved, as with brick, wood, or cement, and sloped to furnish drainage. If a fire evaporator is used it would be well to have a partition at the fire door so that when stirring the fire or adding new fuel no ashes would get into the sirup. In a word, the arrangement should be such that the evaporation can be carried on with dispatch and under cleanly conditions. Many makers use their maple camps for making sorghum sirup also. The same camp and arrangements will serve admirably for the two, providing the location is convenient.

A power mill should be covered; in fact, it could well be placed in a house similar to the boiling sheds shown in figure 22, with sides capable of being raised. The evaporation house might be made large enough to hold the engine as well as the mill.

FUEL.

The fuel for the evaporation and other processes is a very important item. That one should be selected which is the cheapest for the work to be done, whether it be wood, coal, or oil. Quite a number of

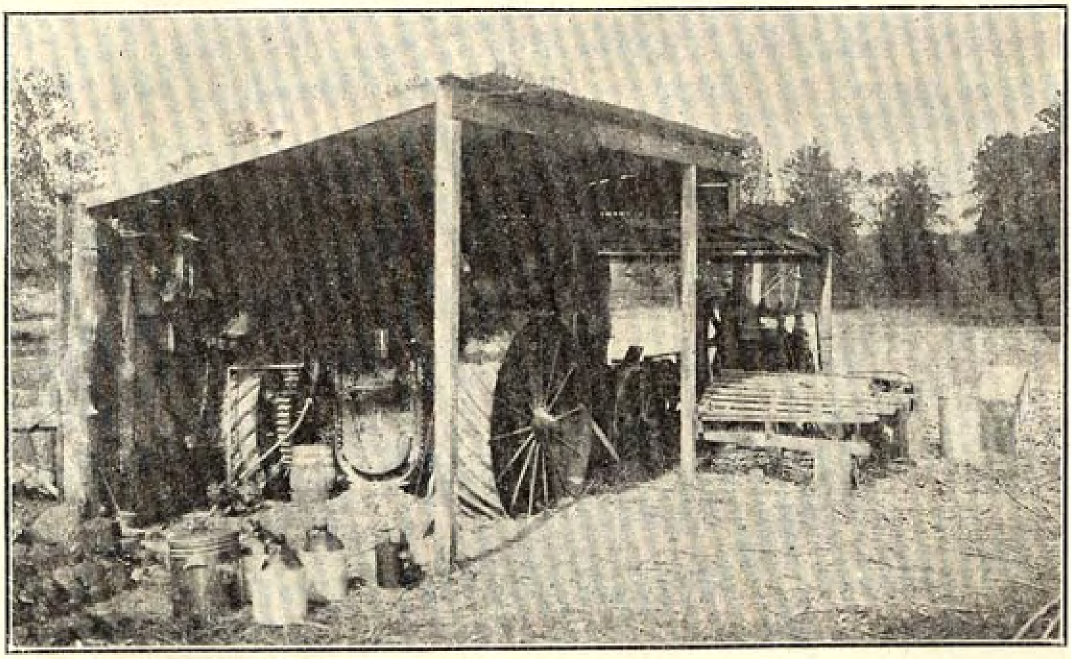


FIG. 21.—Traction engine and cane mill.

makers use a crude-oil burner under their evaporators; this, in connection with a jet of steam, gives a good fire for evaporation and one capable of adjustment. Many trials have been made in using the crushed cane (bagasse) as it comes from the mills as a fuel, but a special fire box is necessary for this purpose (fig. 23).

The greatest trouble with bagasse is its high moisture content, as the usual mill does not press the cane dry, but by spreading the crushed cane out in the sun a good fuel can be obtained. In the sugar-cane industry of Cuba the bagasse furnishes in many cases from 90 to 100 per cent of the fuel for operating the whole plant; in Louisiana it furnishes from 50 to 80 per cent of the fuel. The bagasse in these two places is drier than that obtained by sorghum makers unless double mills are used. Again, these large cane plants are equipped with special furnaces for handling the bagasse.

Figure 23 shows an arrangement for burning bagasse on a small scale under pans or evaporators. It consists of a sheet-iron funnel tapering toward the end nearest the furnace, so as to compress this light fuel slightly as it is pushed through into the furnace, and having a sheet-iron door hinged to the upper surface. This is a safer and better method of firing than to put the crushed canes directly upon the fire. A fork full of the fuel pushes the door inward, and the door closes itself when the fork is withdrawn.

Another form consists of a small oil burner in the furnace, the bagasse being fed to the fire by hand. There may be some danger, however, in this kind of firing.

MAKING SIRUP ON SHARES.

It quite often occurs that a farmer may grow sorghum but does not care to manufacture it into sirup. Upon what basis should the sirup be made? A central factory seldom raises all its own cane—

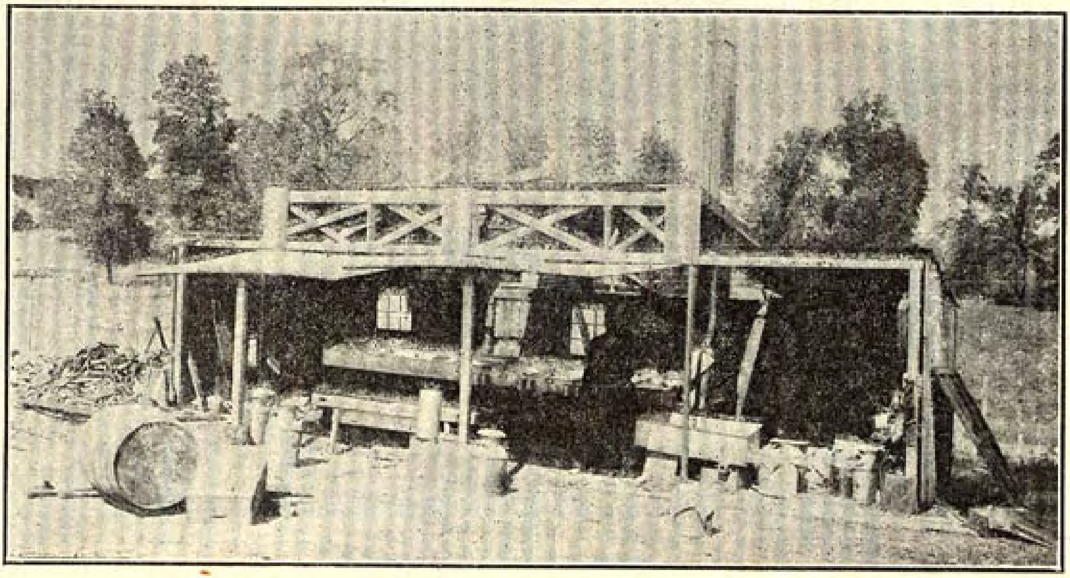


FIG. 22.—Evaporation house.

it buys from the farmers. In this case the agreement is generally drawn up for the cut cane, free of trash, and either stripped or not stripped of leaves at a given price per ton of raw material. On a small scale this is seldom done, one of two general methods being followed in such cases. Either the maker produces the product at a stated price per gallon for the farmer or on shares, that is, giving the farmer a certain number of gallons of sirup (5 to 15) for each ton of cane. In either case it is necessary to keep the cane separate and the juice also, even up to the boiling if the farmer is to receive his share of sirup.

There is, however, a way of approximately determining the amount of sirup that will be made from the cane. By using this method it is not necessary to boil each lot separately, but only to grind the cane separately and then collect the raw juice in tanks where it can be measured. From the gallons of raw juice and its Baumé reading the gallons of sirup that will be made can be calculated.

The settling tanks are convenient for measuring the raw juice. If the tank is oblong or square, take the inside dimensions, length and width, in inches, multiply these together and divide the result by 231 cubic inches to obtain the gallons of juice in the tank for each 1 inch of depth. By inserting a stick or rule in the tank the number of inches of juice is obtained and this figure multiplied by the gallons per 1 inch of depth gives the number of gallons of raw juice. If the measuring tank is round, to obtain the gallons of juice for 1 inch multiply the diameter expressed in inches by itself (in other words, square the diameter) and then multiply this figure by 0.7854; divide the result by 231 cubic inches and the result is the gallons of juice contained in 1 inch of height.

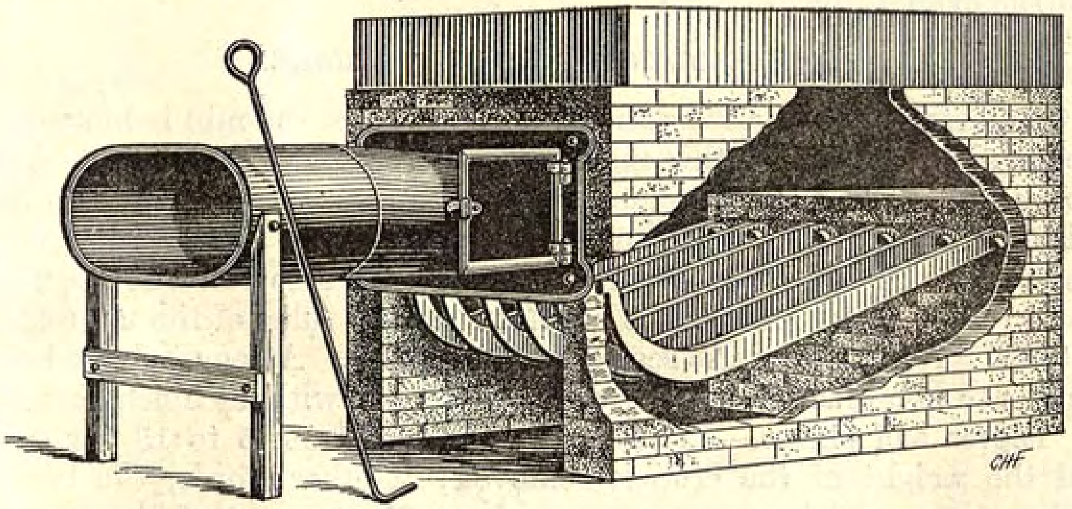


FIG. 23.—A bagasse burner.

The other figure necessary for the calculation is the density of the juice as determined by means of the Baumé hydrometer. This instrument can be placed in the tank, provided the juice is deep enough to allow it to float freely. From these two figures the yield can be obtained. One maker, Mr. A. P. Cleland,[1] has found that 10 gallons of juice with a reading of 6° Baumé make 1 gallon of finished sirup; from this he calculated the following sliding scale:

Juice, degrees Baumé.	Gallons of juice per gallon of sirup.
6	10
6½	9
7	8½
7½	8
8	7½
8½	7
9	6½
10	6
11	5½
12	5

[1] U. S. Dept. Agr., Farmers' Bulletin 135, p. 39.

It is noted that the gallons of juice multiplied by the Baumé reading gives approximately 60 in each case. Each maker can and should prepare for himself such a table as his method of manufacture may not be at all like the one cited. To do this it is necessary to measure several tanks of juice and obtain their Baumé reading, then concentrate the juice to a sirup in the usual way and measure the finished sirup. By multiplying the Baumé reading of the juice by the number of gallons of raw juice and dividing by the number of gallons of finished sirup made, the figure on which to base the table (60 in the case just cited) will be found. With this beginning a table can be prepared for different Baumé readings on the raw juice. In this way as soon as a separate lot of cane is ground the juice can be measured, the density determined, and the number of gallons of sirup due the cane grower can be learned without interfering with the work of the evaporator.

BY-PRODUCTS AND THEIR USES.

Bagasse.—The crushed cane as it comes from the mill is known as bagasse. The use of this material as a fuel has been discussed on page 35. It has also a value as a fertilizer. By returning it to the field and turning it under most of the fertilizing ingredients taken from the soil by the plant are restored. Bagasse can also be used as a roughage for feed, but it has not the food value of the unpressed stalks. Its principal use seems to be as a fuel. Attempts have been made to manufacture paper from bagasse, but without much success.

Leaves and blades.—In stripping the cane from 5 to 15 per cent of the weight of the crop is removed; in other words, the leaves when green weigh on an average about 10 per cent of the topped cane. If they are frostbitten, or dry, or both, they may not be over 4 per cent of the weight of the cane. Some makers on buying cane consider a long ton of unstripped cane equal to a ton of stripped cane—that is, 2,240 pounds are equivalent to 2,000 pounds, which would make the leaves and dirt amount to about 12 per cent. Some varieties bear more leaves than others, so only average figures can be given. The leaves make a good cattle food, or by allowing them to remain in the fields and then burning them with the stubble they furnish a good fertilizer.

Seed heads.—The amount of seed per acre varies with the variety of sorghum and the stand. Estimates ranging from 5 to 30 bushels to the acre are given, an average figure for the usual varieties of sugar sorghum being about 10 bushels. They have a large feeding value, claimed by some to be equal to corn, but most authorities give them a place much below corn. On account of the shape and hardness of the seed, better feeding results are obtained by first boiling or grinding them. Because of the difficulty of removing the hulls and the astringency of the seed coating, the grain is less relished by animals than is that of the nonsaccharine varieties.

ANALYSES OF SORGHUM VARIETIES.

In the following table are given the results of analyses of cane grown in various locations during the year 1910. The data include the Baumé reading and the percentages of sucrose and invert sugar in the expressed juice. It is doubtful whether the average run of sorghum cane of these varieties gives such high figures, but they serve to show what can be expected if the growing season is a good one and the planter uses care with his crop. The samples of Collier and Colman cane show very high percentages of sucrose with rather low invert sugar content.

Analyses of sorghum, made in 1910, arranged according to varieties.

[Results are analyses of expressed juice.]

Variety and locality.	Degrees Baumé.	Sucrose.	Invert sugar.	Total sugar.
		Per cent.	*Per cent.*	*Per cent.*
Sumac:				
Biloxi, Miss.	8.1	4.07	7.37	11.44
Do.	10.1	10.93	3.21	14.14
Dalhart, Tex.	10.6	11.34	3.49	14.83
Do.	8.6	2.88	10.90	13.78
Brownsville, Tex.	9.0	8.52	4.74	13.26
Do.	8.0	4.26	6.70	10.96
Planters:				
Biloxi, Miss.	9.7	10.59	1.91	12.40
Arlington, Va.	9.7	2.98	10.70	13.68
Do.	11.3	4.15	11.69	15.85
Compton, Cal.	9.7	9.27	3.28	12.55
Monette, S. C.	11.6	14.47	2.84	17.31
Do.	12.2	15.38	1.74	17.12
Brownsville, Tex.	7.3	5.58	3.86	9.44
Do.	7.9	8.22	2.05	10.27
Dalhart, Tex.	8.4	4.15	5.78	9.93
Do.	8.6	3.17	6.54	9.71
Red amber:				
Biloxi, Miss.	9.3	9.57	2.72	12.29
Arlington, Va.	9.2	0.75	12.57	13.32
Do.	10.0	3.02	11.65	14.67
Monette, S. C.	10.4	6.41	8.70	15.11
Compton, Cal.	11.9	1.43	14.46	15.89
Dalhart, Tex.	6.3	1.88	6.32	8.20
Brownsville, Tex.	8.3	4.64	6.87	11.51
Do.	7.4	1.81	7.64	9.45
Minnesota amber:				
Biloxi, Miss.	10.7	12.89	1.72	14.61
Arlington, Va.	10.0	3.54	11.15	14.69
Do.	10.5	4.26	11.40	15.66
Compton, Cal.	7.5	5.77	2.95	7.72
Monette, S. C.	10.7	13.00	2.03	15.03
Dalhart, Tex.	7.4	4.98	4.54	9.52
Do.	8.5	4.82	6.78	11.60
Brownsville, Tex.	7.2	5.01	4.18	9.19
Do.	8.0	4.37	6.98	11.35
Orange:				
Biloxi, Miss.	10.3	12.32	1.88	14.20
Arlington, Va.	8.1	2.86	7.35	10.21
Do.	10.5	1.66	14.62	16.28
Compton, Cal.	9.2	7.99	3.38	11.37
Monette, S. C.	....	14.30	1.75	16.05
Do.	12.7	15.53	2.14	17.67
Dalhart, Tex.	6.2	1.70	5.72	7.42
Brownsville, Tex.	6.8	2.64	5.91	8.55
Do.	9.6	8.14	5.35	13.49
Honey:				
Biloxi, Miss.	8.6	8.22	4.44	12.66
Arlington, Va.	11.0	3.58	13.57	17.15
Do.	11.2	11.46	4.48	15.94
Compton, Cal.	11.6	12.59	1.50	14.09
Dalhart, Tex.	9.7	1.73	11.97	13.70
Brownsville, Tex.	8.3	5.66	5.78	11.44
Do.	8.7	8.44	3.42	11.86
Gooseneck:				
Biloxi, Miss.	8.9	8.67	4.42	13.09
Arlington, Va.	8.7	3.84	8.80	12.64
Compton, Cal.	8.5	7.39	2.91	10.30
Dalhart, Tex.	10.5	10.48	4.63	15.11

Analyses of sorghum, made in 1910, arranged according to varieties—Continued.

Variety and locality.	Degrees Baumé.	Sucrose.	Invert sugar.	Total sugar.
		Per cent.	*Per cent.*	*Per cent.*
Colman:				
Compton, Cal	11.9	13.79	1.12	14.91
Monette, S. C	....	15.30	1.28	16.58
Do	11.2	14.25	1.93	16.18
Collier:				
Compton, Cal	10.9	12.14	2.12	14.26
Monette, S. C	13.7	18.39	0.61	19.00
Do	14.0	18.24	0.92	19.16

STATISTICS.

The United States Census reports from 1860 to 1890 show the gallons of sorghum sirup made during the year previous to the census year. These figures are only approximately accurate, as it is quite impossible to obtain exact data because so much sorghum is made on a very small scale; were this included, the totals would be much larger. It is noted in the table that in the year 1879 more sorghum sirup was produced than in any other before or since, namely, nearly 28,500,000 gallons, while in 1899 nearly 17,000,000 gallons were produced.

The production in some States has decreased rapidly since 1880, as for instance, Iowa, Illinois, Kentucky, and Missouri, while in other States it seems to remain about the same, namely, Tennessee, Arkansas, Alabama, and Virginia. In only a few are increases shown, notably North Carolina.

Sorghum sirup produced (United States Census reports).

States.	Year of census report.				
	1900	1890	1880	1870	1860
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1. Tennessee	2,047,655	2,542,533	3,776,212	1,254,701	706,663
2. Missouri	1,990,987	2,721,240	4,129,595	1,730,171	796,111
3. North Carolina	1,419,570	1,268,946	964,662	621,855	263,475
4. Kentucky	1,277,206	2,094,962	2,962,965	1,740,453	356,705
5. Arkansas	1,223,691	1,868,952	1,118,364	147,203	115,604
6. Alabama	1,168,868	1,242,689	1,163,451	267,269	55,653
7. Mississippi	1,162,269	972,216	1,062,140	67,509	1,427
8. Texas	877,232	1,749,910	432,059	174,509	112,412
9. Georgia	767,024	1,342,803	981,152	374,027	103,490
10. Kansas	735,787	1,484,937	1,429,476	449,409	87,656
11. Illinois	625,939	1,110,183	2,265,993	1,960,473	806,589
12. Indiana	579,061	751,808	1,741,853	2,026,212	881,049
13. Virginia	555,321	546,328	564,558	329,155	221,270
14. Iowa	521,212	1,386,605	2,064,020	1,218,636	1,211,512
15. South Carolina	478,190	559,216	281,242	183,585	51,041
16. West Virginia	450,777	512,747	817,168	780,827	....
17. Ohio	341,523	547,630	1,229,852	2,023,427	779,076
18. Wisconsin	160,414	219,070	314,150	74,478	19,854
19. Minnesota	157,605	340,792	543,369	38,735	14,178
20. Indian Territory	97,381	....	....	....	....
21. Nebraska	92,413	634,146	246,047	77,598	23,497
22. Oklahoma	81,891	31,299	....	....	....
23. Louisiana	48,727	107,763	33,770	180	....
24. Utah	28,017	24,293	58,221	67,446	25,475
25. Michigan	24,059	45,524	102,500	94,686	86,953
26. South Dakota	9,859	29,372	....	....	....
27. Arizona	9,031	4,808	5,771	....	....
28. Delaware	8,952	3,371	25,136	....	....
29. California	8,671	1,670	2,4[illegible]9	333	552
30. Pennsylvania	6,514	33,708	69,76[illegible]	213,373	22,749
31. Maryland	4,058	4,732	19,837	28,563	907
32. New Mexico	2,812	3,510	251	1,765	1,950
33. Colorado	2,661	19,964	3,227	....	....
34. Oregon	2,473	2,706	2,293	....	....
35. Nevada	1,465	930	350	3,651	....
Total	16,972,783	24,235,219	28,444,202	16,050,089	6,749,123