that the action of the water shall be uniform. This operation should last about two and one half hours. The vat should be then covered and left to stand from three-quarters to one hour for saccharification.

Another method of saccharifying is to turn boiling water gradually into the mash tank until the mixture has acquired a temperature of from 140° to 180° F. The mass is thoroughly stirred, and the tub is covered and left to subside for from two to four hours, during which time the temperature should not be allowed to fall below 120° F. A small tub needs more heat than a larger tub, and more heat is required in winter than in summer.

A convenient method of regulating the temperature of the mash tank, would be by a coil of pipes on the bottom. This would be connected by a two-way cock to a steam boiler and to a source of cold water. Heat should never be carried over 180° F., and the best temperature is from 145° to 165° F.

The greatest effect of the diastase of the malt upon the gelatinized starch is at 131° F. For ungelatinized starch this is not great enough, hence the greater part of the mashing is carried on at the lower temperature and only towards the end should the temperature be raised to the maximum 150° F.

Every distiller uses his own judgment as to the amount of the mashing water used, its temperature,
the length of time during which the mash rests, and the length of time for saccharification.

Saccharification may be recognized by the following signs: The mash loses its first white mealy look, and changes to dark brown. It also becomes thin and easily stirred. The taste is sweet and its odor is like that of fresh bread.

Corn and other grain may be mashed conveniently in such an apparatus as that described on page 10, as used for potatoes the steam being introduced under pressure.

The water is first placed in the steamer. Steam is introduced into the water and it is brought to a boil. The corn is then introduced gradually, the steam pressure increased to its maximum, and the mass blown out as described in Chapter VII. Hellefreund's apparatus (see page 118) may also be used with ground corn.

The corn or grain not previously crushed or ground is introduced into a steamer in the proportion of 200 lbs. of corn to 40 gallons of water. The steamer should have about 100 gallons of steam space for this amount.

The mashes described above are thick, more or less troublesome to distil, and only simple stills can be used. By the following method a clear saccharine fluid or wort can be obtained.

A mash vat is used having a double bottom. The upper bottom is perforated and between the two bottoms is a draw-off pipe and a pipe for the inlet of water.
Upon the upper perforated bottom is first placed a layer of between two and three pounds of chaff. Upon this is turned in a mixture of 400 lbs. corn and malt in the proportions of \( \frac{1}{4} \) malt to \( \frac{1}{4} \) grain. Eighty-seven gallons of water at a temperature of from 85° to 105° F. is then let in to the bottom, while the mixture is thoroughly agitated for 10 minutes. It is then left to subside for half an hour.

After this steeping process, the mass is again agitated while 175 gallons of water at 190° F. are let into the tub while the mass is continually and thoroughly stirred by mechanical stirrers. Brewing lasts for half an hour, and the liquid is then left to stand for seven hours.

At the end of this period the grain is covered by clear liquid which is drained off through the draw-off cock into the fermenting back.

To the contents left in the steeping tank 135 gallons of boiling water are added as before and the liquid therefrom drawn into the fermenting back.

It usually requires three infusions to extract the whole of the saccharine and fermentiscible matters contained in the grain. In some places, it is customary to boil down the liquors from the three mashings until they have acquired a specific gravity of about 1.05, the liquor from a fourth mashing being used to bring the whole to the correct degree for fermentation, the liquors from the third and fourth being boiled down to the
same density and then added to the rest. In a large Glasgow distillery, the charge for the mash tubs is 29,120 lbs. of grain together with the proper proportion of malt. Two mashings are employed, about 28,300 gallons of water being required; the first mashing has a temperature of 140° F., and the second that of 176° F. In Dublin the proportion of malt employed is only about one-eighth of the entire charge. One mashing is employed, and the temperature of the water is kept at about 143° F. The subsequent mashings are kept for the next day’s brewing.

By this process the grain is entirely deprived of all fermentible substances which have been carried away in a state of liquid sugar.

The whole operation of preparing and saccharifying grain is to-day carried on in steamers, such as described on page 11, and cooking apparatus such as shown in Fig. 1, or in the Henze high pressure steamers and preparatory mash vats described in Chapter II.

In steaming grain without pressure, the finely crushed grain is poured slowly into a vat previously nearly filled with water at a temperature of about 140 degrees F. A little less than half a gallon of water is used for each pound of grain. Care must be taken to stir the mass constantly to prevent lumping. When all the corn is mixed in, steam is allowed to enter and the temperature raised to about 200 degrees F. It should be left at this temperature for an hour, or an hour and a
half, when the temperature is reduced to 140° F. when about 10 per cent. of crushed malt is added and the temperature reduced to 68° F. by means of suitable cooling devices.

When steam cookers are used, the cylindrical boiler is first filled to the proper degree with water at a temperature of 140° F. The meal is then let in gradually being constantly stirred the while. The boiler is then closed and steam gradually let in while the mass is stirred until a pressure of 60 pounds and a temperature of 300° F. has been reached. The starch then becomes entirely gelatinized, the pressure is relieved, and the temperature reduced to 212° F. and then rapidly brought to 145° F. The malt is added mixed with cold water, at such a stage before the saccharifying temperature is reached that the cold malt and water will bring it to 145° F. The malt is stirred and mixed with the mash for five or ten minutes and the mixed mass let into a drop tub when saccharification is completed. It is then cooled as described.

When the Henze steamers are used the grain may be treated in either the whole grain or crushed, as the high pressure to which it is subjected and the "blowing out" act to entirely disintegrate it. In this mode of operation, water is first let into the steamer and brought to a boil by the admission of steam. The grain is then slowly let into the apparatus. The water and grain should fill the steamer about two thirds full. The steamer is
left open and steam circulated through the grain and water for about an hour, but without any raising of pressure. This acts to thoroughly cook and soften the grain.

When sufficiently softened the steam escape cock in the upper part of the steamer (see Fig. 2) is regulated to allow a partial flow of steam through it and a greater flow of steam is admitted though the lower inlet. This keeps the grain in constant ebullition under a pressure of 30 lbs. or so. After another period of an hour the pressure in the steamer is raised to 60 lbs. at which point it is kept for half an hour, when the maximum steam pressure is applied, and the greater portion of the disintegrated mass blown out into a preparatory mass tub, into which malt has been placed mixed with water. The blowing out should be so performed that the temperature in the mass in the tubs shall not exceed 130° F. The mass is stirred and cooled and then the remainder of the mass in the steamer admitted to the tub which should bring the temperature of the mass up to 145° F. It is kept at this temperature for a period varying from half an hour to one and one-half hours and is then cooled to the proper fermenting temperature.

Another method of softening corn so that its starch is easily acted upon by the diastase of the malt is to steep it in a sulphurous acid solution at a temperature of about 120° F. for from fifteen to twenty hours. The mass is then diluted to form a semi-liquid pulp and heated to about
190° F. for an hour or two during which the mass is constantly stirred. The malt is then added, the mass is saccharified, cooled and then fermented.

Another method is to place mixed grain and hot water in a cooker of the Bohn variety (Fig. 45). After half an hour of stirring and cooking under ordinary pressure, the steam pressure is raised to 45 lbs. This is kept up for from two to three hours when the grain is reduced to a paste. Concentrated muriatic acid equal to 2½ per cent of the weight of grain is then forced in, under steam pressure. In half an hour the grain will be entirely saccharified and ready for fermenting.
CHAPTER IX.

ALCOHOL FROM BETES.

Cultivation. The beetroot (*Beta vulgaris*), indigenous to Europe, is cultivated in France, Germany, Belgium, Holland, Scandinavia, Austria, Russia, and to a very small extent in England and New Zealand, and to a very large extent in the United States and Canada. There are many varieties. The most important to the sugar-maker is the white Silesian, sometimes regarded as a distinct species (*B. alba*); it shows very little above ground, and penetrates about 12 in.; it has a white flesh, the two chief forms being distinguished by one having a rose-colored skin and purple-ribbed leaves, the other a white skin and green leaves. Both are frequently grown together, and exhibit no marked difference in sugar-yielding qualities.

Good sugar-beets possess the following broad characteristics: (1) Regular pear-shaped form and smooth skin; long, tapering, carrot-like roots are considered inferior; (2) white and firm flesh, delicate and uniform structure, and clean sugary flavor; thick-skinned roots are spongy and watery; those with large leaves are generally richer; (3) average weight 1½ to 2½ lbs., neither very large
nor very small roots being profitable to the sugar-manufacturer; as a rule, beets weighing more than 3½ lbs. are watery, and poor in sugar; and roots weighing less than ¼ lb. are either unripe or too woody, and in either case yield comparatively little sugar; the sp. gr. of the expressed juice, usually 1.06 to 1.07, even reaching 1.078 in English-grown roots, indicating over 14 per cent. of crystallizable sugar, is the best proof of quality; juice poor in sugar has a density below 1.060; (4) in well-cultivated soil, the roots grow entirely in the ground, and throw up leaves of moderate size.

**Composition of the Roots.** Internally the root is built up of small cells, each filled with a juice consisting of a watery solution of many bodies besides sugar. These include several crystallized salts (mostly of which are present in minute traces only), such as the phosphates, oxalates, malates, and chlorides of potassium, sodium, and calcium, the salts of potash being by far the most important; and several colloid bodies (albuminous [nitrogenous] and pectinous compounds); as well as a substance which rapidly blackens on exposure to the air. The greater part of the sugar in ripe beets is crystallizable, and, when perfectly pure, is identical in composition and properties with crystallized cane-sugar; but it is more difficult to refine this sugar so as to free it from the potash salts, and commercial samples have not nearly so great sweetening power as ordinary cane-sugar.
Beets contain no uncrystallizable sugar; the molasses produced in beet-sugar manufactories is the result of changes which cannot be entirely avoided in extracting the crystallizable sugar.

**Soil.** The best soil for beets contains a fair proportion of organic matter, is neither too stiff nor too light, and crumbles down into a nice friable loam; it must be capable of being cultivated to a depth of at least 16 in. The subsoil should be thoroughly well drained, and rendered friable by autumn-cultivation and free admission of air. A deep friable turnip-loam, containing fair proportions of clay and lime, appears to be the most eligible land for sugar-beets. Lime is a very desirable element. Well-worked clay-soils, especially calcareous clays, are well adapted, if properly drained and of sufficient depth. Peaty soils and moorlands are quite unsuitable, as well as lands which are too dry, like the thin gravelly soils resting on siliceous gravel sub-soils, or too wet and cold, like many of the thin soils above impervious chalk marl.

Speaking generally, the best soils for sugar-beet are precisely those on which other root-crops can be grown to perfection, that is, land which is neither too heavy nor too light, which has a good depth, is readily penetrated by the roots, and naturally contains lime, potash, clay, and sand, as well as organic matter, is such proportions as in good friable clay-loams. An analysis of the soil
should be made previous to planting it with the sugar-beet, as the salts presented in solution in the soil will pass into the juice, and greatly interfere with the processes of sugar manufacture. Certain soils may be at once indicated as unsuitable; they are clover-land, recent sheep-pastures, forest-land grubbed during the preceding 15 years, the neighborhood of salt works, volcanic and saline soils of all kinds. The beet requires a certain supply of potash and soda salts in the soil, but if these are present in excess, as in recent forest-land, the juice does not work well, nor give its proper yield of sugar.

**Manures.** Sugar-beets should be grown with as little farmyard manure as possible; when dung has to be used, as in the case of very poor soils, it should be applied in autumn, or as early as possible during the winter months. The effect of heavy dressings of animal nitrogenous matters or ammoniacal salts, is to produce abundance of leaves, and big watery roots; the latter are comparatively poor in sugar, and contain potash salts derived from the animal matters, which greatly interfere with the extraction of sugar in a crystalized state. Common salt, and saline manures in general, though useful in moderate doses (224 lbs. to 336 lbs. per acre on light soils), should be avoided on the majority of soils, for sugar-beets grown on soils highly manured with common salt produce juice largely impregnated with salt, which is
dreaded by the manufacturer even more than albuminous impurities, and nearly as much as excess of potash salts.

If the land is in good condition, containing sufficient available nitrogen to meet the requirements of the crop, neither guano nor sulphate of ammonia should be used. They largely increase the weight of the produce per acre; but heavy crops are generally poor in sugar, and furnish a juice that presents much difficulty to the manufacturer. If the land is very poor, and if farmyard manure cannot be obtained and be applied in autumn, 336 to 448 lbs. of Peruvian guano, or 224 lbs. of sulphate of ammonia, mixed with 224 lbs. of superphosphate of lime, per acre, may be sown broadcast in autumn, and 224 lbs. more of superphosphate may be drilled in with the seed in spring. Superphosphate of lime and bones are excellent for sugar-beets, and never injure the quality of the crop, like the indiscriminate use of ammoniacal manures. On light soils, in which potash is often deficient, the judicious use of potash salts has been found serviceable, but only in conjunction with superphosphate and phosphatic guanos.

Sowing. The best time for sowing beetroot is the beginning or middle of April. If sown too early, the young plants may be partially injured by frost; if later than the first week in May, the crop may require to be taken up in autumn, before it
has had time to get ripe. About 10 to 12 lbs. of seed is required per acre. As regards the width between the plants, generally speaking, the distance between the rows and from plant to plant should not be less than 12 nor greater than 18 in. Should the young plants be caught by a night's frost, and suffer ever so little, it is best to plough them up at once and re-sow, for they are certain to run to seed, and are then practically useless for the manufacture of sugar. Sugar-beets require to be frequently horse- and hand-hoed. As long as the young plants are not injured, the application of the hoe from time to time is attended with great benefit to the crop. It is advisable to gather up the soil round each plant, in order that the head may be completely covered with soil. Champenois' researches point to the advantage of planting in ridges, by which the supply of air to the roots is greatly facilitated.

The conditions best calculated to ensure the roots possessing the characters most desirable from a sugar-maker's point of view are chiefly as follows: (1) Not to sow on freshly-manured land; it is eminently preferable not to manure for the beet crop, but to manure heavily for wheat in the preceding year; (2) not to employ forcing manures, nor to apply manure during growth; (3) to use seed from a variety rich in sugar; (4) to sow early, in lines 16 in. apart, at most, the plants being 10 to 11 in. from each other; there will then be 38,000 beets on an acre, weighing 21 to 28 ounces
each, or 52,800 to 70,400 lbs. per acre; (5) to weed the fields as soon as the plants are above ground, to thin out as early as possible, and to weed and hoe often, till the soil is covered with the leaves of the plants; (6) never to remove the leaves during growth; (7) finally, not to take up the roots, if it can be avoided, before they are ripe, the period of which will depend upon the season.

Good seed may be raised by the following means: The best roots, which show least above ground, are taken up, replanted in good soil, and allowed to run to seed. This seed is already good; but it may be further improved by sowing it in a well-prepared plot possessing all the most favorable conditions; the resulting plants are sorted, set out in autumn, put into a cellar, and in the spring, before transplanting, those of the greatest density, and which will give seeds of the best quality, are separated. These are transplanted at 20 in. between the rows and 13 in. between the feet, which are covered with about 1½ in. of earth. Finally they are watered with water containing molasses and superphosphate of lime, as recommended by Corenwinder.

**Harvesting.** Sugar-beets must be taken up before frost sets in. When the leaves begin to turn yellow and flabby, they have arrived at maturity, and the crop should be watched, that it may not get over-ripe. If the autumn is cold and dry, the crop may be safely left in the ground for seven to
ten days longer than is needful, but should the autumn be mild and wet, if the roots are left in the soil, they are apt to throw up fresh leaves, and nothing does so much injury. In watching the ripening of the crop, a good plan is to test the sp. gr. of the expressed juice. A root or two may be taken up at intervals, and reduced to pulp on an ordinary hand-grater, the juice obtained by pressing the pulp through calico, and the density observed by a hydrometer. As long as the gravity of the juice continues to increase, the crop should be left in the land. Good sugar-yielding juice has a sp. gr. of about 1.065, rising to about 1.070. Immature roots, cut across, rapidly change color on the exposed surface, turning red, then brown, and finally almost black. If newly-cut slices turn color on exposure, the ripening is not complete; but if they remain some time unaltered, or turn only slightly reddish, they are sufficiently ripe to be taken up. The crop should be harvested in fine, dry weather. In order that the roots may part with as much moisture as possible, they are left exposed to the air on the ground before being stacked, but not for longer than a few days, and they need to be guarded against direct sunlight. Perhaps the best plan is to cover them loosely with their tops in the field for a couple of days, then trim them, and at once stack them.

**Storing.** For storing roots, especial care should be taken to prevent their germinating and throwing
out fresh tops, which is best done by selecting a dry place for the storage ground. They may be piled in pyramidal stacks, about six feet broad at base, and seven feet high. At first, the stacks should be thinly covered with earth, that the moisture may readily evaporate; subsequently, when frosty weather sets in, another layer of earth, not exceeding one foot in thickness, may be added. This is essentially the method generally adopted for storing potatoes and beets.

In continental Europe and Canada, extra pre-

![Fig. 46.—Stack for Storing Beets.](image)

cautions are necessitated by the rigorous climate. In S. Russia, the plan shown in Fig. 46 is sometimes used. The beets are disposed completely below the surface of the soil, in a trench dug with sharply sloping sides. At about 15 in. from the bottom, is an openwork floor of reeds, on which the beets are piled to within a few inches of the level of the exterior soil. On the top, and following the apex of the heap, is laid a triangular ridge-piece \(a\), for the purpose of facilitating evaporation. The whole is covered with a layer \(b\) of straw and
fine earth, the thickness of which is varied according to the indications of the thermometer placed in the center of the mass. Between the floor of the trench and the openwork floor is a space communicating with two vertical channels leading to the outer air, thus providing ventilation. The outlets of the channels can be opened and closed at will. The Russians also often employ regular cellars, as shown in Fig. 47. The structure consists of two stories, covered with a bed of earth, each furnished with a floor of hurdles or open planking, on which the beets are piled to the depth of about one yard. Lateral passages facilitate ventilation, and openings in the roof permit the heated air to escape. The cost of erecting these cellars is heavy, but there is great saving of labor in storing the beets, as it suffices to simply pile them up on the floors. Moreover, the arrangement permits the examination of the contents beyond
the indications of a thermometer; and enables any portion to be removed, even during snowy weather.

**Alcohol from Beets.** Beets contain 85 per cent. of water, and about 10 per cent. of cane sugar, the remainder being woody fibre and albumen; cane sugar not being in itself fermentible,—as is grape sugar,—it has to be converted into "inverted sugar" by a ferment as yeast. Either the sugar beets may be mashed or the molasses which remains from the manufacture of beet sugar (as described in Chapter X). The conversion of the sugar into alcohol is effected in several different ways, of which the following are the principal:

By rasping the roots and submitting them to pressure, and fermenting the expressed juice.

By maceration with water and heat.

By direct distillation of the roots.

The first two methods are the best as by them the woody fibre of the plant which is non-fermentible is separated from the fermentible juice. In both the first and second processes the beets must first be entirely cleaned of adhering dirt, trash and clods of earth, and then rasped, pulped or sliced by certain machinery.

**Cleaning.** Care must be taken in this operation that the beets shall be freed from small stones and adhering hard lumps of earth which would otherwise get into the rasping machinery to the damage and stoppage of the mechanism.
ALCOHOL FROM BEETS.

There are many forms of cleaners but all are alike in this,—that the beets shall be subjected to the action of water while traveling through or over a perforated casing. The simplest machine, and one easily constructed by any carpenter, comprises an elongated cylinder formed of lathes or strips spaced apart such distance as will allow dirt and stones to pass between them. This is mounted on a central shaft and revolves in a tank of water. It should be slightly inclined so that the potatoes or beets to be washed may feed downward from the open upper end-disk or wheel, to the lower end where they are thrown out. At the upper end is a hopper and at the lower, the end disk has inwardly projecting lips, which as the cylinder revolves lifts the beets up and tumbles them out on to an incline which carries them to the rasping machine.

Another form of machine comprises a perforated cylinder of sheet iron, revolving in a tank of water. A better form of cleaner than either of those consists of an inclined trough in which a spiral feeding screw of sheet iron rotates. The beets are fed into the trough at its lower end and are carried upward, slowly, by the feeding screw. Above the trough is a water pipe having a number of outlets by which water may fall on to the beets and into the trough. The water rushing down the inclined trough carries with it all dirt and stones, and by the time the beets have reached the upper end they are entirely cleaned and ready for slicing or rasping.
For pressing out the juice, the beets are mashed into a pulp, while for diffusion the beets are sliced.

**Rasing.** Fig. 48 shows one form of rasping machine. On a suitable supporting frame is mounted a cylinder $a$ having a diameter of about 24 inches. The cylinder is formed of alternate saw blades and wooden washers holding them a slight distance apart. The saws or teeth are so set on the cylinder as not to slice the beets but to shred them up into a fine pulp. The cylinder rotates at a speed of 800 to 1000 revolutions a minute in front of an inclined table, having a jigger whereby the beets are fed downward against the toothed cylinder. The teeth carry the pulp downward and it falls into a receptacle beneath.

It is best to add to this pulp a small portion of sulphuric acid, say two-tenths of one per cent. This prevents by-fermentations.
Pressing. The pulp obtained from the rasper has now to be expressed. This is either done by platen presses or by roller presses. With platen presses the first pressing may be done by screws, but the final pressing should be accomplished by hydraulic presses.

For the hydraulic press, the pulp is placed in woolen sacks, containing 10 to 12 lbs., superposed in the press with their mouths doubled under, and separated by iron plates; about 25 are collected, and the pile is put into a screw-press, called a "preparatory" press, which extracts about 45 to 50 per cent. of the juice. These pressed sacks are piled anew on the movable plate of a powerful hydraulic press, which takes 50 at a charge. Each preparatory press can supply four hydraulic presses, which are ranged around it, so that of the four presses, there will be one charging, one commencing to press, one in full pressure, and one discharging, at the same moment. Motion is communicated to the four hydraulic presses by four pumps mounted on the same bed, and tended by the same workman who directs the pressing. An improvement upon the general form of hydraulic press is that devised by Lalouette, which enables two workmen and one boy to work five presses. These presses turn out about 34,200 lbs. per 24 hours in the first pressing, and 68,400 lbs. in the second. Hydraulic presses are rapidly falling into disuse in the beet-sugar industry, by reason of the superior merits of continuous presses, and the extended adoption of the diffusion system.
Continuous presses for beet were suggested by the roller-mills used in the cane-sugar industry. But the conditions in the two cases are widely different; the bagass of the cane is solid, and readily parts from the juice; whereas the pulp and juice of the beet have a strong tendency to combine, and the roller-surface must therefore be permeable only by the juice. In Poizot et Druelle's press, the pulp passes between two cylinders, carried by endless cloths. The object is to unite the best features of the hydraulic press. To this end, a first gentle pressing is produced against the first cylinder by the elasticity of the principal cloth on which it is borne. Then, encountering a series of four little rollers, performing the functions of the preparatory press, it is next seized between the second and first cylinders, and deprived of the maximum quantity of juice.

Dujardin's roll press is shown in Fig. 49, which is a vertical section of the machine, the side plate being removed. The pulp is forced upward through a pipe $C$ under high pressure. This has a regulating slide valve $D$. The rolls $B B$ revolve towards and nearly in contact with each other, and they are perforated so that the expressed juice may run off through the rolls. These perforations are conical in form with the apex of the cone outward. The cylinders are also covered with a webbing of cloth or horse hair. Below the rolls is block $C'$, which with the outer walls of the chamber, form diverging passages which extend upward, as shown, on either side of the rolls and then downward
Fig. 49.—Dujardin's Roll Press.
along the lower faces of the rolls to the point when they contact. The pulp is compressed with great force against and between the rolls, the juice is forced through the perforations and the residue passes upward and outward under the presser bar $E$ in the form of a ribbon which is guided away by the trough $F$. The pressure of the bar $E$ is regulated by screws and the tighter said bar is pressed against the rolls the greater will be the pressure of the pulp behind the bar and against the rolls, and the greater the juice expressed.

The rolls revolve very slowly only about seven or eight times a minute but the capacity of the machine is very great, it being capable of pressing the pulp of from 85,000 to 175,000 lbs. of beets daily. The residue from the first pressing should be submitted to a further pressing after being macerated with spent wash. This residue may be fed to cattle. The utmost cleanliness is essential to these processes; all the utensils employed should be washed daily with lime-water to counteract acidity.

**Extraction by Maceration and Diffusion.** The object of this process is to extract from the beets by means of water or spent liquor all the sugar which they contain, without the aid of rasping or pressure. Spirit is thus produced at considerably less expense, although it is not of so high a quality as that yielded by the former process. The operation consists in slicing up the beets in a specially constructed slicing machine, into slices of regular
thickness, and then allowing the slices to macerate in a series of vats at stated temperatures. It is essential that the knives by which the roots are cut should be so arranged that the roots are divided into slices having a width of $\frac{1}{10}$ of an inch and a thickness of $\frac{1}{10}$ of an inch, and a variable length; the roots are, of course, well washed before being placed in the hopper of the cutter.

When cut, the beets are covered with boiling water in a macerating of wood or iron for one hour, the water should contain 4.4 of sulphuric acid to every 2200 lbs. of beets. After this, the water is drawn off into a second vat in which are placed more beets, and allowed to macerate again for an hour. This is repeated a third time in another vat, and the juice, which has now acquired a density equal to that obtained by rasping, is run off into the fermenting vat. When the first vat is empty it is immediately refilled with boiling water and fresh beets; the juice from this operation is run into the second vat, when the contents of that one are run into the third. To continue the operation, the beets are completely exhausted by being macerated for an hour with a third charge of boiling water (acidulated as in the former case). The exhausted pulp is removed to make room for fresh slices; and the first vat is then charged with juice which has already passed through the second and third vats. After macerating the fresh beets for one hour, the charge is ready for fermentation. In ordinary weather, the juice should now be at
the right heat for this process, viz., about 71.1° or 75.2° F., but in very cold weather it may require some re-heating.

In Fig. 50 is shown a series of vats for the extraction of the sugar from beets such as is termed a "diffusion battery."

The vessels, 1, 2, 3 and 4 are of wood or sheet iron. Each vessel has a bottom sieve and a top sieve between which the beet slices are to be placed. From the bottom of each vessel below the sieve a pipe $D$ runs to the top of the vessel next in order. From the bottom of the last vessel 4 of the series a pipe $C$ runs back to the top of the one first used. Pipes $A$ and $B$ are connected to each vessel for the admission of water and spent
wash respectively. A discharge pipe $E$ leads from each vessel to a collecting vat 5.

Maceration and diffusion is accomplished as follows: The sliced beets are placed between the sieves in vessel 1 and water or spent wash at a temperature of 185° F. is let in and the beets allowed to macerate for three-quarters of an hour, meanwhile tub 2 is charged with sliced beets. The cock or pipe $D$ between the vessels is opened when the time, three quarters of an hour, has elapsed; hot water or spent wash is admitted by pipes $A$ or $B$ to the vessel 1, which forces the sugar solution therein into vessel 2. When the required amount of fluid has been passed into 2 from 1, the inlet of water into 1 is stopped, and the vessel heated to 185° F.

Vessel 3 is charged with beet slices and in three-quarters of an hour vessels 1, 2 and 3 are connected and water or wash admitted into 1, which forces the solution in 1 into 2 and that in 2 into 3 when it is again raised to 185° F.

The same operation is repeated as to vessel 4 and in three-quarters of an hour all the vessels are connected, hot water or spent wash is admitted to 1 and the sugar solution drawn off from 4 into the vat.

The beets in tub 1 having now been exhausted, the fluid in that vessel is drawn off and the exhausted beets thrown away. 1 is now recharged with beets and the pipe between it and 4 opened. The former operation is repeated except that now
vessel 4 becomes 1, and 1 becomes 4. These successive chargings and dischargings are continued; vessel 3 becomes 1 in its turn and so on.

Fermentation. Before fermentation the juice procured as has been described is brought to about 82° F.; at this temperature it is run off into the fermenting vats. Here it is necessary, as before noted, to add to the juice a small quantity of concentrated sulphuric acid, for the purpose of neutralizing the alkaline salts which it contains, and of rendering it slightly acid in order to hasten the process; this quantity must not exceed $5\frac{1}{2}$ lbs. to every 1220 gallons of juice, or the establishment of fermentation would be hindered instead of promoted. The addition of this acid tends also to prevent the viscous fermentation to which the juice obtained by rasping and pressure is so liable. Although the beet contains albumen, which is in itself a ferment, it is necessary, in order to develop the process, to have recourse to artificial means. A small quantity of brewer's yeast—about $1\frac{1}{2}$ oz. per 22 gallons of juice—is sufficient for this; the yeast must previously be mixed with a little water. An external temperature of about 68° to 78° F. must be carefully maintained. Fermentation lasts for from four to five hours.

The fermentation of acidulated beet-juice sets in speedily. The chief obstacle to the process is the mass of thick scum which forms upon the surface of the liquor. This difficulty is sometimes obviated
by using several vats and mixing the juice, while in full fermentation, with a fresh quantity. Thus, when three vats are employed, one is set to ferment; at the end of four or six hours, half its contents are run into the second vat and here mixed with fresh juice. The process is arrested, but soon starts again in both vats simultaneously; the first is now allowed to ferment completely, which is effected with much less difficulty than would have been the case had the vat not been divided. Meanwhile the second vat, as soon as the action is at its height, is divided in the same manner, one-half its contents being run into the third. When this method is employed, it is necessary to add a little yeast from time to time when the action becomes sluggish.

Direct Distillation of the Roots. This process, commonly called "Leplay's method," consists in fermenting the sugar in the slices themselves. The operation is conducted in huge vats, holding as large a quantity of matter as possible, in order that the fermentation may be established more easily. They usually contain about 750 gallons, and a single charge consists of 2200 lbs. of the sliced roots. The slices are placed in porous bags in the vats, containing already about 440 gallons of water acidulated with a little sulphuric acid; and they are kept submerged by means of a perforated cover, which permits the passage of the liquor and of the carbonic acid evolved; the tem-
perature of the mixture should be maintained at about 77° or 80° F. A little yeast is added, and fermentation speedily sets in; it is complete in about 24 hours or more, when the bags are taken out and replaced by fresh ones; fermentation declares itself again almost immediately, and without any addition of yeast. New bags may, indeed, be placed in the same liquor for three or four successive fermentations without adding further yeast or juice.

The slices of beets charged with alcohol are now placed in a distilling apparatus of a very simple nature. It consists of a cylindrical column of wood or iron, fitted with a tight cover, which is connected with a coil or worm, kept cool in a vessel of cold water. Inside this column are arranged a row of perforated diaphragms or partitions. The space between the lowest one and the bottom of the cylinder is kept empty to receive the condensed water formed by the steam, which is blown into the bottom of the cylinder in order to heat the contents. Vapors of alcohol are thus disengaged from the undermost slices, and these vapors as they rise through the cylinder vaporize the remaining alcohol, and finally pass out of the top at a considerable strength and are condensed in the worm. When all the contents of the still have been completely exhausted of spirit, the remainder consists of a cooked pulp, which contains all the nutritive constituents of the beet except the sugar.
CHAPTER X.

ALCOHOL FROM MOLASSES AND SUGAR CANE.

Another common source of alcohol is molasses. Molasses is the uncrystallizable syrup which constitutes the residuum of the manufacture and refining of cane and beet sugar. It is a dense, viscous liquid, varying in color from light yellow to almost black, according to the source from which it is obtained; it tests usually about 40° by Baume's hydrometer. The molasses employed as a source of alcohol must be carefully chosen; the lightest in color is the best, containing most uncrystallized sugar. The manufacture is extensively carried on in France, where the molasses from the beet sugar refineries is chiefly used on account of its low price, that obtained from the cane sugar factories being considerably dearer. The latter is, however, much to be preferred to the former variety as it contains more sugar. Molasses from the beet sugar refineries yields a larger quantity and better quality of spirit than that which comes from the factories. Molasses contains about 50 per cent. of saccharine matter, 24 per cent. of other organic matter, and about 10 per cent. of inorganic salts, chiefly of potash. It is thus a
substance rich in matters favorable to fermentation. When the density of molasses has been lowered by dilution with water, fermentation sets in rapidly, more especially if it has been previously rendered acid. As, however, molasses from beet generally exhibits an alkaline reaction, it is found necessary to acidify it after dilution; for this purpose sulphuric acid is employed, in the proportion of about 4½ lbs. of the concentrated acid to 22 gallons of molasses, previously diluted with eight or ten volumes of water. Three processes are thus employed in obtaining alcohol from molasses; dilution, acidification, and fermentation. The latter is hastened by the addition of a natural ferment, such as brewer's yeast. It begins in about eight or ten hours, and lasts upwards of 60.

About three gallons of Alcohol may be obtained from one hundred pounds of molasses.

**Beet Sugar Molasses.** The first step in the process of rendering the molasses fermentable is to mix the molasses with water, to a certain dilution, in the proportion of two parts of water to one of molasses. This may be done by hand, but preferably it is performed in a vat provided with stirring or agitating mechanism, such as will effectually mix the water with the viscid syrup, and whereby also the wash may be thoroughly agitated and aerated.

There are numerous forms of mixing vats, all working however, on the principle shown in Fig. 51. In this, the vat $A$ is provided with a central shaft $C$ carrying radial mixing blades $E$. This shaft is
driven by bevel gears $D, F$. As the rotation of these blades would merely tend to create a rotary current of molasses and water, and not to mix them, some means should be used for impeding and breaking up this current. To that end the cover is provided with downwardly projecting rods $I$ which create counter currents, and thoroughly intermingle the two liquids. Another and even better form of mixer consists of a tank into the

![Diagram of Mixing Vat]

**Fig. 51.** Mixing Vat.

lower portion of which enters a perforated pipe of relatively large diameter. This is provided at the end with an air entrance and a steam injector. The injected steam draws in air and the steam and air are forced under pressure into the vat, thus diluting the contained molasses, agitating it and thoroughly aerating it.

The molasses as it comes from the sugar house may
contain anywhere from 30 to 45 per cent of sugar, and this should be diluted with water to a concentration of 16 to 18 per cent of sugar.

The density of the wash after "setting up" is 1.060. It is to be noted that though with improved apparatus a wash as concentrated at 12° or 15° Baume may be worked; yet where simple apparatus is used six degrees or eight degrees is better and much more favorable to rapid and complete fermentation.

After setting up, one gallon of strong sulphuric acid and 10 lbs. of sulphate of ammonia are added for each 1000 gallons of wash. This neutralizes the alkaline carbonates in the beet juice which would otherwise retard fermentation, and it assists the yeast to invert the cane sugar as formerly described. The addition of ammonia is in order to give food to the yeast and obtain a vigorous fermentation.

The yeast used for fermenting molasses is prepared either from malt or grain and is used as concentrated as possible, and in the proportion of about 2 per cent.

The "pitching" temperature of a molasses wash varies with the concentration of the wash, being higher for strongly concentrated solutions than for weak ones. When the wash tests as high as 12° Baume, fermentation begins at about 77° F. and is raised during fermentation to 85° or 90° F. A temperature around 82° F. is best on the average as this is most conducive to the growth of yeast.
Where the vats are large and the syrup considerably diluted the temperature rises very quickly and must be moderated by passing a current of cold water through a coil of pipe on the bottom of the vat.

In the making of molasses mashes it must be remembered that every gallon of molasses will be diluted with about five gallons of water or other fermented liquid matter, and therefore 50 gallons of molasses wash will require a still capable of working up about 300 gallons. It is possible to distill four or five charges during the day of 12 hours and hence a still of 60 gallons will be capable of distilling the beer or wash made with 50 gallons of molasses. A still with a capacity of 100 gallons operating on wash having a strength of one gallon of molasses to five of water, will produce about 10 gallons of proof spirit from each charge; thus a 100 gallon still will make from 40 to 80 gallons of spirit in a day. With unskilled labor, however, it is impossible to get this rate of production and the best that can be done will be about four charges a day.

It may be suggested that in getting estimates on stills it is best to accompany the request with a statement of the character of the mash intended to be treated, the amount of raw materials intended to be used up, the charging capacity required, number of gallons of mash desired to be worked up every 12 hours.

**Fermenting Raw Sugar.** This is accomplished by dissolving the sugar in hot water, then diluting
it, and then adding a ferment,—fermentation being aided by adding sulphuric acid to the diluted molasses, in the proportion of one-half to one pound of acid to every hundred pounds of pure sugar used.

The wash is pitched with compressed yeast in the proportion of 2½ to 8 per cent of the weight of the sugar used. The pitching temperature is from 77° to 79° F., and the period of fermentation is 48 hours.

**Cane Sugar Molasses.** Besides the molasses of the French beet sugar refineries, large quantities result from the manufacture of cane sugar in Jamaica and the West Indies. This is entirely employed for the distillation of *rum*. As the pure spirit of Jamaica is never made from sugar, but always from molasses and skimmings, it is advisable to notice these two products, and, together with them, the exhausted wash commonly called *dunder*.

The molasses proceeding from the West Indian cane sugar contains crystallizable and uncrystallizable sugar, gluten, or albumen, and other organic matters which have escaped separation during the process of defecation and evaporation, together with saline matters and water. It therefore contains in itself all the elements necessary for fermentation, *i.e.*, sugar, water, and gluten, which latter substance, acting the part of a ferment, speedily establishes the process under certain conditions. *Skimmings* comprise the matters sepa-
rated from the cane juice during the processes of defecation and evaporation. The scum of the clarifiers, precipitators, and evaporators, and the precipitates in both clarifiers and precipitators, together with a proportion of cane sugar mixed with the various scums and precipitates, and the "sweet-liquor" resulting from the washing of the boiling-pans, etc., all become mixed together in the skimming-receiver and are fermented under the name of "skimmings." They also contain the elements necessary for fermentation, and accordingly they very rapidly pass into a state of fermentation when left to themselves; but, in consequence of the glutinous matters being in excess of the sugar, this latter is speedily decomposed, and the second, or acetous fermentation, commences very frequently before the first is far advanced. Dunder is the fermented wash after it has undergone distillation, by which it has been deprived of the alcohol it contained. To be good, it should be light, clear, and slightly bitter; it should be quite free from acidity, and is always best when fresh. As it is discharged from the still, it runs into receivers placed on a lower level, from which it is pumped up when cool into the upper receivers, where it clarifies, and is then drawn down into the fermenting cisterns as required. Well-clarified dunder will keep for six weeks without any injury. Good dunder may be considered to be the liquor, or "wash," as it is termed, deprived by distillation of its alcohol, and much concentrated by the boiling it has been
subjected to; whereby the substances it contains, as gluten, gum, oils, etc., have become, from repeated boilings, so concentrated as to render the liquid mass a highly aromatic compound. In this state it contains at least two of the elements necessary for fermentation, so that, on the addition of the third, viz., sugar, that process speedily commences.

The first operation is to clarify the mixture of molasses and skimmings previous to fermenting it. This is performed in a leaden receiver holding about 300 or 400 gallons. When the clarification is complete, the clear liquor is run into the fermenting vat, and there mixed with 100 or 200 gallons of water (hot, if possible), and well stirred. The mixture is then left to ferment. The great object that the distiller has in view in conducting the fermentation is to obtain the largest possible amount of spirit that the sugar employed will yield, and to take care that the loss by evaporation or acetification is reduced to a minimum. In order to ensure this, the following course should be adopted. The room in which the process is carried on must be kept as cool as it is possible in a tropical climate; say, 75° to 80° F.

Supposing that the fermenting vat has a capacity of 1000 gallons, the proportions of the different liquors run in would be 200 gallons of well-clarified skimmings, 50 gallons of molasses, and 100 gallons of clear dunder; they should be well mixed together. Fermentation speedily sets in, and 50
more gallons of molasses are then to be added, together with 200 gallons of water. When fermentation is thoroughly established, a further 400 gallons of dunder may be run in, and the whole well stirred up. Any scum thrown up during the process is immediately skimmed off. The temperature of the mass rises gradually until about 4° or 5° above that of the room itself. Should it rise too high, the next vat must be set up with more dunder and less water; if it keeps very low, and the action is sluggish, less must be used next time. No fermenting principle besides the gluten contained in the wash is required. The process usually occupies eight or ten days, but it may last much longer. The liquid now becomes clear, and should be immediately subjected to distillation to prevent acetous fermentation.

Sugar planters are accustomed to expect one gallon of proof rum for every gallon of molasses employed. On the supposition that ordinary molasses contains 65 parts of sugar, 32 parts of water, and three parts of organic matter and salts, and that, by careful fermentation and distillation, 33 parts of absolute alcohol may be obtained, we may then reckon upon 33 lbs. of spirit, or about four gallons, which is a yield of about 5½ gallons of rum, 30 per cent. over-proof, from 100 lbs. of such molasses.

The following process is described in Deerr's work on "Sugar and Sugar Cane."

"In Mauritius a more complicated process is
used; a barrel of about 50 gallons capacity is partly filled with molasses and water of density 1.10 and allowed to spontaneously ferment; sometimes a handful of oats or rice is placed in this preliminary fermentation. When attenuation is nearly complete more molasses is added until the contents of the cask are again of density 1.10 and again allowed to ferment. This process is repeated a third time; the contents of the barrel are then distributed between three or four tanks holding each about 500 gallons of wash of density 1.10 and 12 hours after fermentation has started here, one of these is used to pitch a tank of about 8,000 gallons capacity; a few gallons are left in the pitching tanks which are again filled up with wash of density 1.10 and the process repeated until the attenuations fall off, when a fresh start is made. This process is very similar to what obtains in modern distilleries save that the initial fermentation is adventitious.

"In Java and the East generally, a very different procedure is followed. In the first place a material known as Java, or Chinese, yeast is prepared from native formulæ; in Java, pieces of sugar cane are crushed along with certain aromatic herbs, amongst which galanga and garlic are always present, and the resulting extract made into a paste with rice meal; the paste is formed into strips, allowed to dry in the sun and then macerated with water and lemon juice; the pulpy mass obtained after standing for three days is