UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1158

Washington, D. C. ▼ July 3, 1923

PRODUCTION OF SIRUP FROM SWEET POTATOES.

By H. C. Gore, *Chemist in Charge, Fruit and Vegetable Utilization Laboratory,* H. C. Reese, *Assistant Development Engineer,* and J. O. Reed, *Assistant Development Engineer, Office of Development Work, Bureau of Chemistry.*[1]

CONTENTS.

SWEET-POTATO BY-PRODUCTS.

No sweet-potato by-products industry exists at present in the United States where sweet potatoes rank second in importance of all vegetables grown. Consequently a large part of this crop is lost each year from decay. When good growing conditions prevail up to harvest time, a great many potatoes become overgrown, forming so-called "jumbo" potatoes. These oversized potatoes, which often constitute 40 per cent of the entire crop, have the same composition as roots of the standard market sizes, but they are of less value for shipping to distant markets and for canning. The development of profitable methods for converting such potatoes into useful products is therefore of great importance. While the production of oversized potatoes is large, the production of undersized potatoes is usually small. The small potatoes are used largely for seed purposes.

Sweet potatoes are richer in carbohydrates, especially starch, than any other vegetable commonly grown. For this reason they are a possible source of many products containing or derived from starch, such as potato flour, dehydrated potatoes, starch, sirup, alcohol,

[1] The work reported in this bulletin was conducted cooperatively by the fruit and vegetable utilization laboratory and the office of development work. The laboratory process for producing sirup from sweet potatoes was worked out by H. C. Gore, who also assisted in the production of sirup at the experimental plant installed at Fitzgerald, Ga. The equipment for the production of the sirup at Fitzgerald was designed and installed by the members of the office of development work, who also determined the production cost and the market value of the sirup. This part of the project was conducted under the supervision of H. E. Roethe. The Union Cotton Oil Co., Fitzgerald, Ga., gave the use of its plant for making the sirup on the commercial scale, and C. A. Newcomer, secretary and treasurer of the company, cooperated with the investigators during the field work. The States Relations Service of the Department of Agriculture and various State extension directors submitted helpful comments and tested the sirup produced. Manufacturers and jobbers of sirups, confectionery, soft drinks, cookies, biscuits, etc., tested samples of sweet-potato sirup and gave their opinions on its quality and possible use.

37996°—23——1

vinegar, breakfast foods, and various kinds of feeds. Dr. G. W. Carver, of Tuskegee Institute, has prepared all of these products, as well as many others,[2] from sweet potatoes.

Sweet potatoes, cooked until soft, crushed into a pulp, cooled to the proper temperature, treated with a little malt, allowed to stand for a short time, and then pressed, give a sweet juice which upon evaporating forms sirup. Because of the large proportion of starch in the sweet potato the yield of sirup is very high, as much as 30 to 35 per cent of the weight of potatoes taken. The dried pomace forms from $3\frac{1}{2}$ to 10 per cent of the weight of the potatoes. The sirup has about the same color as cane sirup, can be filtered clear, and is useful for certain sirup purposes.

Although the sirup apparently is a new product, United States patent 109991, describing a method for its preparation similar to the one devised by the Bureau of Chemistry, was granted on December 6, 1870, to Charles Delamarre, of New Orleans. In his process the potatoes were cooked and then reduced to a pulp by being passed between wooden rollers. Eight pounds of crushed malt to each 100 pounds of potatoes was added, and the mash was heated to boiling. Cold water was added at the rate of 25 gallons for 100 pounds of potatoes and the mixture was allowed to settle, when the supernatant liquid was drawn off. The rest was pressed, the pressed cake being used for cattle feed. The wort was defecated by adding limewater, partially evaporating, and allowing it to stand, when the clear liquid was drawn off and evaporated to sirup. Public service patent 1310012, dated July 15, 1919, was granted for an improved process worked out by the Bureau of Chemistry on the production of sirup from sweet potatoes. In it the process was simplified.

About 1900 Henry S. Morris, of Philadelphia, established a sweet-potato flour plant at Bound Brook, N. J. For several seasons a sweet-potato flour, which sold readily at satisfactory prices, was made there by the following method: Freshly harvested sweet potatoes were thoroughly scoured by brushing machines which removed practically all of the peel. They were then sliced and conveyed to a drier which consisted of a series of special drying floors placed one above another. Here the slices were dried in an ascending current of hot air. The slices were fed in at the top of the drier and were dropped through from floor to floor as they were dried, by opening successively the shutters composing the floors. The dried product was ground while still hot and was very finely bolted. Production ceased about 1906, owing to the lack of demand for the flour.

The Williams Co., of Greenville, S. C., during 1916 produced three sweet-potato products—a crumblike product known as yam nuts, a sweet-potato flour flake, and a sweet-potato flake. Manufacture was protected by United States patents 1238371, 1238372, and 1238373. The general method employed in these three processes was to mix the steamed peeled potatoes with flour, salt, and yeast, allow this dough to ferment, add a large quantity of cooked potatoes to the sponge thus produced, and let it ferment. It was then made into loaves and baked. The loaves were allowed to cool, after which they

---

[2] Tuskegee Institute, Ala., Bull. 38, 1922; "Two great money crops of the South," address at the Voorhees Farmers' Conference, Feb. 16, 1921, Denmark, S. C., published by the Voorhees Press.

were worked up into the crumblike product, flour, or flakes. Production, however, was unprofitable and eventually ceased.

The manufacture of sweet-potato flour by the flake process was taken up by Mangels and Prescott of the Bureau of Chemistry during the spring of 1919.[3] Their method was as follows: The potatoes were washed, steamed under 15 pounds pressure for 15 minutes, and then dried in a drum drier of the type extensively used abroad in treating Irish potatoes. The drier consisted of two revolving drums supplied with steam at from 35 to 53 pounds pressure. The cooked potato was spread out on the cylindrical surface of the drum by means of smaller auxiliary rollers, dried rapidly, and then removed by scraper knives. The flakes thus obtained were ground into flour. This process could not be applied to sweet potatoes on account of the difficulties encountered in securing a product of attractive color and flavor and because the flour obtained was so hygroscopic that it hardened upon storage, forming gummy cakes.

The study of McDonnell[4] on the manufacture of sweet-potato starch has great general technical value. Despite his satisfactory results, the simplicity of the process, and the favorable reports on the market value of starch, commercial development of sweet-potato starch manufacture has never been undertaken.

COMMERCIAL POSSIBILITIES FOR SWEET-POTATO SIRUP.

From 5 to 6 gallons of sweet-potato sirup produced by the Bureau of Chemistry was sent to each of many manufacturers of sirup and various products made with sirup to obtain their opinions as to the quality and commercial application of the sirup. Most of these manufacturers submitted a report.

The consensus of opinion was that the sirup produced during 1922 was superior to that which had been produced during the preceding year. There was, however, a wide variation of opinion as to the quality of the sirup. Some claimed that the sirup was not sweet enough; others that it was too sweet. Some thought the color was too dark; others that it was good. Some reported that the sirup had a sweet-potato taste, which was objectionable; others stated that the sweet-potato taste in the sirup was hardly noticeable, and even if present would not be objectionable. Some said the sirup was either too thin or too thick; others that its consistency was about right. This difference of opinion was to have been expected. Each manufacturer measured the quality of the sirup by the requirements of his product or of his particular method of manufacture.

In several cases the sirup fermented readily. This may not be a serious objection, as it probably may be avoided by concentrating the sirup to a certain degree Brix. This, however, would have to be determined by a series of tests. The claim has also been made that the sirup will scorch when cooking on a fire before it reaches a temperature of 250° F.

The replies of the manufacturers show that the qualities of the sirup limit its field of use. Because of its color the sirup could not be used generally in the manufacture of candies other than colored

---

[3] "Manufacture of sweet-potato flour by the 'flake' process," Chemical Age, 29 (1921): 132–135.

[4] "The manufacture of starch from sweet potatoes," S. C. Agr. Expt. Sta., Clemson College, S. C., Bull. 136, April, 1908.

candies, such as caramels, taffy, and kisses, and those which do not require a grain. The same holds true in baking. Doubtless the sirup would make a good cooking and table sirup in the household. It probably will never come into general use as a table sirup because of its characteristic taste, although it might find favor with those who like that taste.

Sweet-potato sirup has qualities which make it a valuable blend for other sirups. Like glucose, at present the chief material for blending, sweet-potato sirup prevents crystallization of cane sirup.[5]

The commercial application of this sirup is limited by its cost of manufacture as compared with that of other sirups. If sweet-potato sirup could be manufactured at a lower cost than the other sirups, uses would readily be found for it. With the present method of manufacture and with the present market value of the other sirups, however, this is impossible. It may be that in times of emergency, when the price of sugar and sirups soars, sweet-potato sirup can be manufactured at a profit. It is doubtful whether sweet-potato sirup could be used as a substitute for glucose at its present low cost.

EXPERIMENTAL WORK ON SWEET-POTATO SIRUP.

PRELIMINARY WORK.

During the fall and winter of 1920 the Bureau of Chemistry experimented with the sirup making from sweet potatoes in the laboratory. The ease with which sirup could be prepared was demonstrated and the nature of the equipment necessary for its production was determined.[6] The process for the production of sirup from sweet potatoes thus developed gave indications of possessing promising commercial possibilities. Field operations were therefore begun in the spring of 1921 and continued during the first part of 1922, with a view to studying the commercial application of the process, special attention being given to the determination of the cost of manufacturing, the market value, and the possible uses of the sirup. Fitzgerald, Ga., was selected as the most satisfactory place for the experimental plant.

A few hundred gallons of sirup of fair quality was manufactured there in 1921. Small lots of the sirup were distributed among the larger manufacturers of sirups, confectionary, soft drinks, cookies, biscuits, etc., for expression of opinions on its quality, market value, and possible uses. It then became evident that a still better sirup was needed to meet trade requirements. With this in mind, further laboratory work was done.

At the conclusion of these laboratory tests the experimental work at Fitzgerald was resumed during the early months of 1922. The plant was remodeled and numerous improvements were made in the installation. About 300 gallons of sweet-potato sirup was produced.

---

[5] Recent laboratory tests have shown that sweet-potato sirup can be used to prevent crystallization in cane sirup. In the tests crystallization was much retarded by adding 20 per cent by weight of sweet-potato sirup (75.86° Brix) to the cane sirup and entirely prevented by the use of one-third by weight of sweet-potato sirup, the composition of the resulting mixture being three-fourths cane sirup and one-fourth sweet-potato sirup. Two samples of cane sirup were used in the tests. One was Georgia cane sirup of 75.02° Brix, apparent purity 61.35; the other was Louisiana cane sirup of 73.8° Brix, apparent purity 72.66. The tests were made by mixing the cane sirup with different quantities of sweet-potato sirup, inoculating each mixture with a trace of powdered sucrose and letting it stand in cold storage for several months.

[6] "Preparation of sweet-potato sirup," Chemical Age, 29 (1921): 151.

This sirup was distributed in much the same manner as that produced during the preceding year.

WORK AT FITZGERALD, GA.

Buildings.

The apparatus used in conducting the experimental work on the production of sweet-potato sirup on a semicommercial scale was installed in a frame building covered with corrugated sheet iron and provided with a cement floor (Fig. 1). The engine room had the same construction. The boilers for generating the steam were built out in the open, but were covered with a roof made of wooden rafters covered with corrugated iron sheathing. The potatoes were stored in a frame building mounted on wooden piles. The walls were made of slab boards over which pebble-finished tar paper was spread vertically, battens being used to cover the laps. The roof of the building was made of rafters covered with slab boards overlaid with pebble-coated tar paper.

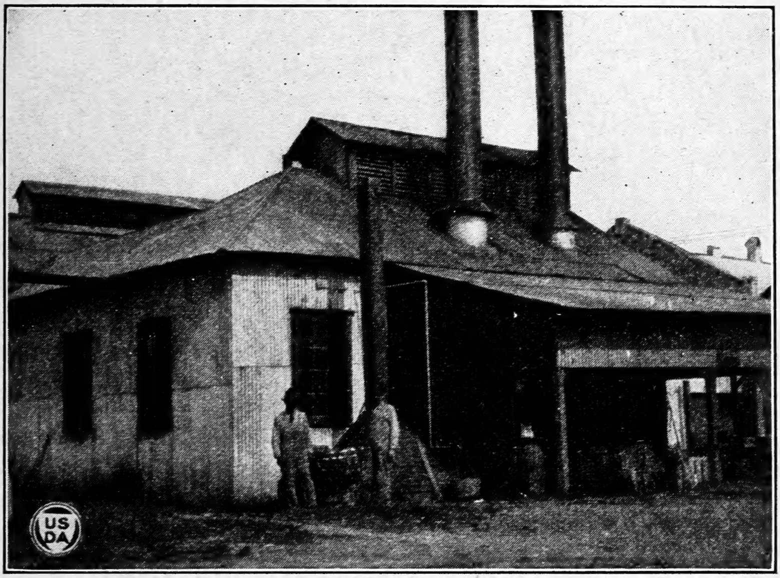


Fig. 1.—Plant at Fitzgerald, Ga., which was used for conducting experiments on the manufacture of sweet-potato sirup on a semicommercial scale.

Plant Layout.

The layout of the experimental sweet-potato sirup plant (Fig. 2) shows the apparatus necessary for the production of the sirup, the floor space required by the various pieces, and their placing. A plant of this size is large enough for an average daily production of 50 gallons of finished sirup. Its capacity could be greatly increased, however, by the addition of a few other pieces of equipment.

Apparatus.

A detailed statement of equipment used is given in Table 1.

TABLE 1.—*Apparatus used in the manufacture of sweet-potato sirup.*

Item No.	Number of units.	Kind.	Floor space.	Weight.	Horsepower.	Capacity.	Revolutions per minute of driving pulley.	Unit value.
			Feet.	*Pounds.*				
1	1	Washer	6½ by 11	850	1	150 bushels per hour	90	$300
2	1	Mash tank	7 by 7	1,200	3	1,200 gallons	72	350
3	1	Hydraulic press	4 by 11	2,800	1½	17 bushels per hour	120	375
4	1	Evaporator	3½ by 18	1,350		40 boiler horsepower		350
5	1	Cooling tank	5½ by 6¾	175	¼	550 gallons	90	55
6	1	Filter press	4¼ by 7½	2,800		18-inch plate, 18-inch frame.		400
7	1	Flavoring and bottling kettle.	7¼ by 7½	90		50 gallons		125
8	1	Drier	14⅓ by 11⅓	1,500	1½	60 square feet (area)	2,000	225

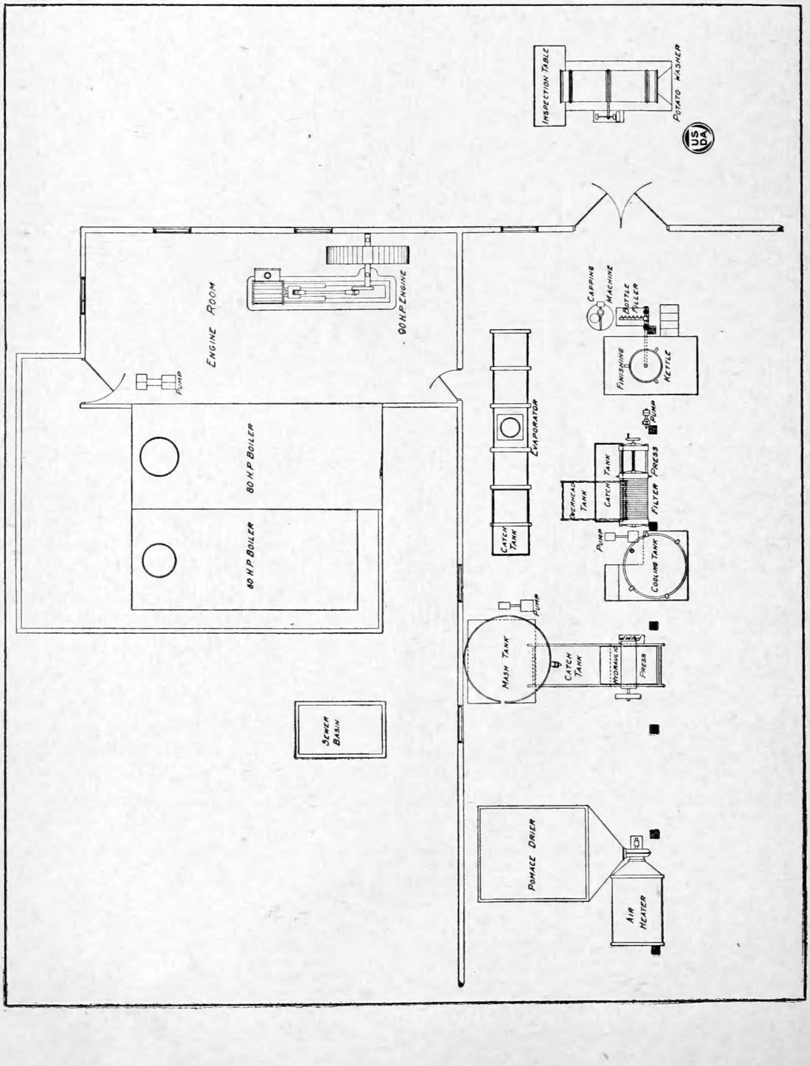


FIG. 2.—Layout of experimental sweet-potato sirup plant, Fitzgerald, Ga.

FIG. 3.—Sweet-potato washer in operation.

WASHER.

A standard-make, rotary-screen cylinder washer (Fig. 3) was used to remove the dirt, sand, etc., from the sweet potatoes before they were placed in the mash tank for steam blanching. A scroll-shaped pipe, running from one end of the washer to the other, carried the potatoes through the machine. The turning over and over of the cylinder caused the potatoes to rub against one another. This rubbing action, together with a spray of water from a perforated pipe, which extended through the cylinder parallel to its axis, thoroughly washed the potatoes.

The driving pulley of the washer was driven at 90 revolutions per minute, which made the cylinder revolve approximately 25 times a minute. With this operating speed, 150 bushels of sweet potatoes an hour could be washed. The washer was installed out of doors to save installation expenses, especially the cost of sewer connections.

MASH TANK.

A large wooden tank, 7 feet in diameter and 5 feet deep, outside dimensions, was used for the steam blanching and the subsequent mashing of the sweet potatoes (Fig. 4). It was made of 3-inch cypress staves dressed down to $2\frac{3}{4}$ inches and had a capacity of approximately 1,200 gallons. Steam for blanching purposes was provided by means of three-quarter-inch pipes running into the tank at every 90°. The admission of the steam was controlled by means of valves in each line. Each pipe had a single row of small holes, 1-inch spacing between perforations, so that the steam would be equally distributed in the tank. The perforations were turned toward the bottom of the tank to prevent plugging.

The tank was equipped with a wooden agitator to break the potatoes into a mash after the steam blanching and also to thoroughly disseminate the malt through the mash during the conversion. The agitator shaft, made of oak, was 6 inches square. To this shaft were fastened four sets of oak paddles, 33 inches long, with a cross section 3½ by 6 inches (Fig. 5). The 3½-inch face of the bottom set of paddles was cut down as a propeller to form a good cutting edge and to beat the mash up from the bottom of the tank as the agitator rotated. The 3½-inch face of each of the other three sets of paddles was cut down into a wedge or V shape, to give the paddles a good cutting edge, thereby facilitating the breaking up of the potatoes into the mash.

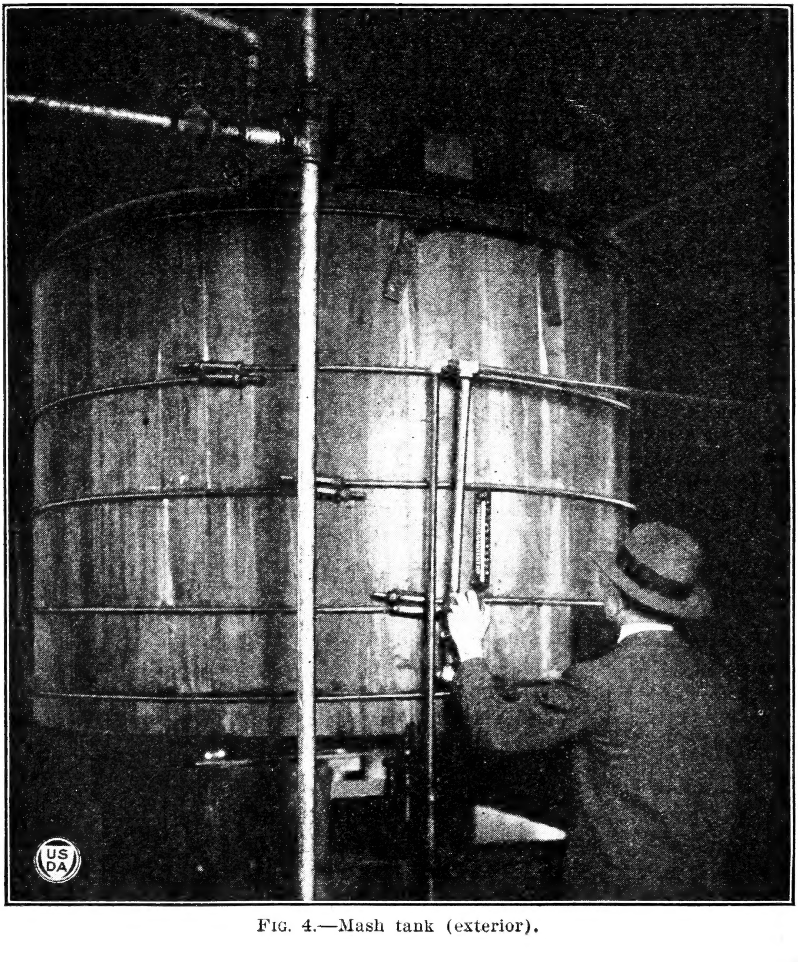


FIG. 4.—Mash tank (exterior).

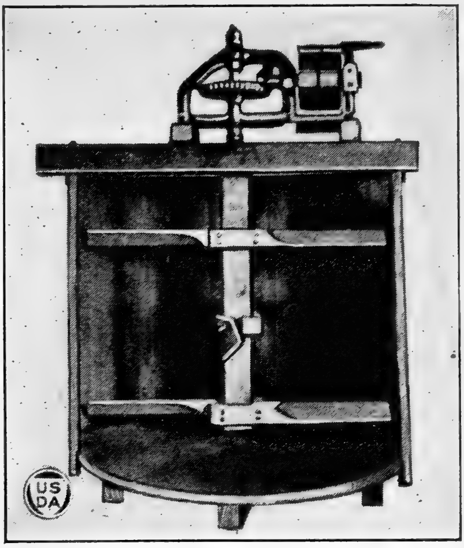


Fig. 5.—Mash tank (cross section).

The agitator was driven by means of a beveled pinion and gear, ratio 1 to 4, giving the agitator a speed of 18 revolutions per minute. Aside from the large starting torque required, this arrangement gave satisfactory service. The potatoes could be broken into a mash within 8 or 10 minutes.

A quick opening, 3-inch valve, fastened to the side of the tank near the bottom, made it possible to draw off the heavy mash rapidly. The tank was fitted with a galvanized-iron cover with hinged doors on either side.

HYDRAULIC PRESS.

The hydraulic press (Fig. 6) used to press the wort from the pomace was of the type employed in the manufacture of grape juice. As originally designed, the press called for the use of 28-inch racks. To meet the demands at Fitzgerald, the pressing area was enlarged to handle racks 48 by 36 inches. With this arrangement, the mash from a 50-bushel batch could be pressed in three hours.

A truck ran on a track from the press to the mash tank. After being loaded with layers of pulp and racks the truck was pushed to the press, where the plunger lifted it against the pressure head, forcing the wort from the pomace. The wort drained into a galvanized-iron catch tank, 6 by 3 feet by 1 foot deep, which was set in between the tracks.

From the catch tank the wort was pumped to an overhead tank, or reservoir, from which it could be drawn as desired into the evaporator.

EVAPORATOR.

A horizontal, continuous open-type evaporator made of maple (Fig. 7) was used in concentrating the wort into sirup. It was 15 feet 8 inches long by 30 inches wide by 12 inches deep. A baffle wall extended from one end down through the middle of the evaporator to within 16 inches of the other end. The inside of the evaporator was lined with 24-gauge galvanized iron. Heat was furnished by two sets of three-fourths-inch copper coils of three pipes each, placed side by side on the bottom of the evaporator. The evaporator required 40 boiler horsepower at 80 pounds gauge pressure. This corresponds to approximately 1,200 pounds of water evaporated per hour. The coils were so installed in the evaporator that the incoming sirup could be heated by the exhaust end of the coils. As the sirup became more concentrated it was heated by hotter steam. In

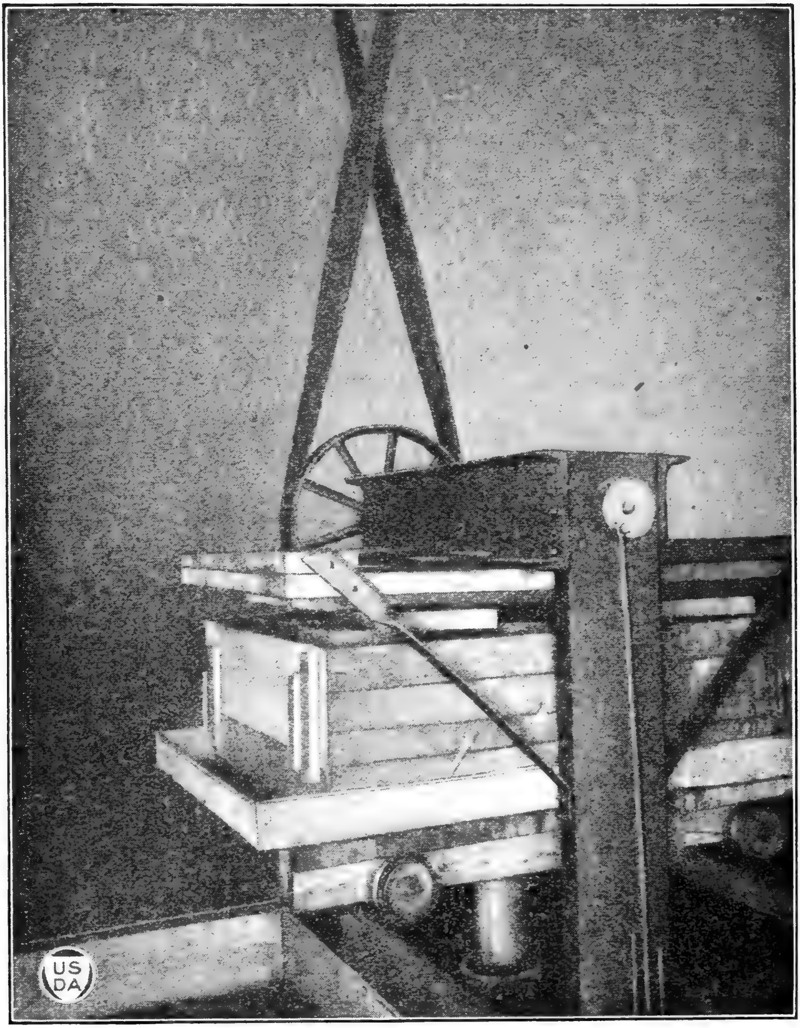


FIG. 6.—Hydraulic press in operation.

other words, the sirup could be heated gradually and reach its highest temperature at the point of discharge.

The steam given off by the sirup during the evaporating operation was conducted to the outside by a large fume pipe, 18 inches in diameter, made of hard pine.

COOLING TANK.

After evaporating the wort into crude sirup it is necessary to allow the product to cool so that certain salts may separate. To cool the sirup a large tank was built of 24-gauge galvanized iron

(Fig. 8). The tank was 5 feet in diameter and 4 feet deep and had a capacity of approximately 550 gallons. The outlet to the filter press was $1\frac{1}{2}$ inches.

The tank, mounted on a platform about 18 inches high, was clamped securely to the platform by four $\frac{1}{2}$-inch iron rods, so shaped as to fit over the top edge of the tank. The tank was also equipped with a mechanical agitator. On the agitator shaft, a steel bar $1\frac{1}{4}$ inches in diameter, were placed four sets of paddles made of 2 by 2 inch oak stock with one face cut down like a propeller to give a good stirring action. Two sets were made to throw the sirup toward the bottom of the tank and two sets were made to throw the sirup upward. In this manner the thrusts set up by the paddles as they came in contact with the sirup neutralized one another. To fasten the paddles to the shaft, a hole $1\frac{3}{16}$ inches in diameter was bored where the two paddles in one set overlapped. The paddles were then placed in position on the shafting and clamped to the shaft by means of four three-eighths-inch bolts.

The agitator was driven by a beveled pinion and gear, ratio 1 to 4, giving the agitator a speed of 22 revolutions per minute.

FILTER PRESS.

After the cooling operation the sirup was filtered in an 18-inch, 18-frame, lug feed, outside delivery, cast-iron filter press (Fig. 8). Twill cloths were used in conjunction with kieselguhr as a filtering medium.

The rectangular catch tank was made of 24-gauge galvanized iron, $6\frac{1}{4}$ feet long by $2\frac{1}{4}$ feet wide by 12 inches deep. The filtered sirup was stored in this tank until it was to be evaporated, when it was pumped to the evaporator.

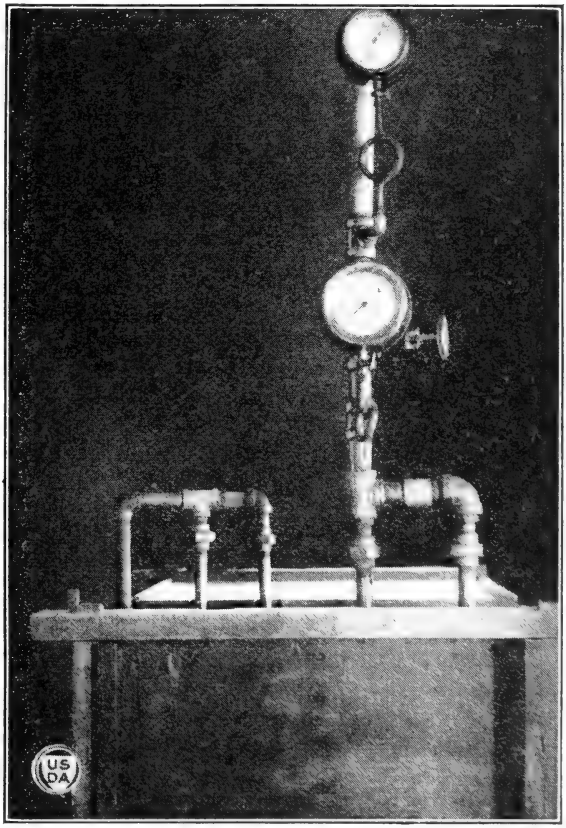


FIG. 7.—Type of evaporator which gave satisfactory results in concentrating the wort and the filtered sirup.

FLAVORING AND BOTTLING KETTLE.

For flavoring the sirup or for putting it in bottles a steam-jacketed copper kettle was used (Fig. 9). As described on page 20, the sirup to be bottled or flavored was carried to and poured into the flavoring and bottling kettle. After it had been heated it was flavored or bottled. The maximum diameter of the kettle was 30 inches, its depth was 24 inches, and its capacity was 50 gallons. It was mounted on an iron stand, bolted to a platform 7½ by 4½ feet by 5½ feet high. The sirup was discharged from the kettle through a 1½-inch outlet, reduced to an inch line. For putting the sirup in cans a half-inch connection was made. For bottling the sirup a series of T-pipe fittings, in which wooden spigots were screwed, was used. The bottles were placed under the spigots.

DRIER FOR POMACE.

For drying the pomace from the pressing operation a plenum chamber drier was constructed (Fig. 10). The air was heated by a set of steam coils inclosed in a wooden housing lined with tin, and was blown into a chamber under the pomace. The heated air passing up through the pomace dried it.

The steam coils for heating the air were made of 1-inch pipe, in sections, each section containing 18.6 square feet of radiating surface. There were 10 sections of coils in the heating unit, giving a total of 186 square feet of radiating surface. With the steam pressure used, the coils heated 1,930 cubic feet of air per minute from 60° to 160° F. The air passed over the coils at a velocity of 360 feet a minute.

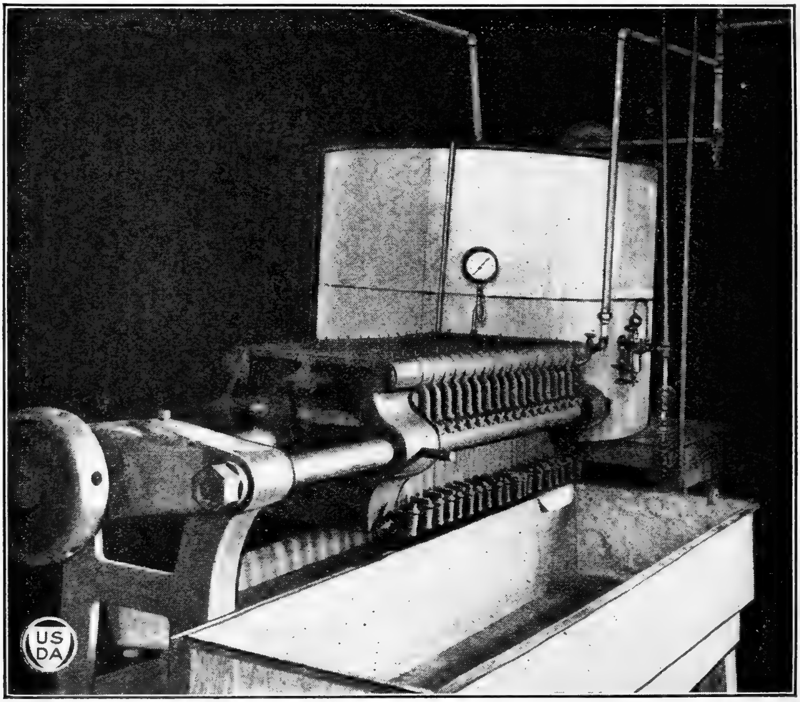


FIG. 8.—Cooling tank and filter press.

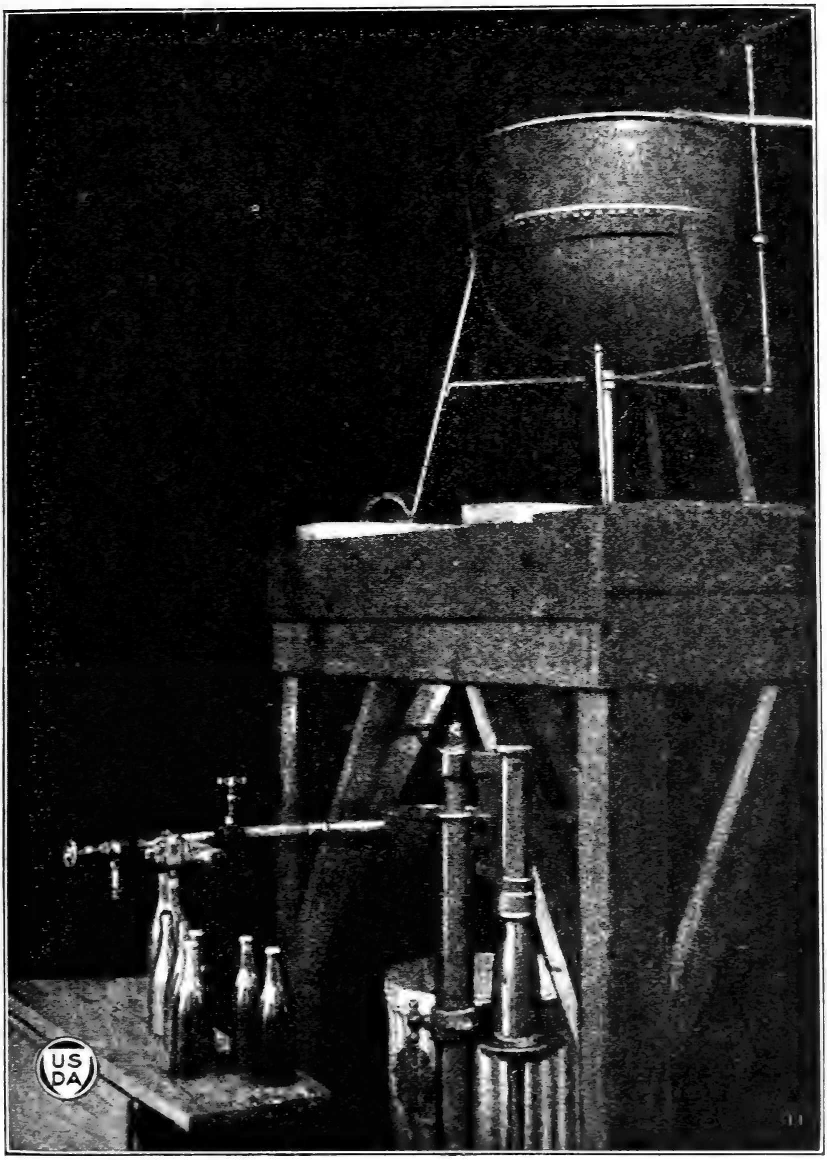


FIG. 9.—Flavoring and bottling kettle.

The coils were so arranged that five sections secured steam from one header line and discharged into one line, while the other five sections were fed by another header and discharged through a separate line. The sections on one header line were alternated with the sections on the other. The sections were also staggered in such a manner as to form baffles to the air as it passed through the heating unit, thus increasing the efficiency of heat transmission. The coils were incased in a housing built of siding, lined with tin. The hous-

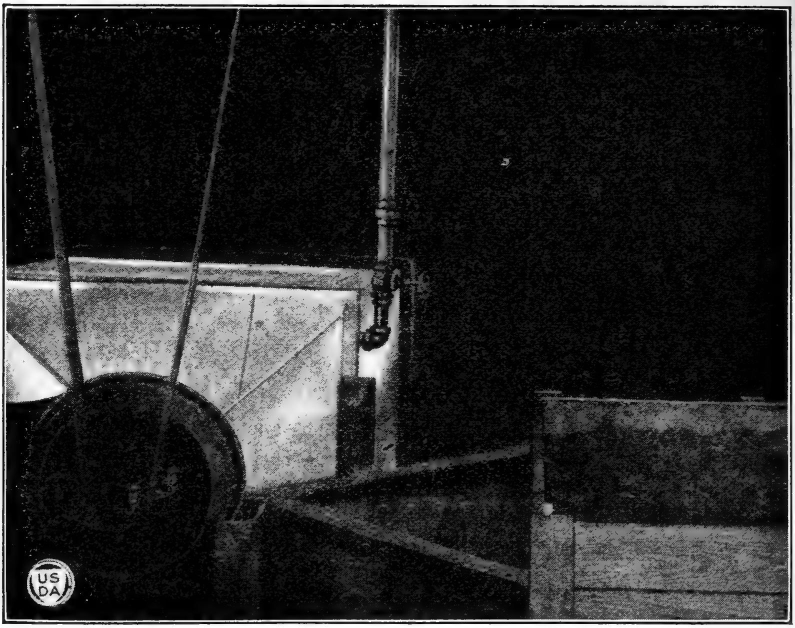


FIG. 10.—Drier used in drying the pomace.

ing was constructed in three parts, two sides and the top, the cement floor forming the bottom. It was built in this way to make it portable. The housing was 3 feet high, 3¾ feet wide, and 5⅔ feet long.

One end of the housing was connected to the eye or intake of a blower fan by means of a rectangular converging section made of 24-gauge galvanized iron. The housing end of the section was 3 by 3¾ feet, and the blower was 9 inches in diameter. The housing end was nailed to the housing, while the blower end was merely slipped over the intake.

The fan, which was a standard make with cast-iron shell and steel plate blades, had a 9-inch intake and a 9-inch exhaust. It had a capacity of 1,930 cubic feet of air at 2,000 revolutions per minute.

The fan discharged the heated air into a chamber under the pomace. This chamber, built of 1-inch Georgia pine and lined with valley tin, was 7¼ feet wide by 8½ feet long inside and 1 foot high. The cement floor of the building formed the bottom of the chamber. The top of the chamber, which made the bed on which the pomace was placed, was constructed by placing 2 by 4 inch boards across the top of the chamber every 2 feet, stretching galvanized iron wire sand screen, 4 meshes to the inch, over them, and laying a covering of burlap over the screen. The chamber bed area was 60 square feet, and the pomace covered it to a depth of approximately 2 inches.

RAW MATERIALS.

The potatoes used at Fitzgerald were of the Porto Rico variety, the only one available. Cured stock taken directly from a storage warehouse was picked over by hand immediately before being used, and all decaying potatoes were removed. Very little decay, only from 1 to 2 per cent, was originally present, and this was almost entirely eliminated as the result of the inspection given.

Pale distillers' malt of high diastatic power was employed. The kieselguhr which served as a filter aid was of California origin. Before being added to the mixing tank it was ignited at a low red heat in cast-iron pans in the fire box of the boiler.

LABOR.

The labor force at the experimental plant, which was entirely adequate, consisted of one mechanic and two laborers. A run of crude sirup was usually made on two consecutive days. The next two days were then required for the finishing of the sirup. Thus in four 10-hour days approximately 140 gallons of finished sirup was produced. By running the apparatus at full capacity approximately 200 gallons of sirup could have been produced, or an average of 50 gallons a day. The mechanic received 40 cents an hour and the two laborers each 20 cents an hour.

The authors acted as the supervising force in directing the operations. In commercial practice a plant superintendent would be necessary.

METHOD OF MANUFACTURE.

A flow diagram of the method of manufacturing sweet-potato sirup (Fig. 11) shows the steps in the operation and the points at which steam and water were used. It also shows how the different materials were handled and at what points they were put into the operation.

WASHING THE POTATOES.

The sweet potatoes were given a visual inspection at the storehouse and all those showing signs of rot were rejected. As the potatoes were inspected they were placed in bushel crates. Upon the completion of the inspection each batch of potatoes was hauled in an auto truck from the storehouse to the washer.

The washed potatoes were placed in bushel crates. The action of the washer wore off the ends of the potatoes, thus effectively removing the withered ends, a possible source of off flavor.

The potatoes were weighed on the platform scales, four crates at a time, and were then carried to the mash tank. Approximately 50 bushels of potatoes to a run or batch were used.

MASHING.

The potatoes were leveled in the tank and the tank covers were closed. Live steam was then admitted at such a rate that gentle streams of vapor passed out between the upper edge of the tank and the covers. The condensate was allowed to drain off as fast as it formed through the gate valve, which was opened slightly for this purpose. This treatment removed from the outer portions of the potatoes certain extractives which if retained impart a dull green color and an off taste to the sirup.[7] One and one-half hours' steam

---

[7] Previous laboratory work (Chemical Age, 29 (1921): 151) had shown that the loss of sweet-potato solids in the condensed water is very small.

cooking was given the potatoes. This softened them so that they could be easily mashed into a uniform pulp by the stirrer, thus breaking down the cells sufficiently to secure a good yield of sirup.

Immediately after cooking, water of the same weight as the potatoes was dumped into the tank and the stock was reduced to a pulp by stirring. With the stirrers still going, the temperature of the mash was raised to 140° F. by running in live steam. The temperature was carefully determined by withdrawing large samples of the mash through the gate valve and testing by thermometer. Readings of the tank thermometers screwed into the sides of the mashing vat were not reliable.[8] When a temperature of 140° F. (the point at which the saccharifying action of malt is most active) had been reached a quantity of ground malt, equivalent to one-fifth of 1 per cent of the weight of potatoes taken, made into a thin mush with cold water, was added. The stirring was continued during the addition of the malt and for a few minutes thereafter so that it would be thoroughly incorporated.

The laboratory work had shown that one-fifth of 1 per cent of malt was sufficient for the conversion of the undigested starch still present after heating the sweet potatoes for 1½ hours, in the case of several standard varieties, including Big Stem Jersey, and that one-tenth of 1 per cent was sufficient for the Porto Rico and Nancy Hall varieties. In the field work one-fifth of 1 per cent was used. Digestion of the starch was complete in from one-half to three-quarters of an hour, the end-point taken being when no color was given when a drop of a portion of the filtered liquid was added to a dilute solution of iodin in potassium iodid. The mash was then ready for pressing.

PRESSING.

In pressing the hot pulp was made up in the form of layers from 2 to 3 inches thick between racks and cloths. The press cloth was just large enough to inclose the pulp completely.

The procedure in laying up the pulp was as follows: The press truck was wheeled under the quick-opening valve of the mash tank and a rack was placed on the pressure platform. On this the form was placed and over it was spread the press cloth, with its edges parallel to the adjacent sides of the form. The center portion of the cloth was then filled with hot pulp so as to fill the form, and the edges of the cloth were folded over, forming the first press cake. The form was then removed, a rack was placed on the press cake, and the form was placed on the rack. Another layer was then built. From 10 to 14 layers constituted a cheese.

When loaded the truck was pushed into the press. Cooked sweet-potato pulp drains so readily that a large proportion of the liquid (technically termed "wort") flowed out of the cheese before the application of any pressure except that caused by the weight of the layers of the cheese. As it flowed off the wort was collected in a galvanized iron tank on the floor between the mash tub and the press, from which

[8] This was due, in part at least, to the effect of the temperature of the tank walls on the armored thermometer bulb. The tank walls were thicker than was anticipated when the thermometers were ordered, and the bulb did not project far enough into the tank to eliminate the influence of the tank-wall temperatures.

it was pumped to the supply tank of the evaporator. The pressure was applied gradually.

In pressing the racks and press cloths tended to slip out of place, owing in part to the lack of guides to make sure that the ram ascended vertically, and in part to the fact that the galvanized wire racks did not maintain their position as well as wooden ones. It is believed that this difficulty could be overcome by the use of wire cloth of coarser weave. It was overcome in the experimental work by placing a series of wooden frames around the cheese as it was being formed. Three frames, with sides from 6 to 8 inches high, were superimposed, fitting one on another, by the use of cleats. During pressing the uppermost, and finally the middle, frame was removed. Three cheeses of 10 to 13 cakes each were required for each 50-bushel lot of potatoes.

After pressing the pomace was shaken out of the cloths, which were then ready to be used again. At the close of each day's work the cloths were washed and hung out on lines in the open air to drain and dry. A batch of 2,500 pounds of potatoes yielded 200 pounds of dried pomace and required 19 hours to dry. The wort received from pressing, collected in the catch tank, was pumped to an overhead tank, which acted as a reservoir, from which it was drawn by gravity to the evaporator as needed.

EVAPORATION TO CRUDE SIRUP.

The wort contained about 15 per cent of solids. It was pale yellow, with a faint, sweet taste. It was evaporated to approximately 60° Brix (cold). The most convenient method for operating the evaporator was to fill it to a mark previously determined by experiment, turn the steam into the coils, and evaporate until the sirup became so thick that a test portion would just begin to fall in blobs or "flake" from the paddle or dipper used in testing. This usually required from 15 to 20 minutes. The steam was then turned off and the sirup was discharged. A new batch of the wort was admitted and the process was repeated. It was expected that the evaporator could be made to operate continuously. This, however, was impracticable, as it was impossible to control the feed and steam supply with sufficient exactness.

The crude hot sirup thus prepared from the potatoes was received in a collecting tank under the evaporator and was later pumped into the cooling tank. Here it was allowed to cool and stand until ready to be converted into finished sirup.

FILTRATION OF CRUDE SIRUP.

The crude sirup is turbid, containing albuminous matter coagulated by the boiling, particles of sweet potato tissue, extraneous matter, and a small proportion of mineral matter of unknown composition which separates upon cooling and standing. After the crude sirup had cooled and stood for about 40 hours, thus allowing time for the salt to separate, it was mixed with enough cold water to dilute it to 45° Brix or below. A quantity of ignited kieselguhr equivalent to 2 per cent of the weight of potatoes taken was first mixed with this water in the catch tank below the evaporator. The same volume

37996°—23——3

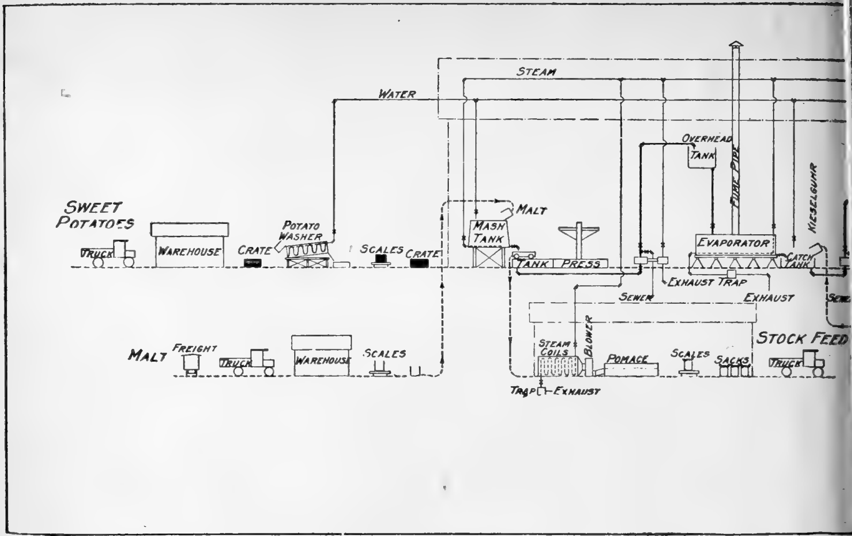


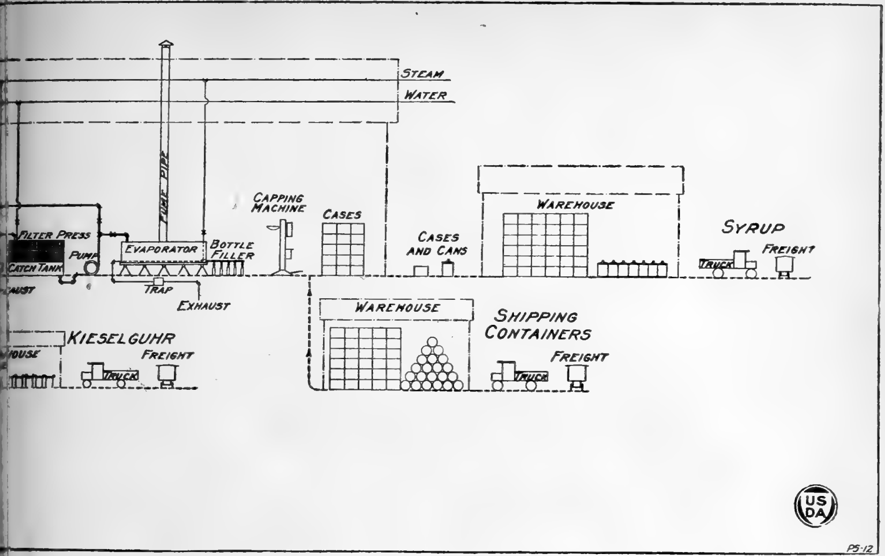
FIG. 11.—Flow diagram for swee

of the crude sirup was then added and thoroughly mixed, and this mixture was pumped into the cooling tank in which the crude sirup was stored. The sirup was then pumped into the filter press. The filtrate was usually clear from the start. A small belt-driven pump was attached to the delivery tank, with valves so arranged that the filtrate could be sent either to the cooling tank or to the evaporator, as desired. The pressure used in filtering was allowed to build up gradually during the filtration to about 25 pounds.

Fifty pounds of kieselguhr proved to be nearly enough to fill the 18 frames of the filter press. The filter cake was washed by pumping cold water in through the feed ports. Laboratory experiments, using a small filter press of the same type, showed that it was practicable to reignite and reuse the kieselguhr. This, however, was not done in the field trials at Fitzgerald.

EVAPORATION OF FILTERED SIRUP.

After being filtered, the sirup was evaporated to the desired density, using the evaporator employed for crude sirup, thoroughly cleaned, of course. As the dilute filtered sirup in boiling foamed more than the crude wort, a special procedure was evolved to overcome this difficulty. Unless the level of the sirup was kept rather low in the evaporator, it had a tendency to foam over every time the freshly filtered sirup was added. When a low sirup level was maintained, however, the steam gauge at the head of the evaporator coils became a convenient guide in indicating when to add a portion of the freshly filtered sirup. As the contents of the evaporator approached the density of the finished sirup, the steam pressure in the coils gradually increased to 40 or 45 pounds. As the stream of filtered sirup was slowly added by means of the pump, this pres-



perimental plant, Fitzgerald, Ga.

sure fell promptly to 30 pounds or less, owing to the greater rate of heat transference from the steam coils to the sirup as it became diluted. When the gauge indicated 30 pounds the supply of fresh sirup was cut off. The pressure was then again gradually built up to 40 or 45 pounds when the operations were repeated, the cycle of operations requiring about 10 minutes. The sirup was discharged at frequent intervals, care being taken, however, never to let the steam coils become exposed to the air.

As in the case of the crude sirup, the approximate concentration at which to stop evaporation was shown by the flaking of a test portion poured from the testing dipper. This procedure gave a sirup more dilute than desirable, the Brix when cold being only about 62.5, so that the flaking indication, although very convenient, is by no means as exact an indicator for the density of the hot sirup as the Brix spindle recommended by Dale[9] and others. The sirup should be concentrated to about 70° Brix (cold).

CANNING AND BOTTLING THE SIRUP.

The finished hot sirup was either allowed to flow from the evaporator directly into the cans or bottles and sealed or it was transferred to a steam-jacketed copper kettle. Here it was reheated to the boiling point and drawn off into cans or bottles. The containers were washed immediately before use and the bottles were heated in hot water before being filled. When filled they were capped with the aid of a foot-power capping machine and placed on their sides to cool, the object being to sterilize the inner surfaces of the seals by keeping them in contact with the hot sirup.

[9] U. S. Dept. Agr. Cir. 149, 1920.

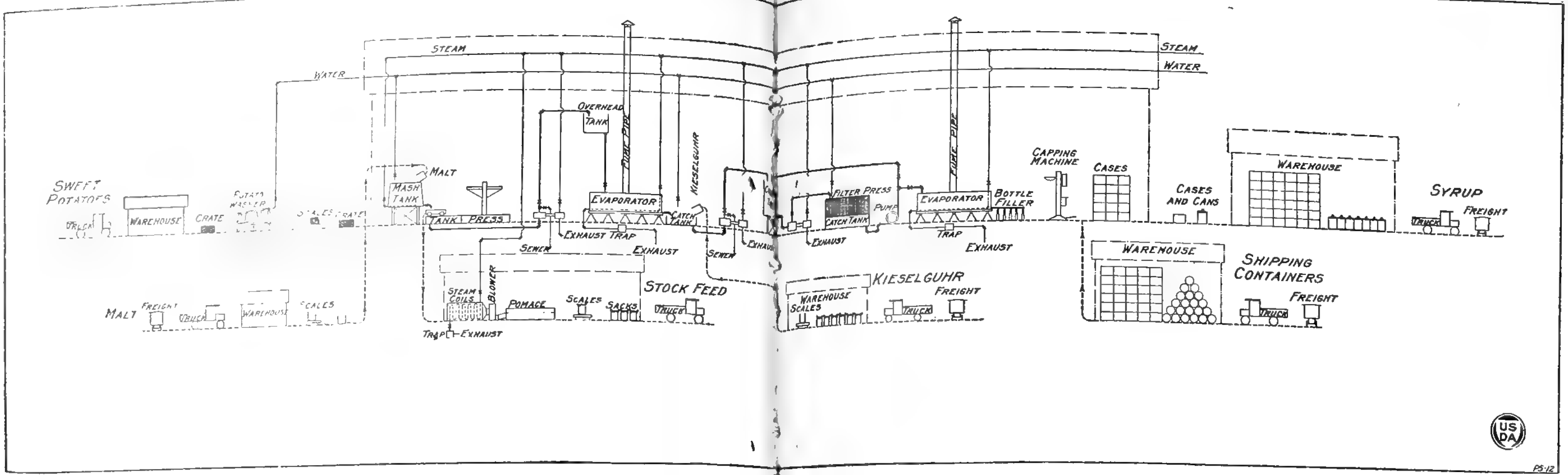


FIG. 11.—Flow diagram for sweet-potato sirup experimental plant, Fitzgerald, Ga.

of the crude sirup was then added and thoroughly mixed, and this mixture was pumped into the cooling tank in which the crude sirup was stored. The sirup was then pumped into the filter press. The filtrate was usually clear from the start. A small belt-driven pump was attached to the delivery tank, with valves so arranged that the filtrate could be sent either to the cooling tank or to the evaporator, as desired. The pressure used in filtering was allowed to build up gradually during the filtration to about 25 pounds.

Fifty pounds of kieselguhr proved to be nearly enough to fill the 18 frames of the filter press. The filter cake was washed by pumping cold water in through the feed ports. Laboratory experiments, using a small filter press of the same type, showed that it was practicable to reignite and reuse the kieselguhr. This, however, was not done in the field trials at Fitzgerald.

EVAPORATION OF FILTERED SIRUP.

After being filtered, the sirup was evaporated to the desired density, using the evaporator employed for crude sirup, thoroughly cleaned, of course. As the dilute filtered sirup in boiling foamed more than the crude wort, a special procedure was evolved to overcome this difficulty. Unless the level of the sirup was kept rather low in the evaporator, it had a tendency to foam over every time the freshly filtered sirup was added. When a low sirup level was maintained, however, the steam gauge at the head of the evaporator coils became a convenient guide in indicating when to add a portion of the freshly filtered sirup. As the contents of the evaporator approached the density of the finished sirup, the steam pressure in the coils gradually increased to 40 or 45 pounds. As the stream of filtered sirup was slowly added by means of the pump, this pressure fell promptly to 30 pounds or less, owing to the greater rate of heat transference from the steam coils to the sirup as it became diluted. When the gauge indicated 30 pounds the supply of fresh sirup was cut off. The pressure was then again gradually built up to 40 or 45 pounds when the operations were repeated, the cycle of operations requiring about 10 minutes. The sirup was discharged at frequent intervals, care being taken, however, never to let the steam coils become exposed to the air.

As in the case of the crude sirup, the approximate concentration at which to stop evaporation was shown by the flaking of a test portion poured from the testing dipper. This procedure gave a sirup more dilute than desirable, the Brix when cold being only about 62.5, so that the flaking indication, although very convenient, is by no means as exact an indicator for the density of the hot sirup as the Brix spindle recommended by Dale[9] and others. The sirup should be concentrated to about 70° Brix (cold).

CANNING AND BOTTLING THE SIRUP.

The finished hot sirup was either allowed to flow from the evaporator directly into the cans or bottles and sealed or it was transferred to a steam-jacketed copper kettle. Here it was reheated to the boiling point and drawn off into cans or bottles. The containers were washed immediately before use and the bottles were heated in hot water before being filled. When filled they were capped with the aid of a foot-power capping machine and placed on their sides to cool, the object being to sterilize the inner surfaces of the seals by keeping them in contact with the hot sirup.

[9] U. S. Dept. Agr. Cir. 149, 1920.

YIELD.

Sweet-potato sirup made in this manner is bland and sweet, with a distinctive flavor. It is not as sweet as cane sirup, cane-sugar sirup, maple sirup, honey, or high-grade molasses. A satisfactory degree of sweetness is secured, however, by mixing 100 parts of the sweet-potato sirup with from 10 to 15 parts of any one of the foregoing sirups. Other flavoring materials, such as imitation maple flavor and vanillin, were less satisfactory for this purpose.

In flavoring various lots of sweet-potato sirup, the freshly-made hot sirup was poured into a steam-jacketed copper kettle, the flavor was added, and the mixture was heated, with stirring, to the boiling point, when it was drawn off into the containers and sealed.

YIELD.

In the six runs made at Fitzgerald during the spring of 1921, in which a total of 8,892 pounds of warehoused Porto Rico potatoes were used, the average yield of crude, unfiltered sirup was 1.55 gallons to each 50-pound bushel of potatoes. This yield was calculated in terms of 72 per cent solids in the sirup. During the first part of 1922 the yield of finished sirup in the final containers on the same basis was 1.37 gallons to each 50-pound bushel of potatoes. As no special pains were taken to secure high yields, this yield no doubt is low. Attention was paid mainly to the production of sirup of uniform high quality. In the practical production of sweet-potato sirup the two most important factors were (*a*) the use of the proper quantity of water in mashing, and (*b*) the technique of the pressing. Water is required to facilitate the mashing of the potatoes into pulp by the action of the stirrer arms and to give the pulp the necessary fluidity so that it will flow from the mash tank and press readily. All things considered, the best quantity is the equivalent of the weight of potatoes taken. For best results, the press cakes should be thin, not more than 3 inches thick when laid up, and should be of uniform thickness. Sufficient time for drainage while under high pressure should be allowed.

PRODUCTION OF SWEET-POTATO SIRUP ON THE COMMERCIAL SCALE.

Although the cost of manufacturing sweet-potato sirup at the experimental plant at Fitzgerald, Ga., was naturally too high for commercial purposes, the data thus obtained formed the basis for estimates on the cost of manufacturing sweet-potato sirup in an improved plant. The proposed plan for a sweet-potato sirup plant makes use of the ideas based on improved practices and on the data and information secured in the experimental semicommercial plant.

The capacity of the proposed plant was set at 100 gallons of plain sweet-potato sirup per 10-hour day, which is the common working day in the sweet-potato sections of the South. A plant of this capacity was taken because in general it would seem to be most practical with the sweet-potato curing house of average size. Sirup plants are probably most practical in connection with sweet-potato curing houses where culls can be utilized for making the sirup.

A normal operating season of eight months may be assumed when a storage house is used. The potatoes begin to be available about August 15 and can be kept in good condition up to April 15, when the rapid rotting caused by high temperatures makes longer storage impracticable. The loss is very small in the early part of the season, but becomes noticeable during the last two months of the period. Under favorable conditions the loss from rotting has been as low as 2 per cent but may, even with normal care, exceed 10 per cent under less favorable circumstances. An operating season of 192 days (8 months of 24 days each) and a shrinkage of 4 per cent have been taken as a basis for the cost calculations.

It is fully realized that the estimated costs for various items will vary with different sections and local conditions. Elaborateness of buildings, possible elimination of the curing house, desired capacity of the plant, and utilization of labor-saving equipment are important considerations.

LAND AND BUILDINGS.

A lot 100 by 200 feet would provide ample space for a plant of the size here discussed. This would allow for the required buildings, for driveways for handling materials and the finished product, and for a railroad siding. It is assumed that the plant would be built in a small town, in which case $1,000 would be a liberal estimate for the cost of the land.

The following buildings are necessary: A sweet-potato storage house, the factory proper, an office, and a boiler and engine house. The size of the buildings can be determined from the plant layout (Fig. 12). The cost of the buildings is determined by the type of construction, which in turn is dependent upon the geographical location of the plant, as well as upon the amount of money which is available. Clearly a plant built in a southern State need not be as substantial as one built in a northern State. Since most of the sweet potatoes are raised in the South, however, the plant was considered as being located in one of the southern States. The type of construction of the buildings would be the same as that described on page 5. The office was taken as being made of weather boarding with a tar-paper roof, the inside of the office finished with ceiling. The approximate cost of such buildings would be:

Potato storage house	$3, 500
Main plant	3, 500
Office	500
Engine and boiler house	900
Total cost	8, 400

LAYOUT FOR PLANT AND APPARATUS.

From the experience and information secured from the experiments conducted at the experimental plant, a plant for the manufacture of sweet-potato sirup was designed. The number and size of the buildings required by a plant of the given capacity may be determined from the layout (Fig. 12). The type and number of pieces of apparatus necessary for the manufacture of the sweet-potato sirup on a commercial scale, as well as the floor space required by the various pieces of equipment and the arrangement of the different pieces in their relation one to another, are shown in Figure 13.

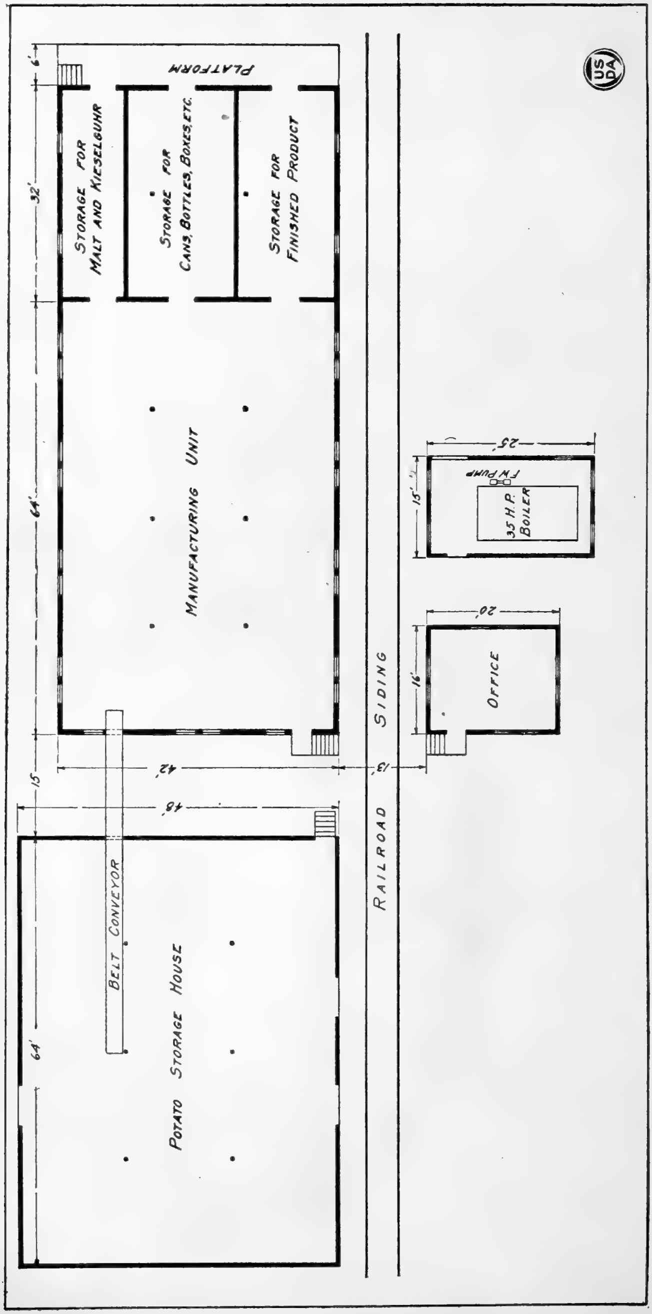


FIG. 12.—Layout for proposed sweet-potato sirup plant.

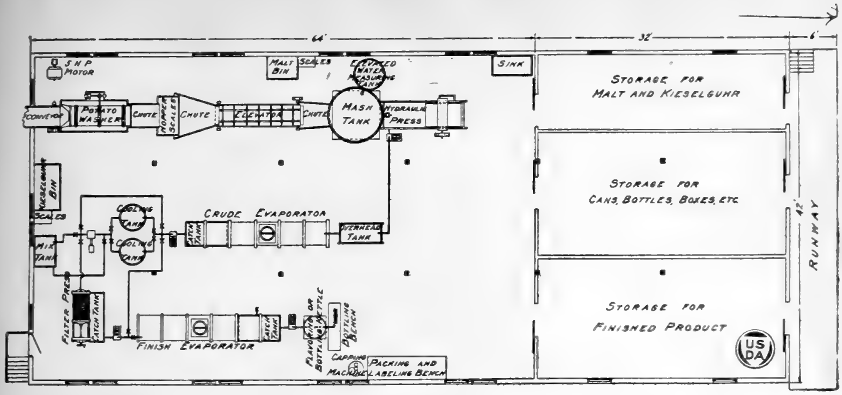


FIG. 13.—Arrangement of equipment in proposed sweet-potato sirup plant.

APPARATUS.

Some of the apparatus used in the proposed plant is of the same size and design as that used in the experimental plant. These are the potato washer, mash tank, hydraulic press, evaporators, filter press, and flavoring kettle (pp. 7–12). Two larger cooling tanks are substituted for the smaller cooling tank, and an additional evaporator is provided for handling the filtered sirup. The following additional apparatus is necessary in the construction of a plant of the capacity of the one proposed:

TABLE 2.—*Additional apparatus in proposed plant.*

Item No.	Number of units.	Kind.	Floor space.	Weight.	Horsepower.	Capacity.	Revolutions per minute of driving pulley.	Unit value.
			Feet.	*Pounds.*				
1	1	Endless belt conveyer.	2½ by 55	550	1	23 feet per minute	15	$170
2	1	Hopper scales	3 by 5	175		20 bushels		200
3	1	Elevator	3 by 10	275	1	104 feet per minute	20	215
4	1	Measuring tank		125				75
5	2	Cooling tanks	7 by 7½	200	¼	225 gallons	90	225
6	1	Mixing tank	3 by 4	40		125 gallons		12
7	1	Evaporator	3½ by 18	1,350		40 boiler horsepower		350
8	1	Boiler	8 by 15		35			500
9	1	Electric motor	1½ by 2	550	5		675	150

ENDLESS BELT CONVEYER.

The endless belt conveyer for carrying the sweet potatoes from the storehouse to the potato washer is a standard type. The belt is 24 inches wide and is approximately 55 feet long. The shape of the supporting idlers gives the belt a concave surface. Power is secured from an electric motor and countershaft. The driving pulley makes 15 revolutions per minute, giving the belt conveyer a speed of 23 feet a minute, using a 6-inch conveyer pulley.

Hopper Scales.

A standard-type beam scale, with a sheet-iron hopper suspended, is used for weighing the potatoes as they come from the potato washer. The hopper is 5 feet long by 3 feet wide by 2 feet deep, which is large enough to weigh 20 bushels, or 1,000 pounds, of potatoes at a time. It is mounted on a pivot.

Elevator.

From the hopper scales the sweet potatoes are dumped into a chute which discharges them into the boot of a standard-type incline elevator, equipped with a few variations to meet the needs in this particular case. The belt, which is 3 feet wide, is equipped with metal buckets that form a sort of pocket in which the potatoes rest and are carried to the top of the mash tank. Here the potatoes are discharged into a chute which dumps them into the mash tank. The elevator is 16 feet between pulley centers. The driving pulley makes 20 revolutions per minute, giving with 20-inch head pulley a belt speed of 104 feet a minute.

Measuring Tank.

After the sweet potatoes have been steam blanched water of the same weight as the potatoes must be added before the mashing operation is started. To facilitate the measuring and handling of the water, an elevated measuring tank is used. The tank is made of 24-gauge galvanized iron and is 4 feet in diameter and 6 feet deep, with a capacity of approximately 4,600 pounds, or 550 gallons, of water. A 1½-inch outlet quickly discharges the water from the measuring tank into the mash tank. The tank can be readily filled by means of a water pipe extending over the top of the tank. The number of pounds of water in the tank at any time may be determined by a float arrangement attached to an indicator which runs on a calibrated scale. The tank is mounted on a platform high enough to permit the water to be discharged into the mash tank by gravity.

Cooling Tanks.

In order to allow the crude sweet-potato sirup to stand for approximately 40 hours and at the same time keep each batch separate, two cooling tanks are required. These tanks are copper-jacketed kettles, 3 feet 2 inches in maximum diameter and 5 feet deep, with a capacity of 225 gallons each. The jackets of the tanks are equipped with steam and water connections for heating or cooling as desired. The sirup can be drawn from the tanks through a 1½-inch outlet.

In order to keep the kieselguhr in suspension during filtration the tanks are equipped with mechanical agitators, which really are propellers mounted at the end of 1½-inch shafts. Each contains three 8-inch blades and is driven by means of beveled gears and pinions. The ratio of the pinions to the gears is 1 to 3. The pinions are driven at 90 revolutions per minute, giving the propellers a speed of 30 revolutions per minute. The kettles or tanks are mounted on steel stands.

MIXING TANK.

It has been found desirable to mix the kieselguhr with water and some crude sirup before mixing it with all the crude sirup to be filtered. For this purpose the mixing tank, rectangular in shape, built of wood, and lined with galvanized iron, is used. This tank is 4 feet long by 3 feet wide by 1½ feet deep and has a capacity of approximately 125 gallons. The outlet is 1½ inches. In order to fill the tank with water a spigot connection extends over the top of the tank, which is calibrated so that the quantity of water needed can be determined accurately.

BOILER.

The boiler for the proposed plant is an approved type of the return tubular boiler. It has a capacity of 35 boiler horsepower. This capacity was taken to give the most efficient operation for a plant of this size and will take care of any peak loads in the plant. The floor space required by the boiler is 8 by 15 feet. The boiler has standard equipment and is designed for 70 pounds gauge pressure operation. The cost of the boiler complete is $500. The feed water pump will cost $200, and $210 is allowed for the boiler setting.

ELECTRIC MOTOR.

A standard type, 10-pole, polyphase alternating current electric motor, with a rated horsepower of 5, furnishes the motive power for the plant. The motor has a speed of 675 revolutions per minute at full load and runs at 110 volts. It weighs 550 pounds and requires an over-all floor space of 2 feet by 18½ inches. The value of the motor complete is $150.

TOTAL COST OF APPARATUS AND EQUIPMENT.

An itemized statement of the cost of all apparatus and equipment necessary for the installation of the proposed plant for the manufacture of sweet-potato sirup is given in Table 3.

TABLE 3.—*Complete cost of installing plant capable of producing 100 gallons of sirup per 10-hour day.*

Equipment.	Cost.	Equipment.	Cost.
Belt conveyer	$170	Pump (cooling tank to filter press)	$200
Potato washer	300	Pump (filter press to evaporator)	67
Hopper scales	200	Pump (evaporator to flavoring kettle)	67
Elevator	215	Scales, tools, trucks, etc	150
Chutes (3)	35	Evaporator catch tanks (2)	25
Mash tank	350	Filter-press catch tank	10
Measuring tank	75	Benches and storage bins	25
Hydraulic press	375	Electric motor, 5-horsepower	150
Overhead tank	15	Boiler, 35 boiler horsepower	500
Evaporators (2)	700	Boiler feed water pump	200
Cooling tanks (2)	450	Boiler setting	210
Mixing tank	12	Piping	150
Filter press	400	Labor in erection	200
Flavoring kettle	125	Belting	50
Capping machine	35	Shafting	150
Pump (hydraulic press to overhead tank)	67		
Pump (evaporator to cooling tank)	67	Total	5,745

MATERIALS.

The same raw materials are used in the manufacture of the sweet-potato sirup in the proposed plant as were used at the experimental plant, namely, sweet potatoes, malt, and kieselguhr. At Fitzgerald No. 1 Porto Rico potatoes were used. In the proposed plant the sirup could be made from culls, the oversized and undersized sweet potatoes, which cost only about 25 cents a bushel,[10] thus greatly reducing one of the main cost items and, in turn, the total cost of production.

The malt and kieselguhr should be the same as those used at Fitzgerald (p. 15).

LABOR.

The following labor layout would be required:

One plant superintendent to supervise operations, handle plant correspondence, look after pay roll, order raw materials as needed, keep record of finished product, make shipments, etc.

One skilled laborer to take charge of plant operation, help with the actual production of the sirup, keep apparatus and equipment in first-class condition, keep plant records, etc.

Three laborers to help with the actual production of the sirup, tend boiler fire, burn kieselguhr, etc.

When it is desired to put the sirup into pint bottles, extra labor is required. To put 100 gallons of sirup into pint bottles, per 10-hour day, three extra men are required.

Since the proposed plant was considered as being located in one of the southern States, the rate of pay prevailing in that section was taken. A superintendent for a plant of this size would probably receive $1,800 a year. The skilled laborer to take charge of plant operations could be secured for $3 a day, and the common laborer could be secured for $1.50 a day. The higher wages which were paid at the experimental plant were necessary because the employment was temporary.

METHOD OF MANUFACTURE.

The method of manufacturing the sweet-potato sirup would be the same as that at Fitzgerald (pp. 15–20). The method of handling the materials, however, has been changed so as to eliminate some of the labor required at the Fitzgerald plant. This is especially true in the handling of the sweet potatoes from the time they are taken from storage and put in the mash tank for steam blanching.

In the proposed plant, the potatoes would be carried to the conveyer belt in the storage house and dumped on the belt which would carry them to the washer. Immediately before the potatoes passed into the washer, two men, one on each side of the belt, would give the potatoes a visual inspection as they passed by. The potatoes showing signs of rot, etc., would be picked off the belt and placed in containers for disposal.

The potatoes would pass through the washer and drop on a chute, which would convey them to the hopper scales. Here the potatoes would be weighed, after which they would be dumped into a second

---

[10] This was the consensus of opinion of sweet-potato growers around Fitzgerald.

chute. The hopper scales are designed to weigh 20 bushels of potatoes at a time. The second chute would conduct the potatoes to the boot of an incline elevator. The elevator would raise the potatoes a little above the top of the mash tank and discharge them into a third chute, which would drop the potatoes in the mash tank. After being leveled, the potatoes would be ready for steam blanching. From this point on the material would be handled in practically the same manner as at Fitzgerald, except in the matter of flavoring or bottling the sirup. At Fitzgerald the sirup to be flavored or bottled was drawn from the evaporator into 5-gallon cans and carried to the flavoring and bottling kettle. In the proposed plant the sirup would be drawn from the evaporator into the evaporator catch tank. From here it would be pumped as needed into the flavoring and bottling kettle. The water to be added to the potatoes after steam blanching would be measured in an elevated measuring tank, and when wanted could be run directly into the mash tank, thus saving time.

The modifications and improvements introduced in the process can be noted by a comparison of the new flow sheet (Fig. 14) with that for the experimental plant process (Fig. 11).

At Fitzgerald experiments were conducted on the drying of the pomace secured from the pressing operation. This pomace was to be used as stock feed after drying. The excessively high cost of drying the pomace, however, made this impractical. In the proposed plant the pomace as it came from the pressing operation would be placed in garbage cans and distributed among the consumers, a method of disposing of the pomace without any expense.

COST OF MANUFACTURE.

The complete cost of manufacturing sweet-potato sirup in a plant of the proposed type, having a capacity of 100 gallons per 10-hour day, has been calculated on the basis of the information secured at Fitzgerald during the experimental runs of 1922. It was assumed that culls would be used in making the sirup and that they would cost 25 cents a bushel. The yield was assumed to be 1.37 gallons of sirup per bushel of sweet potatoes, which was secured in 1922 at Fitzgerald. Operating the plant for manufacturing the sirup in conjunction with another plant would reduce some of the cost, such as that for plant superintendent and office and miscellaneous expenses. Also if a plant of greater capacity were built and operated, the cost per gallon of the finished sirup would be less because of the distribution of some of the fixed charges over a larger number of gallons of the sirup.

The unit prices for the different cost factors are given in the cost estimates. These prices will vary from time to time and with different localities. Therefore it will be necessary for each manufacturer to substitute the prevailing prices in his locality in order to secure cost data adapted to his particular case. However, there should be little difference between his cost figure per gallon and the one given in this bulletin.

The cost of the containers when the sirup is put into 5-gallon cans is 12.2 cents per gallon. The total manufacturing cost of the sirup

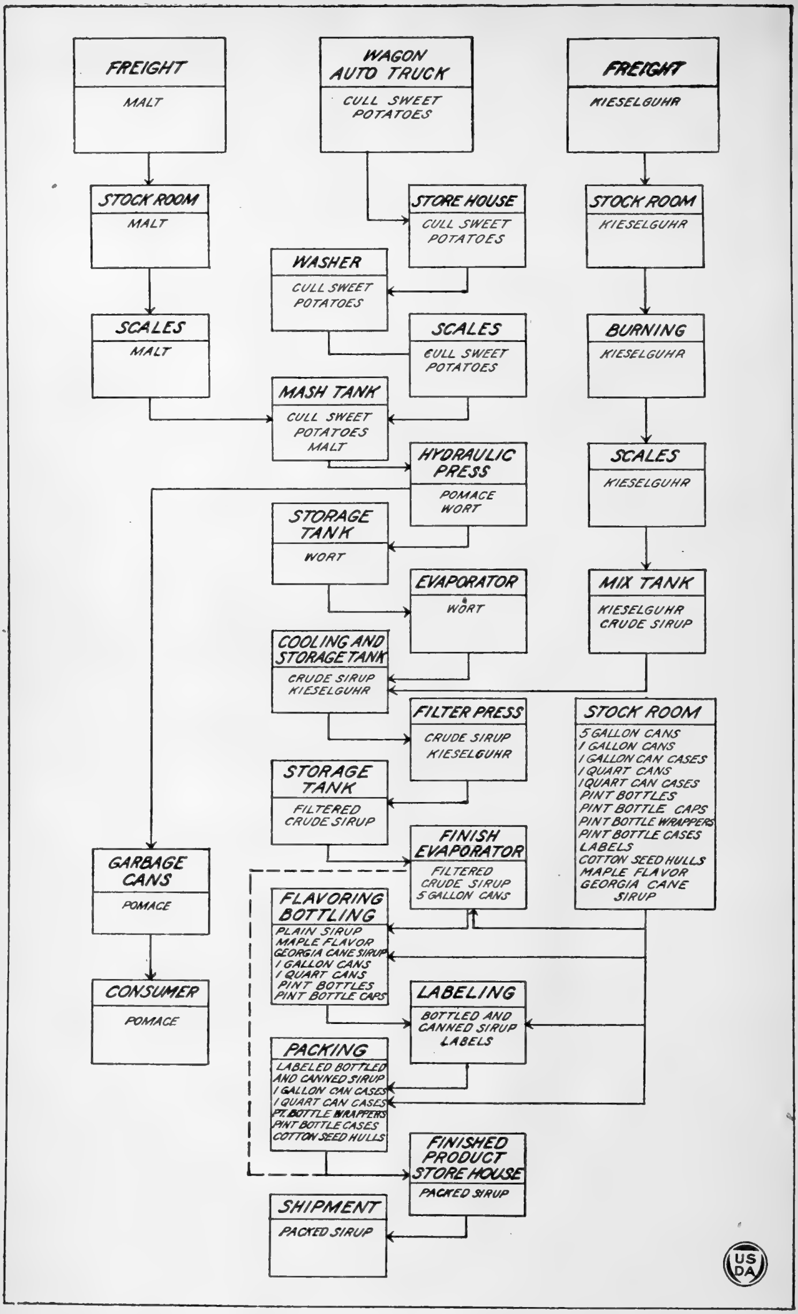


FIG. 14.—Flow diagram for proposed sweet-potato sirup plant.

is 76.5 cents per gallon when put into 5-gallon cans. Thus the cost of the containers forms 15.95 per cent of the total cost, which is rather high. The total cost of manufacturing the plain sweet-potato sirup, exclusive of containers, is 64.3 cents per gallon. Table 4 gives the estimated cost of manufacture per gallon for different kinds of sirup when placed in various types of containers.

TABLE 4.—*Estimated cost of manufacture per gallon of sweet-potato sirup of different flavors in containers of different sizes.*

Type of container.	Cost of—		
	Plain sirup.	Artificial-maple-flavored sirup.	Cane-flavored sirup.
5-gallon can	$0.765	$0.859	$0.751
1-gallon can	.930	1.024	.916
1-quart can	.948	1.042	.934
1-pint bottle	1.318	1.411	1.299

The table shows the total cost of manufacturing the sirup, but includes no cost for selling it. The profitable selling price would be the total cost of manufacture plus the cost of selling plus the profit.[11]

Tables 5, 6, 7, 8, and 9 show the itemized cost of the manufacture of the various kinds of sirups when placed in the different types of containers.

TABLE 5.—*Cost of manufacturing sweet-potato sirup, exclusive of potatoes and containers.*

Cost items.	Cost.		
	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Malt (7.3 pounds at $4.50 per 100 pounds)	$0.33	$0.33	$0.33
Kieselguhr (73 pounds at $4.07 per 100 pounds)	2.98	2.98	2.98
Labor (3 men at $1.50 per day and 1 man at $3 per day)	7.50	7.50	7.50
Plant superintendent ($1,800 per year)	9.38	9.38	9.38
Coal (1,620 pounds at $6.54 per ton)	5.30	5.30	5.30
Light (2.5 kw. hr. at $0.12 per kw. hr.)	.30	.30	.30
Electric power (28 kw. hr. at $0.10 per kw. hr.)	2.80	2.80	2.80
Water (7,000 gallons at $0.25 per 1,000 gallons)	1.75	1.75	1.75
Interest on investment (6 per cent of $15,145=$908.70 per year)	4.73	4.73	4.73
Depreciation on buildings (4 per cent of $8,400=$336 per year)	1.75	1.75	1.75
Insurance on buildings (4 per cent of $8,400=$336 per year)	1.75	1.75	1.75
Depreciation on equipment (8 per cent of $5,745=$459.60 per year)	2.40	2.40	2.40
Insurance on equipment (4 per cent of $5,745=$229.80 per year)	1.20	1.20	1.20
Taxes (1 per cent of $9,400=$94)	.49	.49	.49
Office and miscellaneous expenses	2.00	2.00	2.00
Hauling (6.5 miles at $0.10 per mile)	.65	.65	.65
Artificial maple flavor (100 ounces at $0.0938 per ounce)		9.38	
Georgia cane sirup (11 gallons at $0.50 per gallon)			5.50
Total cost	45.31	54.69	50.81
Cost per gallon	.453	.547	.458

[11] In figuring the cost of manufacture, an item "Interest on investment" which insures a reasonable return on the money invested, is allowed.

TABLE 6.—*Cost of manufacturing sweet-potato sirup, including potatoes, exclusive of containers.*

Cost items.	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Cost of manufacturing sweet-potato sirup, exclusive of potatoes and containers	$45.31	$54.69	$50.81
Potatoes (73 bushels at $0.25 per bushel)	18.25	18.25	18.25
Shrinkage (4 per cent) (3 bushels at $0.25 per bushel)	.75	.75	.75
Total cost	64.31	73.69	69.81
Cost per gallon	.643	.737	.629

TABLE 7.—*Cost of manufacturing sweet-potato sirup in 5-gallon cans.*

Cost items.	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Cost of manufacturing sweet-potato sirup, exclusive of containers	$64.31	$73.69	$69.81
20 5-gallon cans at $0.61 each	12.20	12.20	
22.2 5-gallon cans at $0.61 each			13.54
Total cost	76.51	85.89	83.35
Cost per gallon	.765	.859	.751

TABLE 8.—*Cost of manufacturing sweet-potato sirup in 1-gallon cans.*

Cost items.	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Cost of manufacturing sweet-potato sirup, exclusive of containers	$64.31	$73.69	$69.81
100 1-gallon cans at $0.22 per can	22.00	22.00	
16.67 cases at $0.40 per case	6.67	6.67	
111 1-gallon cans at $0.22 per can			24.42
18.5 cases at $0.40 per case			7.40
Total cost	92.98	102.36	101.63
Cost per gallon	.930	1.024	.916

TABLE 9.—*Cost of manufacturing sweet-potato sirup in 1-quart cans.*

Cost items.	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Cost of manufacturing sweet-potato sirup, exclusive of containers	$64.31	$73.69	$69.81
400 quart cans at $6 per 100	24.00	24.00	
12.5 cases at $0.52 per case	6.50	6.50	
444 quart cans at $6 per 100			26.64
13.88 cases at $0.52 per case			7.22
Total cost	94.81	104.19	103.67
Cost per gallon	.948	1.042	.934

TABLE 10.—*Cost of manufacturing sweet-potato sirup in 1-pint bottles.*

Cost items.	Plain sweet-potato sirup (100 gallons).	Artificial-maple-flavored sweet-potato sirup (100 gallons).	Cane-flavored sweet-potato sirup (111 gallons).
Cost of manufacturing sweet-potato sirup, exclusive of containers	$64.31	$73.69	$69.81
Additional labor (3 men at $1.50 per day)	4.50	4.50	4.50
800 pint bottles at $4.17 per 100	33.36	33.36	
800 caps at $0.35 per 100	2.80	2.80	
800 wrappers at $0.26 per 100	2.08	2.08	
800 labels at $0.165 per 100	1.32	1.32	
66.67 cases at $0.31 each	20.67	20.67	
3.4 sacks of cottonseed hulls at $0.80 per sack	2.72	2.72	
888 pint bottles at $4.17 per 100			37.03
888 caps at $0.35 per 100			3.11
888 wrappers at $0.26 per 100			2.31
888 labels at $0.165 per 100			1.47
74 cases at $0.31 each			22.94
3.77 sacks of cottonseed hulls at $0.80 per sack			3.02
Total cost	131.76	141.14	144.19
Cost per gallon	1.318	1.411	1.299

PRECAUTIONS TO BE OBSERVED.

Although the method used in making sirup from sweet potatoes is simple, the following precautions must be taken to insure the production of sirup of fine quality:

Use pale distillers' malt in the proportion of from one-tenth to one-fifth of 1 per cent of the potatoes taken.[12]

Use washed potatoes, free from decay.

Use kieselguhr as a filter aid.[13]

In cooking, reject the condensed water flowing from the mashing tanks.

Use no wooden equipment in the pores of which potato juice has been allowed to decay.[14]

Clean equipment often enough to avoid all danger of spoilage.

Arrange equipment so that it can be cleaned readily.

Once the operations are started, complete the process without delay.

Avoid letting the sirup thicken or bake on the evaporator[15] coils.

[12] Investigation of the action of the malt showed that to avoid the strong flavors which some kinds of malt impart it was desirable to use a light-colored distillers' malt and to reduce the malt requirement to a minimum. The quantity of commercial pale distillers' malt required was only from one-tenth to one-fifth of 1 per cent of the weight of the potatoes. The principal reason for this very small requirement was that the sweet potato has a very active diastase which digests a large proportion of the starch while the potatoes are being heated.

[13] The laboratory results indicate that in filtering the kieselguhr (diatomaceous earth), used as a filter aid, should be ignited at a low red heat as recommended by Caldwell (U. S. Dept. Agr. Bul. 1025) as a satisfactory method for eliminating the peculiar flavor which the untreated material seems to impart to the sirup. The kieselguhr, if reignited between each use, could be used repeatedly.

[14] The laboratory work also showed the necessity of taking care that the hot wort or sirup never comes in contact with the wooden surfaces of racks, pressure platform, or other equipment, in the pores of which potato juice has been allowed to decay, as such contact is likely to cause contamination in flavor.

[15] The laboratory work showed that color and flavor were injured by allowing the sirup to bake on steam-heated surfaces, this work leading to better evaporating practice.

To produce clear sirup, evaporate crude sirup to 60° Brix or above, let it cool and stand for about 40 hours, then dilute it to 45° Brix with cold water containing kieselguhr, filter, and reevaporate.[16]

GENERAL PROPERTIES OF SWEET-POTATO SIRUP.

Sweet-potato sirup is clear and has an amber color. The taste is sweet, with a slight distinctive flavor and a slight after taste. It is not as sweet as cane sirup, honey, etc., which are characterized by high proportions of sucrose or invert sugar.

COMPOSITION OF SWEET-POTATO SIRUP.

The analysis of a sample of the sirup made at Fitzgerald is given in Table 11.

TABLE 11.—*Chemical composition of sweet-potato sirup.*

Determination.	As analyzed.	Water-free basis.
Solids (by specific gravity) (per cent)	62.50	....
Ash (per cent)	1.02	1.63
Protein (N x 6.25) (per cent) [1]	1.03	1.65
Direct polarization (°V.)	104.7	....
Invert polarization (°V.)	92.2	....
Reducing sugar as invert (per cent) [2]	21.77	....
Reducing sugar as maltose (per cent) [2]	36.23	57.94
Total sugar as invert (per cent) [2]	31.56	....
Sucrose by polarization (per cent)	9.40	14.96
Sucrose by reduction (per cent)	9.30	14.96
Dextrin (per cent) [3]	12.47	19.95

[1] Analysis made in the nitrogen laboratory of the Bureau of Chemistry.
[2] Munson and Walker method. The cuprous oxid on ignition gave over 98.5 per cent of cupric oxid, showing that it was nearly pure.
[3] By fermentation method described in J. Assoc. Official Agr. Chemists, Methods of Analysis (1916), p. 179.

Sweet potatoes contain very little dextrose or levulose, and practically no inversion of the sucrose present occurs during sirup making. For these reasons a much better idea of the composition of the sirup is given by the application of the usual methods of analysis than would otherwise be the case. Thus, this analysis shows that the carbohydrates of the sirup are mostly maltose (57.94 per cent of the sirup solids), dextrin (19.95 per cent of the sirup solids), and sucrose (14.96 per cent of the sirup solids).

COMPOSITION OF SWEET-POTATO POMACE.

The chemical analysis of the dried sweet-potato pomace, determined by the cattle-food laboratory of the Bureau of Chemistry, is given in Table 12.

[16] One of the most difficult problems was the development of a simple method whereby a sirup which would be clear and would remain so on cooling and standing could be produced. The substance which gave most difficulty was a salt of unknown composition which separated out in minute quantities in the finished filtered sirup, thus rendering it turbid. This difficulty could be overcome by concentrating the wort to about 60° Brix and letting it cool and stand for at least 40 hours. During this time enough of the salt separates in the sirup so that by diluting it with cold water to about 45° Brix, filtering, and reevaporating to final density the sirup will remain clear on cooling and standing.

TABLE 12.—*Chemical composition of dried sweet-potato pomace.*

Determination.	Per cent.	Determination.	Per cent.
Moisture	4.59	Protein	23.06
Ash	4.46	Crude fiber	13.50
Ether extract	4.30	Nitrogen-free extract	50.09

This analysis indicates the probable high feed value of this pomace.

SUMMARY.

A method for the commercial manufacture of sweet-potato sirup, based on laboratory and plant experimental work, has been developed by the Bureau of Chemistry. The following important points were brought out in the course of this work:

Conversion of starch is accomplished satisfactorily by using malt equivalent to one-fifth of 1 per cent of the weight of the potatoes, by maintaining a temperature of 140° F., and by allowing the sirup to stand for 45 minutes after the addition of the malt.

The drying of the pomace proved to be uneconomical, although it may have a high value as a feed.

The use of the atmospheric or open-kettle evaporator was practicable in concentrating the crude and filtered sirups.

To produce a permanently clear sirup it was practicable to let the crude sirup cool and stand for 40 hours and then filter it, in order to remove certain salts which caused turbidity.

Satisfactory results were obtained in the filtration of the sirup by using ignited kieselguhr as a filtering aid, 2 per cent of the weight of the potatoes being employed, and filtering cold at 45° Brix.

The yield obtained varied. During the spring of 1921 it was 1.55 gallons of sirup to a 50-pound bushel of potatoes. An average yield of 1.37 gallons of sirup to a 50-pound bushel of potatoes was obtained during the spring of 1922.

Adding 10 per cent of other sirups with a sucrose or invert sugar content increased the sweetness of the experimental sirup.

From the standpoint of quality the sweet-potato sirup has possibilities for use as a table sirup, for cooking purposes, and in the manufacture of colored and short-grain candies, such as taffy, kisses, and caramels. For baking purposes it might find use in dark products, such as ginger snaps. It also has properties suitable for use in blending with other sirups to prevent crystallization.

For the proposed plant of 100 gallons per day capacity the cost of manufacture of plain sweet-potato sirup, exclusive of containers, is estimated to be 64.3 cents per gallon.

The commercial possibilities of sweet-potato sirup are limited by the high cost of manufacture under the present method.

ORGANIZATION OF THE U. S. DEPARTMENT OF AGRICULTURE.

Secretary of Agriculture	HENRY C. WALLACE.
Assistant Secretary	C. W. PUGSLEY.
Director of Scientific Work	E. D. BALL.
Director of Regulatory Work	
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	HENRY C. TAYLOR, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	WALTER G. CAMPBELL, *Acting Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Division of Accounts and Disbursements	A. ZAPPONE, *Chief.*
Division of Publications	EDWIN C. POWELL, *Acting Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
States Relations Service	A. C. TRUE, *Director.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration *Grain Future Trading Act Administration*	CHESTER MORRILL, *Assistant to the Secretary.*
Office of the Solicitor	R. W. WILLIAMS, *Solicitor.*

This bulletin is a contribution from—

Bureau of Chemistry	WALTER G. CAMPBELL, *Acting Chief.*
Fruit and Vegetable Utilization Laboratory	H. C. GORE, *in charge.*
Office of Development Work	D. J. PRICE, *in charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

PURCHASER AGREES NOT TO RESELL OR DISTRIBUTE THIS
COPY FOR PROFIT.—PUB. RES. 57, APPROVED MAY 11, 1922

∇