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Farm Production — of — Sugarcane Sirup

SUGARCANE sirup is a valuable subsistence crop for home use and a small cash crop of considerable importance on thousands of farms. The production of sugarcane sirup in the United States during 1929–39 totaled 20,000,000 to 25,000,000 gallons annually. While expansion of the cane-sirup industry depends on the ability of the industry to find new markets for increased production of sirup, its continued prosperity depends on maintenance of high levels of production of cane and sirup per acre, economies in cost of production, quality of sirup produced, and maintenance of favorable farm prices for sirup. Success in marketing requires first of all the production of uniform and high-grade sirup.

This bulletin describes recent improvements in the procedures recommended for making sirup of better and more uniform quality. The equipment and methods described are those most practicable for small farm or community plants.

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FARM PRODUCTION OF SUGARCANE SIRUP

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USE OF SUGARCANE FOR SIRUP

In the States bordering the Gulf of Mexico sugarcane is an important crop. Many farmers and large plantation owners make it their principal crop. In certain sections of the South it ranks next to cotton. Sugarcane is grown in Louisiana and Florida for the production of both sugar and sirup, but in Georgia, Alabama, Mississippi, and Texas, in which its culture constitutes an extensive industry, and in South Carolina and Arkansas, in which its culture is less extensive, it is grown for the production of sirup only. Sugar and molasses, a byproduct of the manufacture of sugar, are not produced in those States.

When properly made, sugarcane sirup is light in color and has a mild, pleasant flavor. It is widely used as a table sirup with hot cakes, waffles, and biscuits, and it is especially well-liked by those who are accustomed to its characteristic cane flavor. It is considered a valuable subsistence crop for home use and a small cash crop of considerable importance on thousands of farms.

PRODUCTION OF SUGARCANE SIRUP IN THE UNITED STATES

Progress in the sirup industry has been rather slow because few new markets have been developed. Lack of uniformity in quality of sirup has been largely responsible for this condition. Except through the agency of the largest packers and distributors, the industry has generally been unable to assemble enough sirup of uniform quality for carload shipments. Large-scale shipments of "farm-made sirup in buckets" have occasionally been made, it is true, but the sirup thus handled has been a miscellaneous collection from small-scale producers and has varied greatly in quality. Dealers to whom such shipments have been made have frequently been disappointed in the sirup and have been unwilling to receive another shipment. Until sirup of more uniform and acceptable quality can be obtained, the production is likely to remain fairly close to the present level, increasing only slowly and depending primarily on the growth of the local market. The development of new markets depends on the production of sirup of uniformly good quality with which producers and packers can afford to undertake more active and expensive sales efforts.

Table 1 shows the production of sugarcane sirup during recent years in the principal producing States.

TABLE 1.—*Production of sugarcane sirup* [1]

State	1929	1934	1935	1936	1937	1938	1939 [2]
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
Alabama	2, 250, 000	3, 564, 000	3, 810, 000	3, 321, 000	3, 770, 000	2, 500, 000	3, 360, 000
Arkansas	90, 000	58, 000	100, 000	90, 000	175, 000	110, 000	115, 000
Florida	1, 860, 000	2, 145, 000	2, 660, 000	2, 145, 000	1, 872, 000	2, 090, 000	2, 280, 000
Georgia	4, 785, 000	4, 958, 000	5, 890, 000	4, 830, 000	5, 425, 000	4, 389, 000	4, 794, 000
Louisiana	5, 773, 000	7, 001, 000	6, 916, 000	7, 410, 000	8, 210, 000	7, 395, 000	9, 310, 000
Mississippi	3, 247, 000	6, 358, 000	5, 016, 000	3, 640, 000	4, 495, 000	4, 482, 000	3, 780, 000
South Carolina	590, 000	475, 000	550, 000	400, 000	420, 000	380, 000	550, 000
Texas	1, 116, 000	1, 050, 000	1, 040, 000	840, 000	768, 000	875, 000	720, 000
Total	19, 711, 000	25, 609, 000	25, 982, 000	22, 676, 000	25, 135, 000	22, 221, 000	24, 909, 000

[1] From the Agricultural Marketing Service, United States Department of Agriculture.
[2] Preliminary figures.

COMPOSITION OF SUGARCANE JUICE

Such factors as the variety of sugarcane, its maturity, the kind of growing season, soil type, fertilizer practice, and the geographical location where the cane is grown influence the composition of sugarcane juice. Although the composition cannot be fully represented by that of any single sample, the composition of Louisiana cane juice given in table 2 is considered fairly representative. The data in table 3 are the averages of many analyses of the mineral matter found in the juice of the newer varieties now cultivated in Louisiana.

TABLE 2.—*Composition of sugarcane juice*

Constituent	Proportion	Constituent	Proportion
	Percent		*Percent*
Water	83. 00	Amino acids (aspartic, etc.)	0. 12
Cane sugar (sucrose)	15. 00	Other organic acids (aconitic, etc.)	. 10
Invert sugar	. 80	Gums and pectins	. 10
Ash	. 45	Fiber particles	. 12
Proteins	. 05	Fat and wax	. 10
Nucleins	. 03	Earthy matter	. 06
Proteoses	. 01	Chlorophyll, etc	. 01
Nitrogenous bases (guanine, etc.)	Trace		
Amides (asparagine, glutamine, etc.)	. 05	Total	100. 00

TABLE 3.—*Mineral composition of sugarcane juice*

Constituent	Proportion of the ash	Constituent	Proportion of the ash
	Percent		*Percent*
Potash (K_2O)	43.90	Manganese (MnO)	0.12
Soda (Na_2O)	1.90	Silica (SiO_2)	2.70
Lime (CaO)	4.80	Phosphoric acid (P_2O_5)	13.30
Magnesia (MgO)	7.30	Sulfuric acid (SO_3)	14.20
Iron oxide (Fe_2O_3)	.33	Chlorine (Cl)	7.00
Alumina (Al_2O_3)	2.20		

HARVESTING

The harvesting should progress with the millwork, no more cane than can be worked in 2 days being stripped and cut at one time. Sugarcane deteriorates rather rapidly after harvesting, a portion of the sugar becoming inverted. Moreover, when the weather is hot and dry, moisture is evaporated from the stalks, so that less juice is extracted and a lower yield of sirup results.

TOPPING AND STRIPPING

Certain varieties of sugarcane mature comparatively early and may be harvested early in the season without sacrifice of sirup quality. Others, which are very desirable from the standpoint of yield, are relatively late in maturing, and if topped early in the season in the usual manner are likely to give sirup of poor quality.[1] The late-maturing varieties, however, may be topped considerably lower than usual when they are not sufficiently mature. The point at which to top can be estimated fairly well by chewing the cane, the unripe, green top having relatively little sweetness. Some sirup makers cut the cane nearly in half at the beginning of the season and use the top half as seed cane for fall planting. As is well known, the butt is the sweetest part of sugarcane, and the top portion germinates well when used for seed. If the cane is not properly topped, the sirup is likely to be darker, not so clear, and of poorer flavor, a fact to which little attention is usually given. Juice from the tops contains more acidity, mineral matter, coloring substances, and strong, bitter principles—all of which contribute to poor sirup quality. This juice, moreover, contains less sugar and more water and consequently requires a longer time for evaporation. The longer evaporation period results in stronger, darker sirup.

Low topping is strongly recommended. This practice produces sirup of the best possible quality and is considered practicable when the value of the tops for use as seed cane, or for animal feeding purposes, is taken into consideration. It is not necessary, as some believe, to grind green tops in order to prevent sugaring of the sirup. Sugaring can be prevented by another method, which does not sacrifice sirup quality (p. 30).

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[1] Information concerning improved disease-tolerant varieties suitable for culture in the sirup-producing States may be found in the following publications:

BRANDES, E. W., SHERWOOD, S. F., and BELCHER, B. A. SUGARCANE FOR SIRUP PRODUCTION. U. S. Dept. Agr. Cir. 284, 48 pp., illus. 1933.

BELCHER, B. A., and SHERWOOD, S. F. TWO NEW VARIETIES OF SUGARCANE FOR SIRUP PRODUCTION. U. S. Dept. Agr. Cir. 461, 4 pp. 1937.

Sugarcane should be well stripped in harvesting, as the leaves add considerably to the cost of transportation to the mill, give trouble in milling, and, when dry, absorb some of the juice from the mill, thereby reducing the yield of sirup.

When a killing frost or freeze is expected, sugarcane is usually windrowed, that is, it is cut as rapidly as possible and laid on the ground between the rows, the leaves serving as a protection. Seed cane, of course, should be harvested and planted, or else banked for spring planting, well in advance of the time a killing freeze is expected. Light frosts that kill the leaves without injuring the lateral buds of the cane do not injure the cane for sirup-making purposes. On the contrary, these light frosts stop the growth of the cane and help to mature it. Windrowed cane, of course, should be worked up as promptly as possible after a freeze, but the standing cane should first be harvested.

FIGURE 1.—Sugarcane estimated to yield 30 tons per acre.

YIELD PER ACRE

With some varieties and in certain sections the yield of millable sugarcane, properly topped and stripped, may be as much as 40 tons to the acre. It may be as low, however, as 8 or 10 tons per acre. Average yields of 15 to 20 tons per acre are common in most of the sirup-producing States. Figure 1 shows a good crop of one of the new varieties of sugarcane. With small farm mills, about 17 or 18 gallons of sirup (U. S. gallons) can be made from a ton of cane. If the crop yield is 18 tons of millable cane an acre the production of sirup is about 300 to 325 gallons an acre. Under favorable conditions some of the newer varieties give 500 gallons or more to the acre. The yield depends on the mill, on the care taken in milling the cane and making the sirup, and particularly on the variety of sugarcane, the soil and fertilizer, the attention given to planting and cultivating, and the kind of growing season.

LOCATION, LAY-OUT, AND SIZE OF THE PLANT

The sirup maker should consider location and arrangement carefully before putting up a plant. Although it is impossible to enter into a thorough discussion of the subject in this bulletin or to lay down hard and fast rules, a few important points should be kept in mind. The plant should be easily accessible to those bringing in the crop and the fuel, and it should have adequate means for storing and taking care of the finished product. It should also be near an abundant supply of water, so that all the equipment may be washed as often as necessary. The importance of cleanliness in making sirup cannot be too strongly stressed. As one object of skimming and evaporation is the removal of suspended material and the sterilization of the sirup by heat, it is obviously unreasonable to permit dirt of any kind to contaminate the sirup after it has been made. All equipment that has stood idle for several days may be thoroughly washed with strong limewater, which neutralizes acids and to a certain extent prevents fermentation. If lime is used, however, all equipment should be carefully washed again before operations are resumed, as the addition of excessive lime to juice or sirup is injurious. It is sometimes desirable to use a disinfectant, such as a solution of bleaching powder, followed, of course, by thorough rinsing. In addition to keeping the evaporator and tanks free from sediment and scale, it is well to dispose of the skimmings in such a way that they do not create an unsanitary condition around the mill. Screens and covers should be used as freely as practical to protect the sirup from dust and insects. In a small plant it is not necessary to cover all the equipment, although as much roofing as practicable is desirable.

HILLSIDE LAY-OUT

A hillside location is best for small plants. The mill should be placed on the highest level, the raw juice should run into a long trough or tanks below, and the evaporators should be placed still lower. This arrangement takes advantage of gravity, making it unnecessary to carry the juice from place to place. The evaporators also should have sufficient elevation to insure convenient handling of both the semisirup and the finished product. This plan can be carried out with mills of different sizes, including power mills. The hillside lay-out is shown in figure 2.

Placing the mill shed some distance from the evaporator diminishes the noise nuisance from a gasoline engine. Elevating the base of the mill 4 or 5 feet above the top of the evaporator makes it possible to bring the juice from the mill to the evaporator by gravity and also makes prompt removal of the bagasse unnecessary. A platform 12 feet square and 4 feet high, made of heavy material, provides space for a good supply of cane and, if covered, affords shelter during bad weather for the man who feeds the mill.

Figure 3 shows a device for unloading bundles of sugarcane from wagons or trucks to the platform preparatory to milling. This equipment may be constructed rather inexpensively and will soon pay for itself.

Movable shields may be used to prevent the wind from blowing too strongly on the pan. Too much wind retards evaporation and makes for inefficient as well as unpleasant working conditions. Walling up the house or shed for the evaporator or the use of movable shields causes vapors from the pan to rise and escape through a ventilator, thus interfering as little as possible with the work of the sirup maker. A partition in the pan house is desirable because it keeps escaping vapors from coming in contact with the cans in the canning room. Such vapors cause the cans to rust very quickly. The storage room should also be as dry as possible for sanitary reasons.

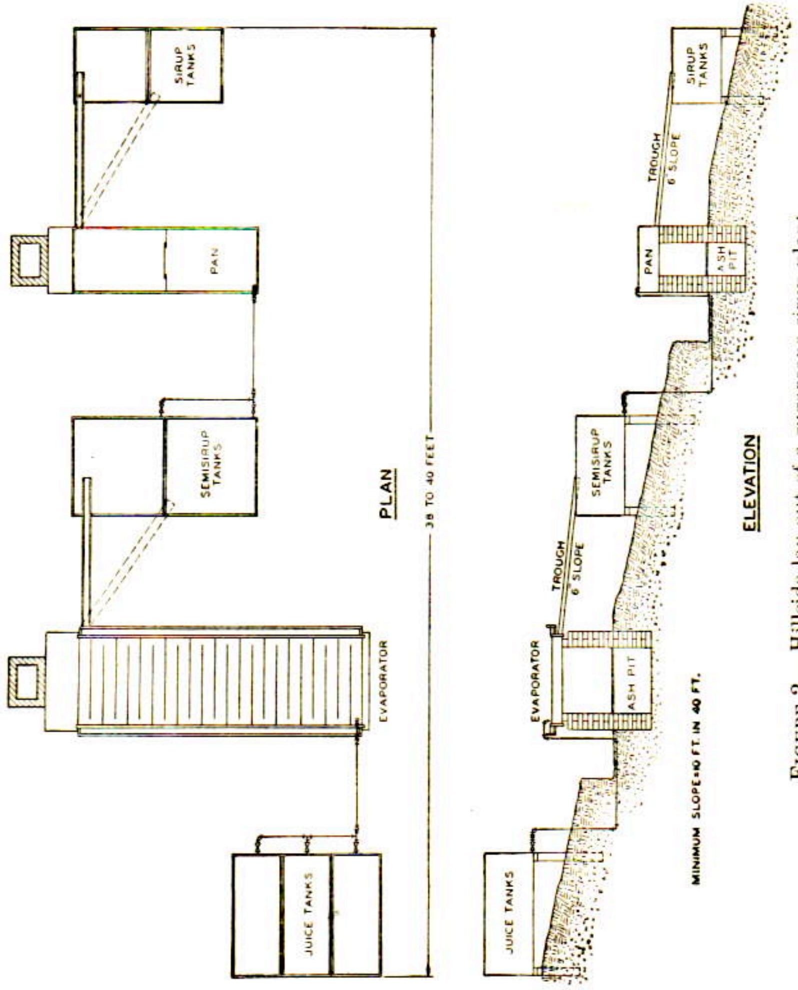

FIGURE 2.—Hillside lay-out of a sugarcane-sirup plant.

If possible, the ground around the evaporator should be hard-surfaced and sloped enough to furnish drainage. The arrangement and equipment should be such that sirup can be made efficiently and under sanitary conditions.

The use of tanks or a long trough set up between the mill and the evaporator makes it possible for the juice to settle before being drawn into the evaporator. Care in removing as much as possible of the impurities of the cold juice by settling before running it into the evaporator will be well repaid by the improved quality of the sirup.

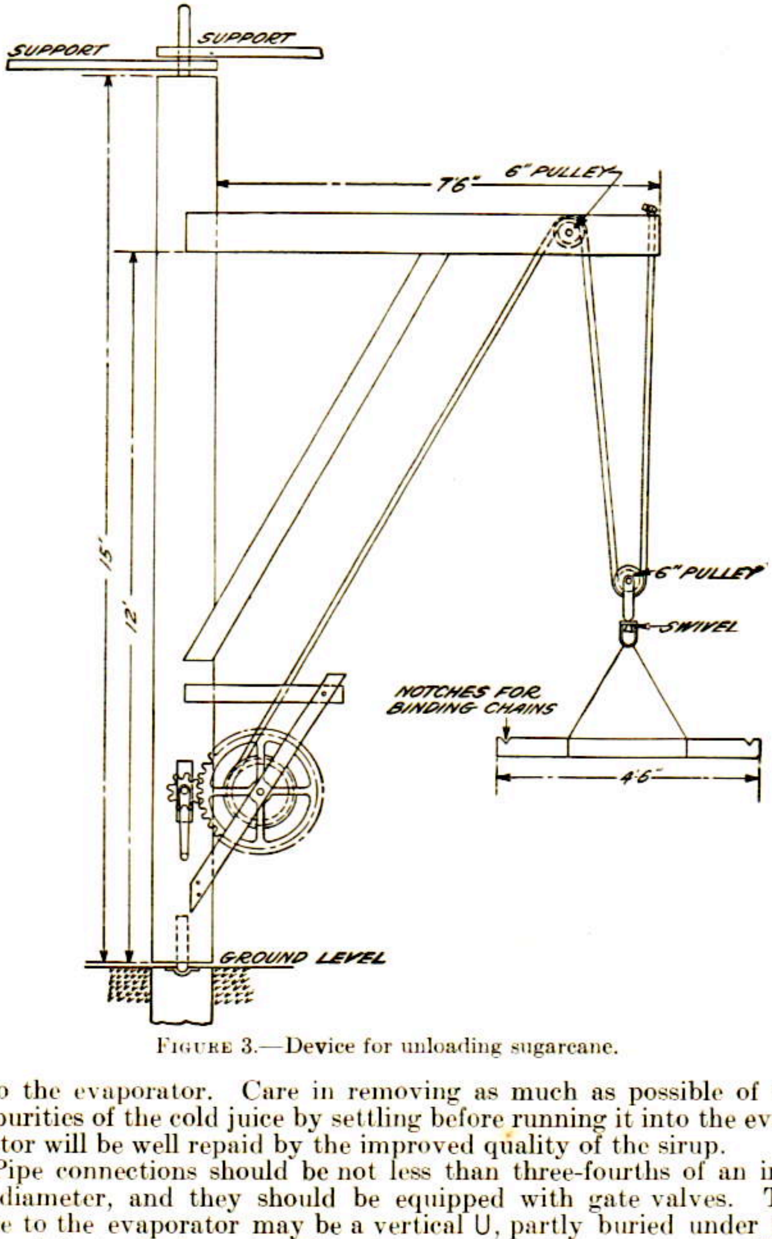

FIGURE 3.—Device for unloading sugarcane.

Pipe connections should be not less than three-fourths of an inch in diameter, and they should be equipped with gate valves. The pipe to the evaporator may be a vertical U, partly buried under the ground instead of passing directly across to the evaporator. This gives an unobstructed passage around the pan. The discharge end of each tank or trough should be slightly lower than the other end, so that it may be completely drained. A second opening, fitted with a valve or plug, is used for draining and washing. Thin covers or screens to fit the tanks will assist in keeping out insects and trash.

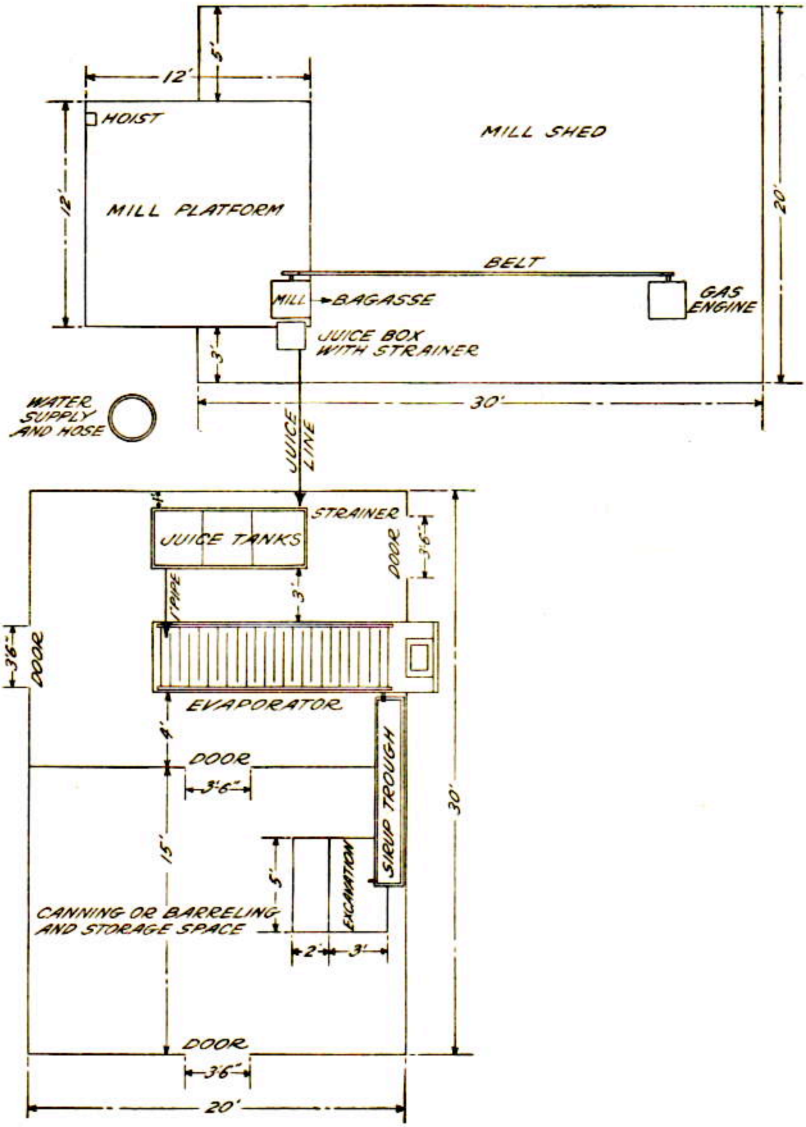

FIGURE 4.—Plan of sirup plant in which only one evaporator is used.

Figure 4 shows a convenient arrangement for a power mill with an 8-horsepower engine and a 12-foot evaporator when only one evaporator is used. The side elevation of the mill shed and the sectional side elevation of the pan (evaporator) house for the same arrangement, when on level ground, are shown in figures 5 and 6. It is inconvenient and comparatively expensive to shelter a horse-driven mill, on account of the space required for the sweep.

The juice flows from the mill through a coarse four-mesh screen into a small juice box, one with a capacity of 4 cubic feet being large enough (fig. 4). A 1¼-inch pipe carries the juice from this box to juice-settling tanks in the pan house near the evaporator. If single or double juice-settling troughs are used, instead of tanks, the mill juice may be strained directly into them. This arrangement reduces the contamination of the juice by mill trash and provides a better opportunity for straining the juice through a sack or screen. Three juice-settling tanks, each large enough to hold a 2-hour juice supply from the mill, or long troughs for continuous settling, are provided for settling the cold juice. If large enough, these also permit continuous operation of the evaporator if it becomes necessary to stop the mill. Juice entering settling tanks or troughs is strained through a coarse

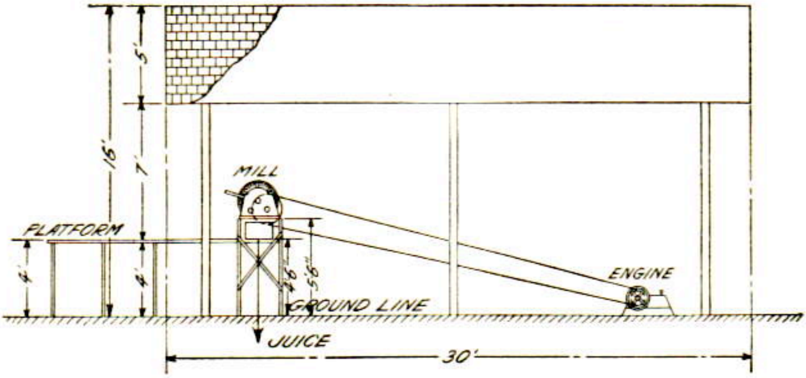

FIGURE 5.—Side elevation of mill shed.

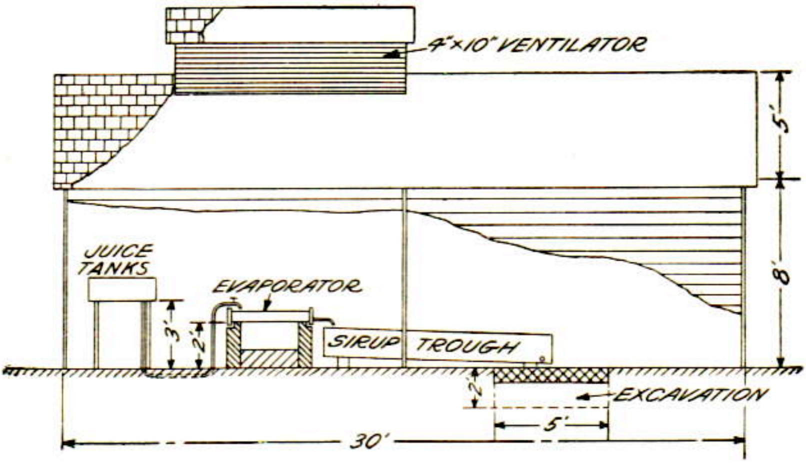

FIGURE 6.—Sectional side elevation of a pan house on level ground.

sack or through a wire screen to remove crushed leaves, particles of soil, finely ground stalk in suspension (bagacillo), and other foreign material.

SIZE OF MILL, ENGINE, AND EVAPORATOR

The small size of individual plantings of sugarcane and the fact that the total tonnage produced in a given locality is not always centralized enough to permit efficient operation of a large plant frequently make it more desirable for farmers to produce the sirup on a comparatively small scale. This reasoning applies both to individual and to custom, or community, plants. The capacity of mill, engine, and evaporator should be so chosen as to permit economical and steady operation. The sirup-making season usually lasts only 5 or 6 weeks, during which period a horse-driven mill, with a small evaporator, can handle a season's output ranging from 1,500 to 2,500 gallons of sirup. A power mill, with a large evaporator operated continuously, is adequate for a 5,000- to 10,000-gallon output. Table 4 may be of assistance in selecting mills, engines, and evaporators of appropriate capacity.

TABLE 4.—*Equipment for small-scale sirup making*

Capacity of mill in tons of sugarcane per 12-hour day	Power	Length of evaporator	Capacity of mill in tons of sugarcane per 12-hour day	Power	Length of evaporator
	Horsepower	*Feet*		*Horsepower*	*Feet*
3 to 5	[1] 1	[2] 7.5	12 to 15	10	15
6 to 8	[1] 2	[3] 10.5	16 to 20	15	[4] 12
9 to 11	6 to 8	12			

[1] Horse- or mule-operated.
[2] Or a 60-gallon kettle.
[3] Or a 100-gallon kettle.
[4] Two 12-foot evaporators.

EXTRACTING THE JUICE

The juice is obtained from sugarcane by milling, that is, by running the stalks between the iron rollers of a mill. Small animal-power mills may be obtained with upright or horizontal rolls. Larger ones, with horizontal rolls (fig. 7), are operated by power. Mills with grooved rolls are easier to feed, and in such mills the stalks tend less to twist to one side.

A good mill is one that can be taken apart easily and new pieces substituted when breaks occur. It must run smoothly and true for good results. The rolls must be capable of adjustment. In setting up such a mill, care should be taken 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 perhaps a break in the mill. Power mills are either single- or double-geared, so they can be connected with an engine or electric motor. Figure 8 shows a small power mill driven by an electric gear motor. A feed table is an important addition to a milling outfit, especially for a power mill, as it allows the stalks to be arranged in some order before they enter the rolls so that a more even feed is provided.

Careful adjustment before starting is necessary in small power mills to obtain good extraction and avoid loss and delay from the breaking of parts. Setting the small front roll too close to the large roll prevents the mill from taking the cane readily. A clearance space of approximately three-eighths of an inch between the front roll and the large roll permits the cane to enter the mill promptly and keeps it from being cut up too much before it reaches the last roll. The clearance space between the last small roll and the large roll should be about one-sixteenth of an inch. With this setting of a three-roller power mill and full-capacity feed, the stalks are pressed fairly dry. The speed of the mill should be regulated according to the recommendation of the manufacturer. It is usually about 27 feet per minute for the large roll, which is equivalent to 10 to 12 revolutions per minute for the average small power mill. As the size of the mill increases, the number of revolutions per minute should decrease. The engine speed for the types commonly used ranges from 375 to 425 revolutions per minute.

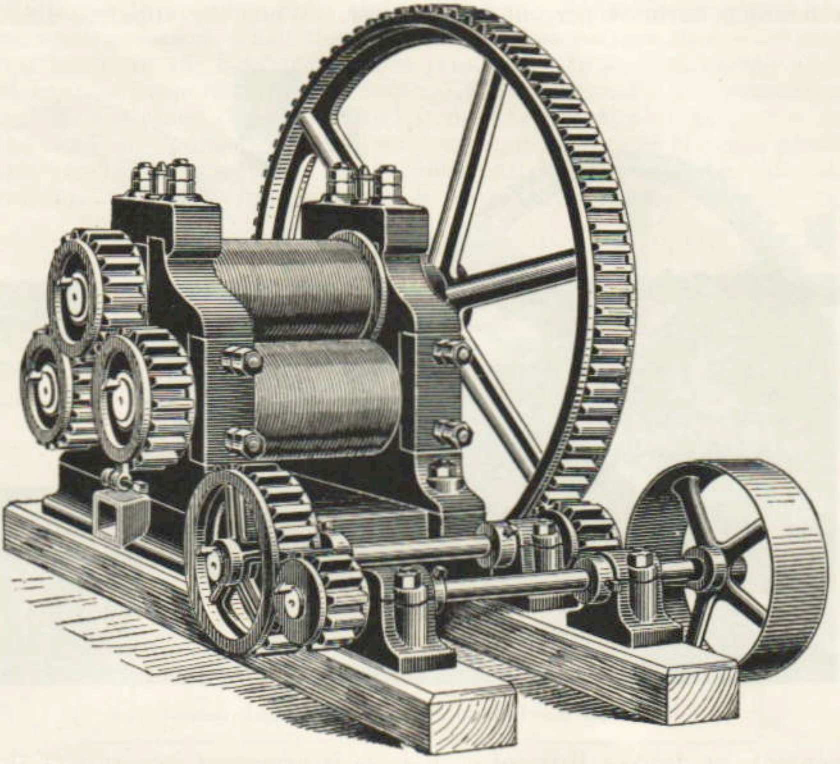

FIGURE 7.—Three-roller power mill.

The "feed," or quantity of cane in the mill at one time, should be light or heavy according to the adjustment of the rolls. When they are set "open," or apart, the feed should be heavy; when they are set close together the feed should be light. In all cases it should be regular and uniform. It is evident that with open-set rolls juice is wasted when the feed is light; with close-set rolls there is also a loss of juice when the feed is irregular and uneven.

Sugarcane ordinarily contains more than 70 percent of water and 10 to 15 percent of fiber, but it is impossible to obtain all the water as juice. With a three-roller power mill, the weight of the juice extracted should be 50 to 65 percent of the weight of the cane, unless it is very hard and dry. With a good mill and close setting, 60-percent extraction is not too much to expect from the best varieties of cane, if it has been a season of normal rainfall and if the cane has not dried out too much between harvesting and milling.

Although the percentage of total solids is not identical with the number of degrees indicated on the Brix hydrometer scale, the solids content of the juice may conveniently be expressed in terms of this scale. With good sugarcane this is usually 14° to 18° Brix; that is, the juice has approximately 14 to 18 percent of dissolved solids, the remaining 82 to 86 percent being water. When the apparent solids content, or degrees Brix, of such juice is expressed in terms of the Baumé hydrometer, it is said to have a "density" of 7.8° to 10.0° Baumé. The degrees of the Baumé scale do not correspond even approximately to the percentage of apparent solids; for all practical purposes in testing sugarcane juice, Baumé degrees ×1.8 equals Brix degrees.

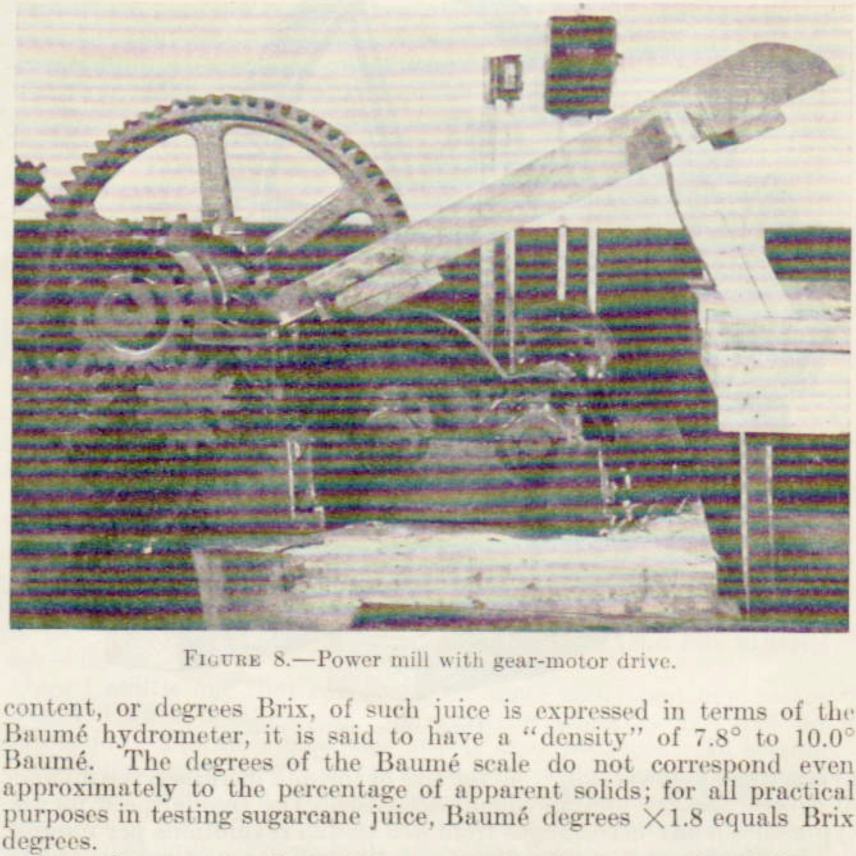

FIGURE 8.—Power mill with gear-motor drive.

Assuming an extraction of 60 percent, that is, 60 pounds of juice per 100 pounds of cane, and an average Brix reading of 15° for the juice, the juice from 100 pounds of sugarcane, if evaporated to a sirup of 74° Brix without losing any of the dissolved solids, should yield $15/74 \times 60$ pounds, or 12.1 pounds, of sirup. A United States gallon of sirup at 74° Brix weighs 11.45 pounds; hence, the 12.1 pounds of sirup is equivalent to 1.05 gallons. This represents the theoretical yield in gallons of sirup from 100 pounds of cane. Theoretically, therefore, a ton of cane yields 21 gallons of sirup. The actual yield of sirup per ton, however, with 60-percent extraction and with juice testing 15° Brix, is only 17.5 to 19.5 full United States gallons. (No. 10 cans do not hold a full United States gallon of sirup.) Not all the dissolved solids in the juice are retained in the sirup, and some juice is unavoidably lost by skimming, settling and decanting, and straining. This loss is especially great in small farm outfits. The actual yield of sirup, therefore, is about 12 to 18 percent below the calculated theoretical yield.

With smaller mills, driven by horsepower or even by gasoline or kerosene engines, and with cane of poor quality, the extraction is frequently as low as 50 percent, instead of the 60 percent assumed for the larger three-roller mills and good cane. Moreover, early in the harvesting season, when the crop may be less mature, the juice may test less than 15° Brix or even less than 14°. In such cases, the yield of sirup is proportionately reduced. When unusually low extraction is being obtained by a small mill, it may be practicable to gather up the bagasse ("pomace" or "chews") and put it through the mill again. Oftentimes half again as much juice can be obtained by "double passing" as results from putting the cane through only once.

YIELD OF SIRUP

The variation in yield of sirup due to differences in juice extraction and quality of the juice is shown in table 5.

TABLE 5.—*Variation in yield of sirup caused by difference in percentage of juice extraction and quality of juice*

Apparent solids content of juice		Approximate yield of 72° to 74° Brix sirup per ton of cane					
		50—percent juice extraction		60—percent juice extraction		70—percent juice extraction	
° Brix	*° Baumé*	*No. 10 cans*	*Gallons*	*No. 10 cans*	*Gallons*	*No. 10 cans*	*Gallons*
10.8	6.0	13.9	12.0	16.7	14.4	19.5	16.8
11.7	6.5	15.1	13.0	18.1	15.6	21.1	18.1
12.6	7.0	16.2	13.9	19.4	16.7	22.7	19.5
13.5	7.5	17.3	14.9	20.8	17.9	24.3	20.9
14.4	8.0	18.5	15.9	22.3	19.2	26.0	22.4
15.3	8.5	19.7	16.9	23.6	20.3	27.6	23.7
16.2	9.0	20.8	17.9	25.0	21.5	29.2	25.1
17.1	9.5	22.0	18.9	26.4	22.7	30.8	26.5
18.0	10.0	23.2	20.0	27.9	24.0	32.5	28.0

Table 5 is based on experience with Co. 290 cane. Some of the smaller barrel, higher fiber varieties and cane which has dried out from remaining in the field too long after being cut may actually yield from 10 to 15 percent less sirup per ton of cane than can be made from fresh-cut Co. 290 cane, although if the juice were of the same quality and an equal percentage juice extraction were obtained the yield should be approximately the same for different varieties of cane.

MAKING SIRUP ON SHARES

Farmers may often grow sugarcane without caring to manufacture it into sirup themselves. Upon what basis should the sirup be made by a custom mill? One of two general methods is usually followed. The maker charges the grower a stated price per gallon, or he makes it on shares, that is, he gives the grower a certain percentage of the sirup produced.

When sirup is being made on shares, the following method may be used to avoid boiling the juice from each lot separately. The cane is ground separately, and the juice from each lot is collected in tanks where it can be measured. From the quantity of juice and its Baumé reading, the quantity of sirup that will be made may be calculated with a fair degree of accuracy.

Settling tanks are convenient for measuring the raw juice. If the tank is rectangular, take the inside dimensions, length and width, in inches, multiply these and divide the result by 231 (the number of cubic inches in a gallon) to obtain the gallons of juice in the tank for each inch of depth. The number of inches of juice may be determined by inserting a stick or rule into the tank, and this figure, multiplied by the gallons per inch of depth, gives the number of gallons of raw juice.

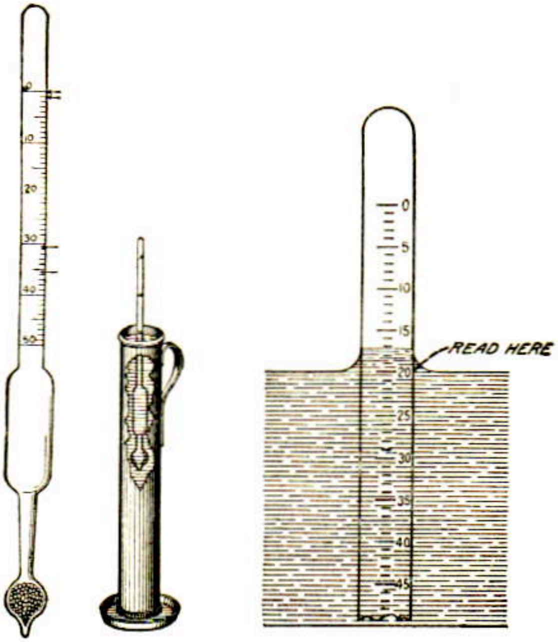

FIGURE 9.—Hydrometer suspended in a cylinder of juice. Note the point on the scale at which the reading should be made.

If the measuring tank is round, multiply the diameter, in inches, by the diameter, in inches (identical figures). Multiply this result by 0.7854 and divide the result by 231. The figure thus obtained shows the number of gallons of juice in the tank for each inch of depth.

The other figure necessary for the calculation is the density of the juice as determined by means of a Baumé hydrometer. This instrument is preferably suspended in a cylinder of juice (fig. 9), but it can be placed in the tank, provided the juice is deep enough to allow it to float freely. From the volume and Baumé reading, the yield can be calculated. The density of the raw juice will be determined more accurately if the reading is not made for at least 30 minutes, or until most of the air in the juice has escaped. In one typical case, 10 gallons of juice with a reading of 6° Baumé made 1 gallon of finished sirup. From these and similar data the following sliding scale was calculated for use with that particular sirup maker's equipment.

Degrees (Baumé) of juice:	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

The number of gallons of juice multiplied by the Baumé reading gives approximately 60 in every case. Each sirup maker should prepare such a table for himself, as his method of manufacture may not be like the one used here. To do this, it is necessary to obtain the Baumé reading of several tanks of juice, then concentrate the juice to sirup in the usual way, and measure the finished sirup. 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 gives the figure on which to base the table. (The figure happened to be 60 in the example given.) With this beginning, a table can be prepared for different Baumé readings on the raw juice. As soon as a separate lot of cane is ground, the juice can be measured, the density determined, and the quantity of sirup due the grower calculated from the table without interfering with the continuous work of the evaporator.

At some custom mills where settling and treating tanks are used for the semisirup, the operators prefer to measure these tanks and gage the semisirup from each individual's lot of cane, rather than use the above method of gaging the juice. After a little practice in observing the rate at which the juice from different lots of cane is evaporated and semisirup is made, the sirup maker may gage the semisirup with a reasonable degree of accuracy. The yield of sirup is approximately one-half the volume of 20° Baumé semisirup.

TREATING THE JUICE

In making sirup, 1 gallon of sirup is usually obtained from 6 to 7 gallons of juice, 5 to 6 gallons of water being evaporated. Sugarcane juice, however, contains many substances besides sugar and water. As first obtained at the mill, the juice contains some suspended soil which has adhered to the stalks, particles of finely ground stalk or fiber in suspension (bagacillo), and certain dissolved substances. Among the dissolved nonsugar substances, which are commonly classed as impurities because they represent material other than sugar but which are just as much a part of the juice as is the dissolved sugar itself, are organic and inorganic salts, proteins, pigments, gums, and wax. These so-called impurities affect the quality of the sirup, but not all of them are objectionable. Although it is never necessary or feasible to remove all of them, some must be eliminated to make a sirup of satisfactory flavor, color, and clarity. In small-scale practice, the manufacture of sirup consists in the evaporation of excess water and the removal of certain impurities by straining, skimming, and settling.

The juice coming from the mill should first be well strained and settled before it is run into the evaporator. Juice tanks or troughs should be built to slope a little toward the evaporator in order to facilitate drawing off as much well-settled juice as possible without excessive loss and subsequently for washing out the settlings. The draw-off openings should preferably be made in the bottom of tanks or troughs, in the low end. Short inside nipples of adjustable length, made by bending a piece of sheet copper to fit, can be inserted in the openings, so that all well-settled juice can be drawn off without stirring up the settlings. It is advisable, of course, to wash out tanks or troughs frequently. The settlings can be combined with the skimmings and used for feeding livestock (p. 38).

In rainy weather, when the fields are muddy, the cane usually carries more soil to the mill. During this kind of weather special care should be exercised to remove the soil either by washing the cane or by settling the cold juice thoroughly before drawing it into the evaporator.

The addition of chemicals to the juice throws out certain impurities but generally leaves in their place part of the foreign substances added, and very often completely changes the flavor of the resulting sirup. As a rule, the small producer of sirup should not attempt to employ chemical methods of clarification. Even on a larger scale great care must be used in adding chemicals, as a slight excess of some of the substances used may ruin the color and flavor of the sirup.

Sulfur dioxide and hydrated lime, or phosphoric acid compounds and hydrated lime, or hydrated lime or carbonate of lime alone, without the addition of acid, are sometimes used to clarify sugarcane juice. As previously stated, however, it is usually best not to use chemical clarification in farm-scale sirup production. Only a few of these methods, therefore, will be described in detail in the present bulletin. It is believed that such measures as planting the best sirup-making varieties of sugarcane, selecting the proper land and fertilizer, using good sirup-making equipment, and exercising care in making the sirup are factors of fundamental importance in governing sirup quality. Proper attention to these factors seems advisable, rather than reliance on remedial methods for clarifying poor-quality juices.

MILK OF LIME

Although it is not needed with sugarcane of good quality, especially when properly topped, a small amount of milk of lime is sometimes used to modify excessive acid flavor or tang of the sirup. The use of lime in the proper manner tends to give sirup from poor-quality cane a milder flavor.

The lime should be used very carefully because too much of it may make the sirup dark and remove too much of the characteristic sugarcane flavor. Ordinary hydrated lime is mixed with water to make a thin milk (about 1 pound of hydrated lime per gallon of water), and some of this is stirred, little by little, into one-third of a tank or barrel of the cold juice from the mill. After each addition the juice is tested with bromthymol blue test paper. The addition of lime is not continued until the juice turns the test paper deep blue; it is stopped as soon as the test paper turns green. As the third of a barrel or tank of juice thus treated is purposely overlimed, the remaining two-thirds of the barrel or tank is filled with fresh juice from the mill without the addition of more lime. After mixing, the full barrel or tank of juice will possess the proper degree of acidity. The juice must be left slightly acid to make the best quality sirup.

Litmus papers may also be used for controlling the addition of the lime. When litmus is used instead of bromthymol blue papers, it is again the best plan to add the lime to one-third of a barrel or tank of the cold juice. The lime is added little by little, and stirred in, until blue litmus paper does not turn red when dipped into the juice, or until red litmus paper first turns blue. In other words, no more lime is added after the acidity of the juice is barely neutralized. As the third of a barrel or tank of juice thus treated is purposely overlimed, the remaining two-thirds of the barrel or tank is filled with fresh juice from the mill without the addition of any more lime. After mixing, the full barrel or tank of juice will possess the proper degree of acidity.

Litmus paper can be obtained from the local drug store in small vials or in sheets. Either the blue or the red litmus is satisfactory. If sheet litmus is used, a piece should be cut for immediate use, clipped into small 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 paper, and a little lime spoils the red litmus. A piece of litmus paper may be picked up by the moistened fingertip without touching the rest of the paper.

CARBONATE OF LIME

Ordinary hydrated lime is strongly caustic, but carbonate of lime (whiting, English chalk, precipitated chalk) is not. When this material is used, the juice should be boiled in contact with it in order to secure the desired effect. Any excess of the carbonate of lime, together with the precipitated material not removed by skimming, can be settled out in the tanks in which the semisirup is ordinarily settled.

As an alternative, carbonate of lime may be used at the semisirup stage of evaporation. It is "boiled in" for a few minutes before the semisirup is removed from the evaporator to the settling and treating tanks. When the cane is a little sour, some of the acid is removed by the evaporation of juice to semisirup, so that less carbonate of lime is required for treating the semisirup. If an excess is used, it settles out overnight.

DECOLORIZING CARBON [2]

A relatively recent development is the use of activated vegetable decolorizing carbon to produce lighter colored and milder flavored sugarcane sirup. This is not recommended for sugarcane of good quality, from which sirup of excellent color and flavor can be made by customary methods. The use of decolorizing carbon makes it possible to produce sirup of improved color and flavor from sugarcane of poor quality. It should be recognized that carbons remove

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[2] This process is not recommended for farm-scale use in making sorgo sirup, owing to greater difficulty in removing the carbon.

some of the desirable cane flavor as well as flavors of objectionable nature, giving a flavor of less "depth" or "body," but certain markets prefer very mild, light-colored sirup to those of darker color and more pronounced flavor, which are usually in demand in sections where the sirups are produced. Decolorizing carbons are not classified as chemicals, in the ordinary meaning of the word.

The method recommended at present for using vegetable decolorizing carbon in the production of sugarcane sirup on the farm is as follows: Settle the cold juice in the usual manner in troughs or tanks, and then allow it to run into a smaller tank at the cold-juice end of the evaporator, where batches of juice can readily be mixed with the carbon. The average proportion of decolorizing carbon required is 1½ pounds for every 100 gallons of juice. For juice of very poor quality this proportion of carbon may be doubled. The cost of the decolorizing carbon is about 1 to 3 cents per gallon of finished sirup.

The carbon is very light in weight and tends to float on top of the juice. It should be mixed thoroughly with the juice by stirring. The carbon-treated cold juice is then run into the evaporator, kettle, or batch pan at the desired rate in the usual manner. In order to keep the carbon well distributed in the juice, stir the juice from time to time while it is running into the evaporator or just before it is put into the kettle or batch pan.

An evaporator is operated in the customary way except that the carbon-treated juice is run in a little faster to maintain a greater depth of juice, skimming is done more carefully, and the sirup is purposely drawn off as semisirup, to permit filtering it through felt filters, or settling it, in order to remove the relatively small proportion of carbon still remaining after thorough skimming. When kettles and batch pans are used, the juice is heated to boiling more slowly than usual and carefully skimmed before boiling actually begins. It is then skimmed as thoroughly as possible in the usual manner and evaporated to semisirup density. The density at which the semisirup should be taken out of the evaporator, kettle, or batch pan for straining or settling is 18° to 20° Baumé, measured at a temperature close to boiling.

To secure the beneficial effect on the color and flavor of the sirup, the carbon must be intimately mixed and boiled with the juice. Most of the carbon is removed with the skimmings, but some rather heavy, coarse carbon particles usually remain to be filtered or settled out. The method for removing all traces of the carbon from the sirup, without a filter press, is simply a combined skimming and farm-scale straining process, or a combined skimming and settling process.

Felt filters are recommended for straining the hot semisirup, or large batches of semisirup may simply be put into a tank and permitted to settle overnight. The settling process may be combined very advantageously with the invertase process for preventing sugaring (pp. 30–32). The same equipment may be used. It is important to remember that small batches of semisirup should always be filtered, as they cool too rapidly to settle efficiently.

When the semisirup is settled overnight in tanks, great care should be taken in drawing off the clear sirup to open the draw-off valve slowly so that no carbon or other sediment will run into the finishing-off pan. To avoid loss of sirup, the small quantity of semisirup and sediment that remains in the bottom of the settling tank may be removed through the wash-out connection and returned to the next batch of fresh juice to be settled. The same settling tanks and finishing-off pan are used that are used in the invertase process of preventing crystallization. In fact, the carbon process and the invertase process may be conducted simultaneously.

If felt filter bags are used to filter the semisirup they should be washed out several times with hot water to remove the characteristic odor of new felt. Thereafter, each time the bags are used, they should first be immersed in hot water and as much water as possible wrung out of them. This makes them filter more rapidly.

It is sometimes advisable to use a little milk of lime or carbonate of lime to improve the flavor of sirup made by the decolorizing carbon process. When milk of lime is used, it is carefully added before the cold juice is settled (p. 16), and the carbon is added afterward to the well-settled juice, at the evaporator supply tank.

The names and addresses of firms selling decolorizing carbon and felt filter bags may be obtained from the Agricultural Chemical Research Division, Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture.

EVAPORATING THE JUICE

Although the quality of sirup depends to a large extent on the variety of sugarcane, the type of land on which the crop is grown, the fertilizer used, and the kind of growing season, it may also be greatly influenced by the equipment and the process used in making it and by the skill of the sirup maker.

When heat is applied to the juice certain proteins and other nonsugar substances become coagulated. If allowed to settle, some of this coagulated material rises to the surface of the juice, and some sinks to the bottom. By the most approved practice, this material is removed by skimming as soon as it appears on the surface of the juice. Success in making sirup depends first of all on the thoroughness with which the juice is skimmed before it begins to boil rapidly. The agitation of the juice caused by active boiling breaks the coagulated material into smaller particles, which are more difficult to remove. This breaking-up of coagulated material is commonly referred to by sirup makers as "boiling-in" the impurities. Additional nonsugar substances separate as boiling continues and the juice becomes denser, making it advisable to continue the skimming until the juice has been evaporated to the density of finished sirup, even though careful skimming has been done at the beginning of the evaporation.

KETTLES

Of the many types of equipment used for concentrating juice to sirup, kettles are probably the oldest. A product of fair quality results when they are properly operated, although, in general, kettles are not to be recommended for new sirup plants, since they are relatively inefficient from the standpoints of operating cost, sirup quality, and sirup-making capacity.

The advantages in using kettles for small-scale sirup making are: (1) The density of the finished sirup may be readily controlled; (2) the method requires but little skill; and (3) a long period is available for skimming, thus making it possible to obtain a clean sirup. The disadvantages are: (1) A long period is required for evaporation, frequently 3½ hours or longer; (2) a dark product may be obtained as a result of the prolonged slow boiling; and (3) the sirup-making capacity is relatively small.

The flame must not be allowed to rise above the level of the boiling juice in a kettle; otherwise the sirup will burn and have a scorched taste. Another precaution necessary when making sirup in this kind of apparatus is to concentrate a single charge. Adding fresh juice to the boiling sirup always results in a dark sirup with poor flavor and clarity. After a charge has been concentrated, the kettle should be swung from the fire, the sirup poured out, and the sediment washed out before it has had time to burn. If the kettle cannot be removed from the fire, after two or three charges remove the fire and clean the kettle.

BATCH PANS

Instead of kettles, batch pans about 8 to 10 inches deep made of copper, galvanized iron, heavy tin, or sheet iron are used by many sirup makers. A single pan may cover the whole space occupied by the furnace, or two or three pans may be used, one back of the other. These may or may not be connected so that the juice can flow from one to another. Some prefer a home-made pan constructed of 1¼-inch lumber, with a bottom of copper, galvanized iron, or sheet iron carefully luted to the sides. If properly operated, this type of pan gives good results.

STUBBS PAN

The Stubbs pan, sometimes known as the Louisiana-type evaporator (fig. 10), is continuous. Although not so widely used as the well-known, shallow, baffle-type, continuous evaporator, it possesses the following advantages: (1) It requires somewhat less skill for efficient operation; (2) when this pan is properly operated and the furnace construction is good, the skimmings collect automatically on the cool-juice surface; (3) only a slightly deeper layer of juice is maintained in this pan than that carried on a shallow, baffle-type evaporator; (4) the high partition separating the finishing-off compartment from the rest of the pan makes it possible to regulate more efficiently the evaporation of semisirup to the density of finished sirup in controlled batches without danger of flooding or admitting improperly skimmed semisirup; (5) the density of the sirup can be more easily controlled than by the use of the more shallow evaporator; (6) sirup of excellent quality can be made on this type of evaporator; and (7) this is a type of continuous evaporator that may be constructed on the farm.

Figure 10 shows the design of the Stubbs pan. The juice enters continuously at *a*, travels down the pan lengthwise on the juice side of the high, longitudinal partition, around the end of this partition, and then toward the finishing-off compartment at the chimney end. The finishing-off compartment should be provided with a tight-fitting, easily workable gate to admit batches of semisirup as desired. The design of the furnace for this evaporator is similar to that for the shallow evaporator (fig. 11) except that the chimney is built to one side, next to the finishing-off compartment, and the fire is prevented from striking against the corner of the pan where the raw juice enters, either by use of a damper or by building a solid perpendicular wall across this corner of the furnace. This transverse wall, or solidly filled-in corner of the furnace, helps to keep the juice from boiling at the raw-juice end of the pan, the result being a relatively cool juice surface on which the skimmings collect and can be removed without danger of boiling in. The arch of the furnace is so constructed that the highest point is about 1½ feet beyond the center of the pan toward the sirup end. As this is the part of the pan, on the sirup side, where the juice is being concentrated to semisirup density, and as the heat is closest underneath, the surface of the boiling juice (foam) stands higher in the pan at this point. The height of the foam gradually diminishes toward the end over the firebox and from there to the cool raw-juice corner. In other words, the foam, carrying the skimmings with it, cascades down around the end of the longitudinal center partition of the pan and flows back to the incoming raw-juice surface, which is not boiling at all. This type of pan, therefore, does not require skimming troughs, although the skimmings automatically collect in somewhat the same fashion in just one part of the pan, where they may be more easily removed.

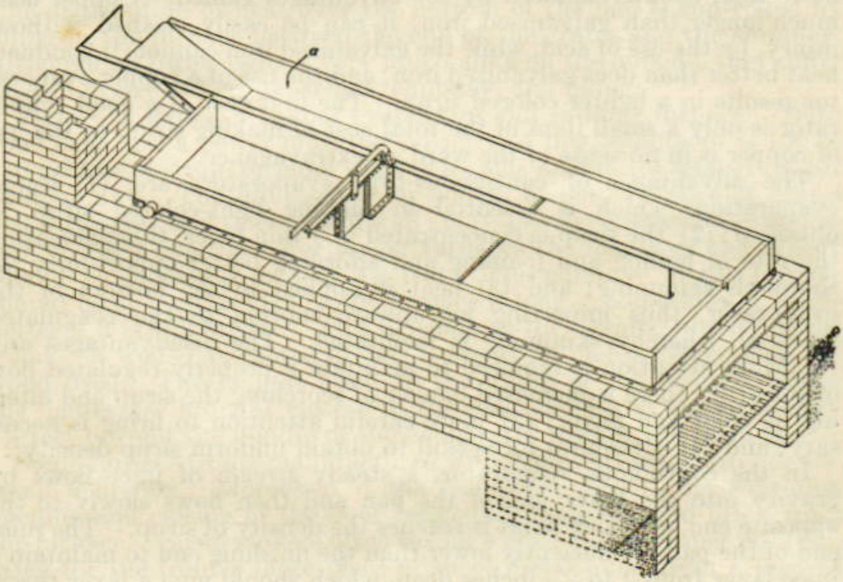

FIGURE 10.—Stubbs-type evaporator. This model is 12 feet long, 3 feet 6 inches wide, and 10 inches deep. The juice side (*a*) is 15 to 20 inches wide, and the other side is 22 to 27 inches wide. The finishing-off section is 4 to 5 feet long.

EVAPORATORS

Continuous evaporators, sometimes called patent evaporators, have many points of superiority to recommend them. The bottoms are sometimes corrugated to give a larger heating surface, and an automatic supply valve may be used to regulate the depth of the liquid in the evaporator. They are constructed in such a way as to produce a quick concentration of the juice to sirup and, with proper operation, to facilitate efficient skimming.

Most of the sirup made by farmers operating on a relatively small scale is made on open, galvanized-iron or copper evaporators. These evaporators are shallow and have crosswise baffles. A galvanized-iron evaporator is cheaper than one of copper; with proper care it will last a reasonable length of time; while new it will produce sirup of as good quality as can be made in the copper evaporator. Sugarcane juice, however, is always slightly acid and consequently gradually corrodes galvanized iron. When the zinc surface of the galvanized iron becomes corroded and pitted, the juice is boiled in contact with the exposed iron, which may react with certain constituents of the juice to produce a dark sirup. Although a copper evaporator costs nearly twice as much as one of galvanized iron, the extra expense is more than counterbalanced by the advantages gained. Copper lasts much longer than galvanized iron; it can be easily cleaned, without injury, by the use of acid, while the galvanized iron cannot; it conducts heat better than does galvanized iron; and the use of a copper evaporator results in a lighter colored sirup. The first cost of a good evaporator is only a small item in the total cost of making sirup, so the use of copper is in no sense of the word an extravagance.

The advantages of continuous-type evaporators are: (1) Rapid evaporation, which is essential in making light-colored sirup, is obtained; (2) the sirup is concentrated in a thin layer, thus increasing the rate of boiling and foaming and affording better opportunity for thorough skimming; and (3) heat is applied to the bottom of the evaporator, thus imparting an upward motion to the coagulated material, whereby skimming is facilitated. The disadvantages are: (1) More attention is required to maintain a properly regulated flow of juice; (2) there is increased danger of scorching the sirup and altering its color and flavor; (3) more careful attention to firing is necessary; and (4) it requires more skill to obtain uniform sirup density.

In the continuous evaporator, a steady stream of juice flows by gravity into the lower end of the pan and then flows slowly to the opposite end, at which point it reaches the density of sirup. The juice end of the pan is sufficiently lower than the finishing end to maintain a juice layer from 2 to 2½ inches deep, which should give a layer three-fourths to 1½ inches deep (preferably only three-fourths inch) in the finishing end of the evaporator. In other words, the juice end of the evaporator is mounted on the furnace about 1 inch lower than the sirup end. The evaporator should be level from side to side. As a rule, the juice enters the front end of the pan and during evaporation moves toward the back or chimney end. In some instances, however, the juice enters at the chimney end and is drawn off as sirup at the front end. During evaporation to sirup the juice, with continuous skimming, flows toward the finishing end of the evaporator, while cold juice from the supply tank is run in to maintain the desired level in the juice end of the pan. The heat applied to the juice from the bottom of the pan increases from the juice end to that part of the evaporator where there is danger of scorching the sirup. Beyond this point, the heat applied gradually decreases, until only a small amount is required under the last compartment, from which the sirup is drawn off. The hottest portion of the pan, and consequently the place where the juice boils most vigorously, is where concentration to sirup is a little more than half completed. This scheme of operating a continuous evaporator makes it easier to regulate the boiling and skimming.

The skimmings are carried back to the juice end of the pan with the foam and may there be readily removed.

FURNACE FOR EVAPORATOR

The furnace for a continuous evaporator must be properly constructed, and the fire must be carefully controlled. In direct-fire evaporation, success depends to a great extent on the construction and operation of the furnace. The capacity of a plant equipped with a mill and evaporator of the best type may be reduced as much as 50 percent by an improperly constructed furnace. The quality of the sirup may also suffer greatly because of improper skimming and slow evaporation, both of which are caused by poor furnace construction. The distribution of heat over the bottom of the pan is controlled by filling in the furnace between the end of the grates and the chimney. Although all furnaces look very much alike on the outside, they differ greatly in size of firebox, ashpit, chimney, and filling.

Figure 11 shows a 12-foot evaporator and suitable furnace. With good cane and a power mill, the capacity of this equipment is 100 to 150 gallons of sirup, or more than twice this amount of semisirup, per 12-hour day. The dimensions for width, height, distance of grates below the pan, and thickness of wall apply also to furnaces for evaporators of other lengths. For longer furnaces the length of the firebox should be increased to 4 or 4½ feet. The chimney of the furnace should be at least as high as the furnace is long. Sometimes it works better if it is still higher. This depends on the burning quality of the wood. A well-constructed firebox is about 2½ inches longer than the wood used. The highest point in the filling of the furnace, where the flames are brought closest to the pan, should be approximately 1½ feet beyond the middle of the evaporator toward the sirup end.

Some furnace fronts manufactured with grates attached provide too small a firebox. Moreover, if the fronts are heavy, the continual opening and closing of the door frequently tears the end brick from the furnace. Sirup makers often install a grate in the proper position, using for the front a large piece of sheet metal hung from a joist of the pan shed. This inexpensive arrangement works very satisfactorily, affording a larger door for firing and rapidity in opening and closing. The firebox should by all means be provided with a door of some sort. If possible, the furnace should be so located that the prevailing winds tend to blow the steam away from the sirup maker's side of the evaporator. The ashpit should be reasonably deep to permit free access of air to the firebox from beneath.

Beginning at the bottom of the ashpit, a transverse double-thick brick wall is built up to the bottom of the grates and furnishes a support for their back end. The wall is then reduced to one thickness of brick and extended about 6 inches above the grates. This keeps the filling of the furnace in place and prevents it from falling back into the firebox. The filling is banked up against this wall and gradually slopes up to the highest point, which is about 1½ feet beyond the center of the pan. Beyond this point the filling slopes gradually downward to the last compartment of the pan, where it drops off suddenly. If dirt is used for this filling, it should preferably be covered with a layer of brick cement or hard clay to keep the contour of the filling from being changed by a strong draft.

A 3- by 4-inch damper in the chimney may be used to regulate the draft. Enough air to give good combustion of fuel should be admitted,

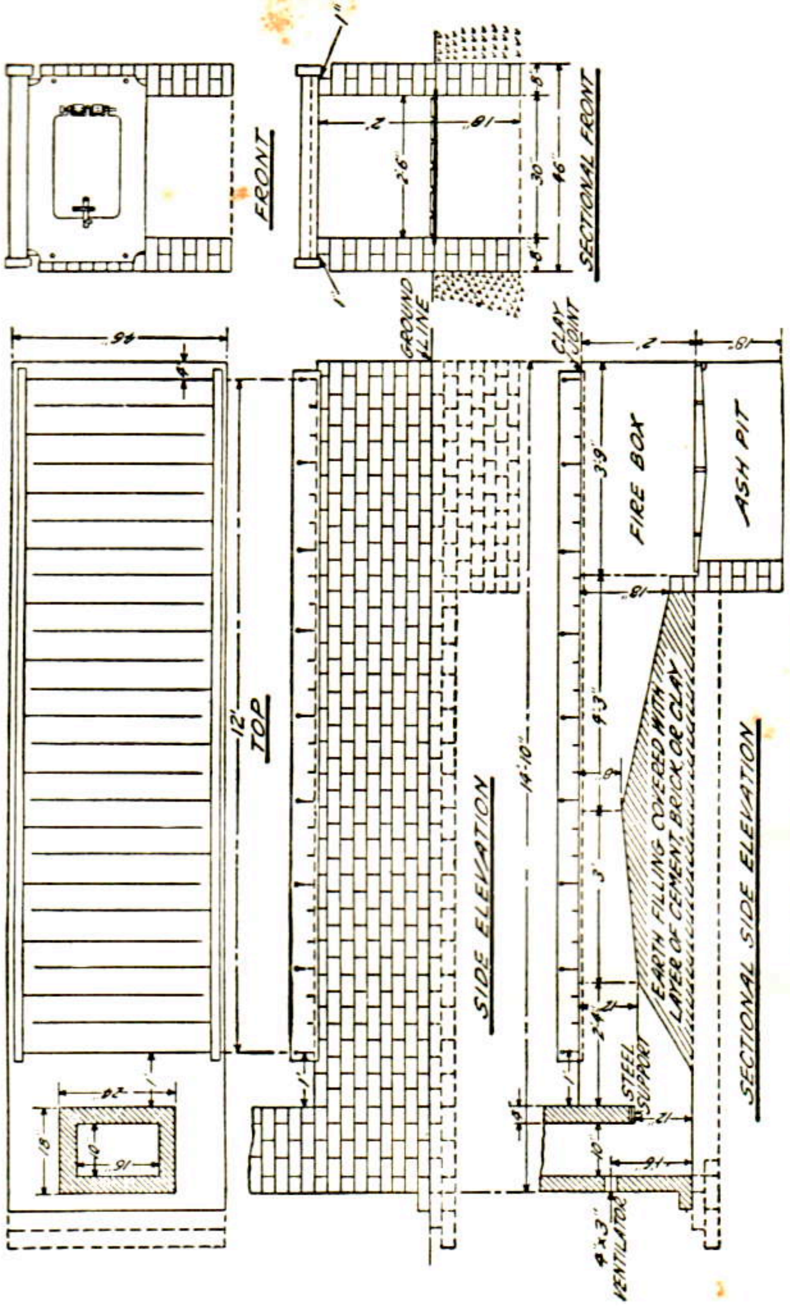

FIGURE 11.—A 12-foot continuous evaporator and furnace.

although fuel should not be wasted. With proper draft, the flames should extend only slightly, if any, beyond the base of the chimney.

The evaporator is set on a single line of bricks laid lengthwise on the double-thickness brick wall on the side next to the fire. The evaporator should be level from side to side, and about 1 inch lower at the front, or juice end. A good joint between the furnace and evaporator is conveniently made with clay or mortar. With the width of furnace given in figure 11, about an inch of each side of the metal bottom of the evaporator projects over the outside edge of the single line of brick, giving an air space that protects the wooden sides of the evaporator from the heat of the furnace. The front of the evaporator should be within 6 inches of the front of the furnace. A space of 1 to 2 feet between the front of the chimney and the back of the evaporator is desirable. A small crack is sometimes left next to the back end of the evaporator to admit air to the chimney end of the furnace, the draft thus created preventing too close contact of the flame with the sirup end of the pan. As shown in figure 11, the top of the opening into the chimney should be 12 inches below the bottom of the evaporator.

FUEL FOR EVAPORATOR

The foregoing description applies primarily to furnaces burning wood. Whenever wood is more expensive than oil (table 6), a furnace of somewhat similar design may be equipped to burn oil efficiently. Since steam is not ordinarily available for small-scale sirup manufacture, however, it is impossible to atomize the oil by use of steam, as is customary in large-scale operations. Nor is it practicable to utilize the heat of the furnace for preheating the fuel. For these reasons a mechanical oil burner must be used, and it is not feasible to burn oils of such high viscosity that they require heating before atomization. Fuel oils lighter than 18° Baumé, or of such viscosity that they will flow readily without heating, are usually required in small installations. All mechanical oil burners need power for atomizing the fuel and injecting the proper quantity of air. The oil may be pumped, but it usually is supplied by gravity. The air pressure is supplied by a power-driven blower or an air compressor. If electricity is available, a small motor is an ideal source of power for operating a blower or compressor. Otherwise, the power required may be obtained from a small gasoline engine (one-half horsepower). The fuel required for a 12-foot evaporator (p. 24) is estimated to be approximately 15 gallons of oil (on 12° Baumé basis) per hour, assuming a production of 16 to 17 gallons of sirup per hour.

Table 6 will serve as a guide in determining whether oil, coal, or wood is the most economical fuel. The figures have been prepared on the assumption that red or black oak, weighing 3,250 pounds per cord, is the wood used, that the oil has a density corresponding to 12° Baumé and a calorific value of 18,500 British thermal units per pound, and that coal has a calorific value of 12,000 British thermal units per pound. Oil can be burned more efficiently than coal, and coal can be burned more efficiently than wood. It is assumed in this table that 1 cord of wood is equivalent to 1,300 pounds of coal and 1 pound of oil to 1.6 pounds of coal. It is also calculated that it will cost 75 cents per cord to handle the wood, 75 cents per ton to handle the coal, and nothing to handle the oil, although, of course, the cost of the mechanical oil burner should be taken into consideration.

TABLE 6.—*Comparative costs for fuels*

Cost of oil per gallon	Cost per ton below which coal is a more economical fuel than oil	Cost per cord below which wood is a more economical fuel than oil	Cost of oil per gallon	Cost per ton below which coal is a more economical fuel than oil	Cost per cord below which wood is a more economical fuel than oil
$0. 03	$3. 87	$2. 25	$0. 07	$10. 03	$6. 25
. 04	5. 41	3. 25	. 08	11. 56	7. 25
. 05	6. 95	4. 25	. 09	13. 11	8. 25
. 06	8. 49	5. 25			

OPERATION OF EVAPORATOR

The evaporator should be thoroughly clean when operation is started. If sediment from the previous operation has been deposited on the bottom and sides, a copper evaporator may be cleaned by allowing a hot dilute solution of commercial hydrochloric (muriatic) acid (about a cup of acid to 1 inch of water) to stand in it for a short period. This partly dissolves the sediment, so that it can be removed by slight scrubbing while water is run through the pan. As galvanized iron, however, is badly corroded by contact with acid, such evaporators should not be cleaned with acid. Evaporators may be cleaned also by boiling water in them and scrubbing, but this is laborious and time-consuming. The evaporator should be cleaned thoroughly every 2 or 3 days, depending largely on the quantity of deposit adhering to it. An additional wash-out opening, with plug, in the front or juice end, since this is lower, will greatly facilitate washing. When two juice evaporators are in use, it is convenient to clean one every day and use the other for evaporating the first supply of juice in the morning.

When operated during the day only, the evaporator should be kept partly full of water overnight. This can be accomplished satisfactorily by flooding the pan with water after drawing off as much sirup or semisirup as possible. At the end of the day the evaporation need have reached only the semisirup stage. If the semisirup is well skimmed before removal, in the morning it may be put back into the sirup end of the evaporator. The sirup compartment is shut off from the rest of the pan by means of a gate until the evaporator is working well again with fresh juice. Starting with juice in the pan over only two-thirds of its length, with either water or semisirup in the sirup compartment, blocked off with a gate, is the easiest way to begin the day's operation.

Transferring juice or sirup of low density to parts of the pan where the sirup is becoming too dense is bad practice, but it is sometimes unavoidable at the start. As soon as sirup is being finished in the back compartment of the evaporator and clean semisirup is being made from the fresh juice, it is time to permit a continuous flow of juice. The flow of juice ordinarily should be kept as nearly constant as possible without dipping from one compartment to another. Such dipping detracts from the clarity of the sirup, owing doubtless to the mixing of juice and sirup at different stages of clarification. Mixing of high- and low-density juice usually causes a persistent cloudiness in the finished product. The rate at which juice is run into the evaporator and sirup is run out is now controlled by the sirup maker. Most of his time is occupied in keeping the flow well regulated. His station is at the sirup end of the pan, where he can constantly watch the density of the sirup during the final stage of concentration and correct any irregularities. The sirup maker should tell the fireman when the fire needs attention, for a steady fire is necessary to regulate the evaporator properly.

When the evaporator has begun to work well, the juice seldom boils in the first compartment, which is the coolest part of the evaporator, unless for some reason the inflow of cold juice is temporarily stopped. This juice has a smooth, relatively cool surface, over which the scum forms a blanket. This is occasionally removed with a perforated skimmer (fig. 12). An extra-wide skimmer for juice skimmings is a labor saver. If the furnace is properly constructed, the boiling of the juice increases in vigor toward the back end of the pan as far as the section under which the fire is hottest. This causes the scum to run counter to the flow of juice to the cooler or front portion of the evaporator.

FIGURE 12.—Sirup skimmer.

By the time the juice reaches the hottest part of the pan, which is about 1½ feet beyond the middle, it has been evaporated nearly to semisirup density and is fairly well cleaned. As the sirup becomes more concentrated, however, additional impurities separate out, and this material also should be carefully removed by skimming. For efficient skimming, a hot fire must be maintained to "roll" the foam. In addition to firing, the fireman can easily remove skimmings from the juice end of the pan, in this way greatly assisting the sirup maker. Firing at the proper time, however, should be his main consideration.

SKIMMING TROUGHS FOR EVAPORATORS

After the furnace is hot, the foam and skimmings can be made to roll over the edges of the evaporator into troughs built along the sides, so that the skimmings all along the sides of the evaporator will run back through the troughs and collect on the cool juice surface, where they may be more readily removed by a wide skimmer.

Skimming troughs (fig. 13) are a great help, as they eliminate the necessity of so much hand skimming all along the sides of the evaporator. They make it possible to produce a brighter, clearer, and less turbid sirup, because the skimmings are floated over the sides of the evaporator with the foam and are less likely to be boiled in. They also reduce loss of sirup. A skimming trough may be attached to each side of an evaporator at practically no expense. A piece of 1- by 4-inch smooth lumber of the same length as the evaporator makes the bottom of each trough, and a similar piece makes the outside wall. Or the troughs may be made entirely of copper or galvanized iron. Some sirup makers prefer narrower troughs and some prefer them wider. For the skimming troughs to work well, it is best to have the sides of the evaporator (side bars) not more than 5 inches high (inside measurement); the sides of a deeper evaporator should be cut down.

At the sirup end of the evaporator the bottom of each trough is flush with the top of the evaporator side bar, while at the juice end it is bracketed to the side of the evaporator from 1 to 2 inches below the top. This gives the trough a slope toward the juice end of the evaporator, making the skimmings run that way. A crosswise partition is sometimes made in each trough about halfway of its length to prevent mixing the clarified semisirup with the juice. It allows the semisirup skimmings to run back into the middle of the evaporator and the juice skimmings to be carried into the cold juice end through small openings cut out of the evaporator side bars. There are solid ends, of course, in both troughs, so that the skimmings, carried along by a small quantity of foam and juice, will have to run back into the evaporator. This prevents loss of juice.

FIGURE 13.—Evaporator with skimming troughs.

EVAPORATING TO UNIFORM DENSITY

One of the difficulties most commonly experienced in using a continuous evaporator is that of concentrating the sirup to uniform density. The method of determining the density by weighing a can of the sirup is sometimes used, and when cans are filled uniformly this gives fairly good control. Many operators are able by experience to judge fairly accurately the density of sirup while it is still boiling. Some do this by dipping a skimmer or a sirup "rake" into the boiling sirup, holding it up, and noting how the cooling sirup "flakes off." No amount of experience, however, can take the place of accurate measuring, and the uncertainties of guessing the density by the flaking-off method can be easily eliminated by the use of a sirup maker's thermometer. Sirup from different varieties of cane boils differently. A good thermometer is more useful in the operation of a shallow evaporator than is the hydrometer, often recommended for the purpose. In using the hydrometer, it is necessary to draw off a cylinder of sirup from the evaporator and float the hydrometer in it (fig. 9). This procedure is troublesome when a shallow evaporator is used because the sirup is in such a thin layer that it is not easily dipped out. The hydrometer, although very useful when sirup is made in a deep evaporator by the batch or noncontinuous process, is considered less valuable than a sirup maker's thermometer for use with the shallow continuous evaporator.

The thermometer most suitable for the purpose is one protected by a substantial copper case, and with a 10-inch scale graduated from approximately 50° to 250° F. The bulb of such a thermometer should be very close to the bottom of the protecting copper case but should not quite touch it. If the bulb stands too high in the case, a little of the bottom of the centerpiece in the case may be cut off. This design is necessary in order that the thermometer bulb may be entirely covered by the shallow layer of boiling sirup (three-fourths of an inch deep). The bulb, however, should not touch either the bottom or side of the evaporator. By providing a broad metal back-piece so that it will stand up, such a thermometer may be kept continuously in the sirup to indicate accurately the point of final evaporation, when the sirup should be allowed to run out of the evaporator. Even though the thermometer is used only to check the sirup maker's guess as to the proper density, it will prove very useful. Sirup which tests 39° to 40° Baumé (73° to 75° Brix) at ordinary temperature with a hydrometer graduated at 20° C. (68° F.) boils at 225° F. at sea level at the time when it should be allowed to flow from the evaporator. In testing a sirup for density in this manner, occasionally determine the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Water should boil at 212° at sea level, 211° at an altitude of 500 feet, and at 210° at an altitude of 1,000 feet. For every 500 feet above sea level, roughly speaking, the boiling point is lowered 1°, so that, when an accurate thermometer is used at a point 500 feet above sea level, finished sirup would boil at 224°, and at 1,000 feet above sea level it would boil at 223°. Sugarcane sirup is usually finished at a temperature 12° to 13° higher than the boiling point of water, if sirup of average density is desired, although a slightly different finishing temperature may be adopted equally well. The bulb of the thermometer should be cleaned by being scoured from time to time; otherwise it may not give an accurate temperature reading.

The sirup density may be checked, if desired, by means of a sirup maker's Baumé hydrometer (fig. 9). Sirup of good density, when tested at close to the boiling temperature, should be about 35° to 36° Baumé. At ordinary temperature this same sirup will test about 39° to 40°. Sirup testing 39.5° to 40° at ordinary temperature weighs 11.4 to 11.5 pounds net per full United States gallon and from 9½ to 10 pounds net per No. 10 can, depending on how full and at what temperature the can has been filled.

Scorching is another difficulty sometimes experienced in open-pan evaporation when a single continuous evaporator is used for making finished sirup. Such sirup acquires a red color and a burnt flavor. Scorching is accompanied by a white puff of vapor, and can always be detected by careful observation. Experienced sirup makers detect it by odor almost instantly. Poor furnace construction, causing local overheating of the sirup, is sometimes responsible for scorching. Sediment adhering to the bottom of the pan may result in a scorching area. Scorching from this cause may be stopped by thoroughly scraping the surface over which it occurs, care being taken, of course, not to damage the pan. In case the sirup is of too high density at the point where the scorching occurs, sirup of lower density should be forced in from the next compartment.

When sirup is evaporated to uniform density as described above, only one evaporator is used. This is the most common method, as it requires the minimum equipment. When the invertase process is used for preventing sugaring, the addition of tanks for treating semisirup and a finishing-off pan is recommended. By employing this additional equipment it is also possible to make more rapid use of the juice evaporator, increase the daily production of sirup, and make clearer or brighter sirup.

HOW TO PREVENT SUGARING

Sugaring, or crystallization, depends largely on the variety of sugarcane and its maturity. The degree of sugaring depends partly on the density of the sirup, more crystallization, of course, being experienced with thicker sirups. Stirring the finished sirup while it is cooling or afterward causes more rapid sugaring.

Crystallization may be prevented by mixing the sirup with commercial glucose, or corn sirup, but this procedure cannot be used in making a product to be sold as pure sugarcane sirup. Moreover, the cost of corn sirup in small quantities is likely to be so high that in seasons when sugarcane sirup is plentiful, there would be little or no profit on the additional gallons of sirup produced by using the corn sirup. The small-scale sirup maker would thus have an additional quantity of sirup to market with difficulty at low prices.

The invertase process for preventing cane-sugar crystallization is a practicable process in which an extract of yeast (invertase) is used during manufacture of the sirup. The yeast extract converts a portion of the cane sugar into the two sugars—dextrose and levulose (invert sugar)—so that the resulting more properly balanced sugar content of the sirup will not crystallize objectionably, even after the can has been opened.

Invertase is a clear, water extract of yeast and not a chemical in the ordinary meaning of this term. Because of the extremely small proportion used, moreover, it cannot be detected in the sirup by either odor or flavor. Invert sugar (dextrose and levulose) is just as sweet and wholesome as cane sugar, but it sugars or crystallizes much less readily. The sugar in honey is principally invert sugar. Directions for using invertase are given below.

INVERTASE PROCESS

In brief, the invertase process as applied to sugarcane sirup is carried out as follows: The juice from the mill is settled, and carefully skimmed and evaporated as usual in an evaporator, kettle, or batch pan. The evaporation, however, during 1 day's operation is carried only to the semisirup stage, which is about two-thirds of the total evaporation. When it tests on an average 20° Baumé while still very hot, the semisirup is collected for invertase treatment in one or more tanks having a capacity sufficient to hold the entire day's output. The invertase is permitted to act on the cane sugar in the semisirup while any sediment is settling out. Moreover, it is a good plan to arrange to settle the semisirup to remove sediment, regardless of whether or not invertase is used.

As invertase is destroyed at fairly high temperatures, the semisirup should be allowed to cool to 140° to 145° F. before the invertase is added. (Semisirup which tests 20° Baumé when practically at a boiling temperature will test 22° to 23° Baumé at 140° to 145°.) The proportion of invertase required ranges ordinarily from 40 to 60 cubic centimeters for every 100 gallons of semisirup. Small prescription bottles, glass vials, or cylinders, graduated in cubic centimeters, usually sold in drug stores, are recommended for measuring the invertase accurately. The invertase is mixed with a little water (about a pint) and then added to the tank of semisirup. Because of the small proportion of invertase added, the sirup must be well stirred to mix it thoroughly with the invertase. After adding the invertase, be sure to cover the tank or barrel in order to keep out dirt and to keep the semisirup as warm as possible overnight.

Although about 50 cubic centimeters of invertase per 100 gallons of semisirup is usually required, it may be necessary to vary the quantity somewhat in certain cases, owing to differences in the proportion of cane sugar and invert sugar originally present in the juice, the proportion of cane sugar converted into invert sugar during evaporation, and the strength of the invertase. The best way to determine for the first time whether too little or too much invertase has been added is to observe the color and flavor of the first batch of sirup and its tendency to crystallize after evaporation to final density. If the sirup does not differ appreciably in quality from sirup obtained from the same kind of cane when no invertase was used, and if no sugar separates from the sirup, it is safe to conclude that the proper quantity has been added. If, however, the color and flavor of the finished sirup differ appreciably from those of sirup of the same density made without invertase, slightly less invertase should be used thereafter. Conversely, if the finished sirup shows a tendency to deposit cane sugar, the proportion of invertase used for the next lot should be increased.

The tendency of sirup to undergo cane-sugar crystallization may be easily and quickly tested by permitting a small sample (about a pint in a glass jar) to cool until it is lukewarm and then adding about a teaspoonful of ordinary granulated sugar and stirring occasionally over a period of 2 or 3 hours. If no sugar in excess of that which has been added appears in the sirup after it has stood overnight, the quantity of cane sugar which is likely to be deposited later will be very small at the most. The smallest proportion of invertase that will prevent cane-sugar crystallization should be used, and once this has been determined approximately, the same amount may be used regularly for the same variety of sugarcane if the crop is in the same condition.

Since invertase does not act instantaneously, a certain period is required for it to convert the necessary quantity of cane sugar into invert sugar. It has been found convenient to allow approximately 12 hours (overnight) from the time the invertase is added to the semisirup before evaporation to final sirup is started. The invertase is usually added at night, and final evaporation of the semisirup is begun when operation is resumed next morning, using the batch or finishing-off pan (p. 33).

The cost for invertase in the process described above is about half a cent per gallon of final sirup. Those who have serious trouble with cane-sugar crystallization will find this process very much worth while.

Although it is best to have the equipment on a hillside, to make use of gravity flow throughout (fig. 2), a convenient procedure for handling the semisirup when the equipment has to be set up on level ground is to let it run from the evaporator, kettle, or batch pan in small batches or continuously into a pail, bucket, or tub, and then to pump or pour it into a semisirup-holding-and-settling tank. This tank should be elevated from the ground and should be provided with a draw-off pipe and wash-out opening with suitable valves. The tank should be elevated sufficiently to allow the semisirup, when ready, to run by gravity directly into the finishing-off pan, the tank also being sloped a little toward the draw-off end. The draw-off line should be from 1 to 2 inches from the bottom to avoid drawing off any sediment.

To avoid loss of sirup, the small quantity of semisirup and sediment that remains in the bottom of a settling tank when it is nearly empty may be removed through the wash-out connection and returned to the next batch of fresh juice that is to be allowed to settle in the juice-settling tanks. When empty, the semisirup-settling tank should be carefully washed before it is used again.

The semisirup should be allowed to stand overnight in order that the invertase may have sufficient time to react, and to permit thorough settling. For continuous operation, therefore, at least two settling tanks should be provided. Each tank should be not more than 3 feet deep and of sufficient capacity to hold a day's run of semisirup. In planning the size of these tanks, it can be assumed that 2 gallons of semisirup make 1 gallon of finished sirup and that there are 7½ United States gallons to the cubic foot. If the operation is continuous, one tank is filled and one is emptied each day. Some sirup makers prefer to use three of these tanks. Well-constructed cypress tanks of planed lumber provided with covers hold the heat very well, thus permitting efficient settling. Tanks made of wood and lined with thin copper, however, make the best settling tanks. It is best not to use galvanized iron, as this soon becomes corroded. The tanks for semisirup are inexpensive, as they can ordinarily be made at home. Clean wooden barrels with covers are satisfactory for holding small quantities of semisirup overnight.

FINISHING-OFF PAN

The finishing-off pan recommended for evaporating semisirup to the finished sirup density may be home-made, with cypress or poplar sides and galvanized-iron or, preferably, copper bottom, or it may be made entirely of metal by a local tinsmith. When a 12-foot continuous pan is used in evaporating juice to semisirup, a small batch pan about 5 feet by 2½ feet by 8 or 10 inches is large enough for evaporating the semisirup to sirup. By use of a larger batch pan, however, such as that shown in figure 14, the sirup can be made faster, which is an advantage when the sirup maker wishes to finish earlier in the day so as to give his attention to other work. This batch pan should preferably have a center partition provided with a tight-fitting gate and be mounted on a suitable furnace of its own.

An ordinary batch pan, if used as a finishing-off pan, may be so mounted on a furnace that it can be lifted off the fire onto suitable supports when the sirup is done. When the pan has a good gate, however, as shown in figure 14, it need not be lifted off the fire. A "pusher" or sirup "rake" may be used to help run the batches of finished sirup out rapidly. Semisirup from the other compartment is then run in immediately to keep the bottom of the pan covered and thus prevent scorching. The draw-off opening, which should be flush with the bottom of the pan, should be 2½ to 3 inches wide to permit running batches of sirup out rapidly.

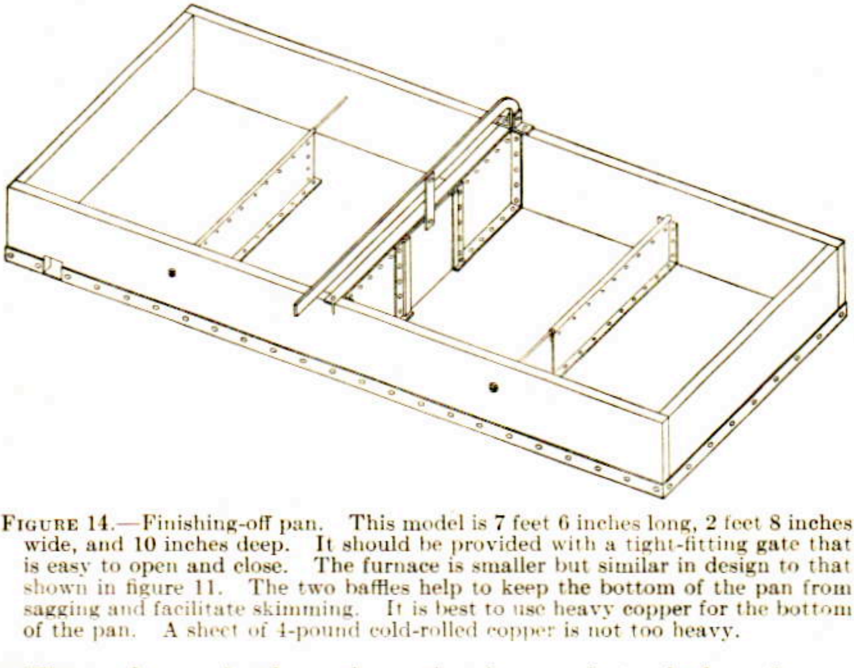

FIGURE 14.—Finishing-off pan. This model is 7 feet 6 inches long, 2 feet 8 inches wide, and 10 inches deep. It should be provided with a tight-fitting gate that is easy to open and close. The furnace is smaller but similar in design to that shown in figure 11. The two baffles help to keep the bottom of the pan from sagging and facilitate skimming. It is best to use heavy copper for the bottom of the pan. A sheet of 4-pound cold-rolled copper is not too heavy.

Those who use kettles or larger batch pans, instead of continuous evaporators, for sirup making can use these for evaporating semisirup to finished-sirup density. Moreover, with certain changes in an evaporator and method of operating it, sirup makers who are using continuous evaporators can make semisirup and finished sirup on the same evaporator at the same time. A separate batch pan, however, is very convenient to supplement a continuous evaporator and makes possible an increased daily production of sirup, owing to the increased boiling capacity. In addition, it is easier to handle a separate batch pan than to make both semisirup and finished sirup on the same evaporator. The extra cost is small, considering its value.

Some sirup makers prefer to use a small Stubbs type evaporator for a finishing-off pan (fig. 10). This type of evaporator is popular because it is easy to regulate and skim.

In boiling the semisirup to finished-sirup density, it is advisable to evaporate as rapidly as possible to avoid altering the flavor of the sirup. Start with a small fire and stir the thin semisirup until the pan is hot; then evaporate rapidly, paying attention as usual, however, to careful skimming. It is best to work with rather small batches.

The sirup can best be evaporated to uniform density in a finishing-off pan by using a Baumé hydrometer. In ordering sirup maker's thermometers and Baumé hydrometers, it is best to mention that they are to be used in making sugarcane sirup. The Agricultural Chemical Research Division, Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, will supply the names and addresses of firms from whom papers for testing the acidity of the juice, Baumé hydrometers, sirup maker's thermometers, and invertase may be obtained.

REMOVING SEDIMENT FROM SIRUP

Some sirup makers experience difficulty with an excessive amount of sediment. This depends as much on the type of soil on which the crop was grown, the variety of sugarcane, the fertilizer used, the kind of growing season, the maturity of the crop, degree of topping the cane, and the juice extraction obtained as on the skill of the operator. Straining the sirup when boiling hot through cloth strainers through which the sirup will pass within a reasonable time does not remove much except the coarser sediment. Moreover, when cooled to atmospheric temperature, the sirup at final density cannot be filtered efficiently on the farm by any known means. Sedimentation is in general the most feasible procedure for removing this material from sirup.

Sirup that contains an excessive quantity of suspended material of the heavy type should remain in a settling trough or tank until this material has settled to the bottom. This takes overnight or sometimes even longer. Clear sirup may then be drawn off from the top and barreled, or reheated and canned; and to avoid loss of sirup the layer of sediment, if it contains much sirup, may be returned to the cold-juice settling tank.

The sirup should be allowed to settle when warm but not too hot. Before running it to the settling tanks, cool it to about 150° F. to prevent the deterioration in quality caused by too long a retention of high temperature. Wooden troughs or insulated tanks, which should be covered, may be used to keep the sirup warm and thus facilitate sedimentation. Sirup that has settled overnight or longer should be reheated for canning (p. 35).

Large flocs of an objectionable lightweight material form in some sirups, but sometimes only after long standing. Such material does not settle well and is troublesome to remove by reheating and skimming. If this occurs, the next year it is advisable to seek the remedy by using different land or fertilizer, topping lower than usual, or possibly using a different variety of sugarcane.

CANNING

Sugarcane sirup of the usual density should be canned to prevent fermentation. As the sirup has been thoroughly sterilized by boiling, it does not ferment if packed while hot in clean containers and sealed immediately. The cans or glass containers must be airtight; otherwise, fermentation or molding may occur. Large containers, like used barrels, should be thoroughly washed several times with boiling water or, if possible, steamed, and then dried before sirup is put into them. Clean new barrels need not be washed.

As the sirup flows from the evaporator, strain it through muslin or light domestic. Allow it to cool somewhat either for canning or for barreling, as excessive canning temperatures impair the quality. An inexpensive and very convenient arrangement for cooling the sirup consists of one or more screened cooling troughs into which the sirup may be run, or poured, which are high enough off the ground to allow it to run into the cans by gravity. For filling half-gallon and smaller cans, the sirup should be at a temperature of 190° F. or as close to it as possible. For gallon cans, the sirup should be 180°; and for barreling, it should be cooled to at least 120°. These temperatures are recommended for farm-scale sirup canning; somewhat lower temperatures may be used by canning plants where large stacks of sirup in cans hold the heat for a longer time.

Sirup that has been allowed to stand for some time in order to remove the sediment should be reheated to the proper temperature for canning. For this purpose the finishing-off pan can be employed if a very small fire is used, the sirup is stirred while cold to prevent scorching, and the temperature is watched carefully. Or the loosely sealed cans, nearly filled with well-settled sirup, may be placed on a low rack in the larger evaporator and heated by means of boiling water in the evaporator. When a thermometer shows that the sirup is at the proper temperature, the cans may be removed and sealed. These methods, although troublesome, are preferable to canning directly from the evaporator sirup containing an excessive amount of dregs or sediment. The use of a steam-jacketed kettle or a tank provided with steam coils is best for reheating the sirup, but this equipment is seldom available on the farm.

MARKETING

It is sometimes worth while for all the sugarcane-sirup producers in one locality to cooperate in marketing their product. A system of grading then becomes imperative. As a rule, buyers expect uniform quality even though the sirup is bought at different times and from different manufacturers. They are not informed regarding manufacturing conditions and do not understand why all sugarcane sirup does not have the same taste and appearance. By fixing standards, it is possible to grade sugarcane sirup as to color, flavor, clarity, and density. A system of grading makes it possible to market the sirup to better advantage.

As ordinarily filled, a No. 10 can of sirup contains only about 86 percent of a United States gallon. On this basis the cost to the producer of a No. 10 can of sirup is only a few cents more than the cost of a gallon of sirup sold by the barrel. The difference between the contents of a No. 10 can and a full United States gallon almost compensates for the greater expense of the cans, labels, and cases. The producer who sells his sirup in cans, however, should make a reasonable additional charge for the time spent in canning the sirup properly and delivering it to the purchaser.

Many sirup producers prefer to sell their sirup in barrels to large-scale packers and distributors, who do not want the sirup put up in cans. Moreover, when the production exceeds the demand of the nearby market, shipment of sirup in barrels is often made to large-scale canners or packers who are in a better position to distribute the sirup successfully to more distant markets throughout the year. Sirup makers should cooperate with packers and distributors of sirup, who assist greatly in finding new and wider markets. The buyers, in turn, should pay a fair price for sirup in barrels.

COST OF MAKING SIRUP

The following tabulation gives the estimated approximate costs of materials, equipment, and labor required to construct a relatively large, farm sirup-making outfit, including a power mill suitable for grinding 10 tons of cane per 10-hour day and making 150 to 200 gallons of sirup daily. These costs vary somewhat from year to year and also for different localities. The engine, for example, instead of being a new one costing $200, may be an old automobile engine of satisfactory quality costing only a small fraction as much. On the other hand, more money can sometimes be spent to good advantage on the sheds, furnaces, piping, tanks, and pans.

Lumber and building supplies, sheet metal, piping, etc	$180. 00
Brick, lime, sand, etc., for furnaces	50. 00
Labor for building sheds, furnaces, tanks, pan, etc	100. 00
Mill and accessories	250. 00
12- to 15-foot copper evaporator	50. 00
Engine and freight	200. 00
Total investment	830. 00
Interest at 6 percent and depreciation at 10 percent for 1 year	132. 80

The itemized daily cost of operating this plant is estimated roughly as follows:

1 sirup maker	$3. 00		
1 fireman	2. 00		
1 mill feeder	2. 00		
1 bagasse carrier	1. 50		
Total labor		$8. 50	
Wood, at $3 per cord		6. 00	
Oil		. 75	
Gasoline (12 gallons, at 25 cents per gallon)		3. 00	
Total operating cost per day		18. 25	
Operating cost for 45 days (45 × 18.25)			$821. 25
Interest at 6 percent and depreciation at 10 percent for 1 year			132. 80
Total manufacturing cost for season's operations			954. 05

Assuming that 10 tons of sugarcane are ground per day and that 18 gallons of sirup (United States gallons) per ton of cane are obtained, the output of sirup in this plant during a 45-day operating season would be 180 × 45, or 8,100 gallons.

The manufacturing cost, exclusive of the cost of the cane, is 11.8 cents per gallon. At custom plants operating on a toll basis, the manufacturing cost per gallon is the consideration governing the toll charge, which usually amounts to one-quarter to one-third of the sirup.

The cost for the cane per gallon of sirup, assuming a value of $4.50

per ton of cane delivered to the plant and a yield of 18 gallons of sirup per ton, is 25 cents per gallon. The total cost for the sirup, therefore, is 36.8 cents per gallon. If the sirup sells at 40 cents a gallon net, the profit is 3.2 cents per gallon. On this basis, the profit for a 45-day season would be $259.20. In addition to this, the farm family often supplies most of the labor, thereby saving the expense of hired help, and may produce some, or all, of the sugarcane. The field profit is often greater than the manufacturing profit.

COMPOSITION AND FOOD VALUE

The following advisory standard for cane sirup, promulgated under the Federal Food and Drugs Act of 1906, is being used as a guide in the enforcement of the Federal Food, Drugs, and Cosmetic Act, pending the adoption of a standard under the latter Act, and also in the enforcement of several State food laws:

> Cane Sirup. Sirup made by the evaporation of the juice of the sugarcane or by the solution of sugarcane concrete. It contains not more than 30 percent of water and not more than 2.5 percent of ash.

As a rule, sirups containing not more than 30 percent of water have a Brix reading of 72°, or higher, at ordinary temperature, corresponding to a Baumé reading of at least 38.5°. The average density of sugarcane sirup that is considered acceptable to most people is probably closer to 73° Brix, or 39° Baumé, at ordinary temperature, measured by a hydrometer graduated at 20° C. Sirup that tests 35° Baumé at a temperature close to boiling will test about 39° Baumé at ordinary temperature. For a drop of every 10° F. in the temperature of the sirup while it is cooling, the Baumé reading of the sirup increases approximately one-fourth of a degree. For example, if a sirup at 220° F. tested 35° Baumé, at 60° F. it would test $\frac{160}{10}\times\frac{1}{4}=4^\circ$ higher, or 39° Baumé. This method of calculation applies fairly closely in the case of farm-scale sirup operations, although on a large factory scale some allowance must be made for additional evaporation while large tanks of sirup are cooling.

Sugarcane sirup containing 28 percent of water contains a total of 72 percent of sugars, mineral matter, and organic nonsugar substances. On an average, sirup that contains 28 percent of water will contain about 65 to 67 percent of total sugars (cane sugar and invert sugar), 1.0 to 2.5 percent of mineral matter (determined as ash), and about 3.0 to 4.0 percent of organic nonsugar substances.

Variations in the composition of cane juice, which depend principally on the variety of cane, type of soil, kind of fertilizer, and degree of maturity of the cane, are reflected in the composition of the sirup. There may be other variations in the composition of the sirup, such as the transformation of a portion of the cane sugar into invert sugar during the process of making the sirup, in order to prevent crystallization (p. 30). The removal of skimmings and sediment during the process of making the sirup also causes the composition of the sirup to differ somewhat from that of the juice. Aside from these factors and the removal of a large proportion of the water by evaporation, the sirup has essentially the same composition as the juice. The percentage of total mineral matter in the sirup, for example, is roughly

4 to 5 times that in the juice (table 2), owing to concentration by evaporation.

Since it contains approximately 66 percent of sugars and much smaller proportions of the other constituents, sugarcane sirup owes its food value essentially to its sugar content. The mineral matter and organic nonsugars naturally add somewhat to its food value. The sugar it contains has a fuel or energy value of 1,188 calories per pound of sirup. In addition to this, sugarcane sirup is valued because of its characteristic flavor, which contributes to palatability and greater variety in the diet.

BYPRODUCTS

BAGASSE

The crushed cane as it comes from the mill is known as bagasse, but it is sometimes called pomace or chews. It may be used as bedding material for farm animals or as a temporary filling for low and muddy places on the farm. When properly composted and then spread over fields and plowed under, it is of some value in supplying humus and improving soil texture. In some sections it is customary to give cattle access to the bagasse which has been spread over the fields, care being taken not to let them eat too much of it at first. As bagasse resulting from good milling practice is mostly fiber or cellulose, it has relatively little value for feeding, although it is sometimes put down in trench silos. Bagasse finely chopped and mixed with varying proportions of cottonseed meal, molasses, etc., is also used as a cattle feed. The bagasse from large sugar factories may be used for the manufacture of building board and other cellulose products, but this method of utilization is not now practicable for small sirup plants.

SKIMMINGS

Skimmings have recognized value in feeding farm animals, especially hogs. As this sometimes results in scouring, however, the quantity fed at any one time should be limited to the amount which experience has shown to be safe.

LEAVES AND TOPS

In general, when the leaves and tops are green, they weight from 20 to 30 percent of the total crop, or from 30 to 40 percent of the weight of mill cane after proper topping and stripping. If they are frostbitten or dry they obviously weigh considerably less. The leaves may be eaten by cattle, or if left in the fields and plowed under, they are of some value as humus. The green leaves and tops have been used for silage and for making artificially dried feeds. When sugarcane is properly topped, as good practice demands in the production of best-quality sirup, the value of the leaves and tops is an important item.

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