When the diastase of the malt has had time to act the mash is inoculated with a smaller special mash of rye and malt in which a pure culture of lactic acid bacteria (*Bacillus delbruckii*) is growing. The mash is now incubated for about sixteen hours at the proper temperature (*ca.* 50° C., 122° F.). During this time the proteins of the grains are partially hydrolyzed and some lactic acid is formed. The liquor now contains largely sugars, resulting from the action of malt diastase on the starch, lactic acid, amino acids, and other hydrolysis products of the proteins, all in a highly assimilable form for the yeasts, and the cellulose residues from the cereals.

This sour mash is filtered and the filtrate, now called "wort," is heated (Pasteurized) to kill off the lactic acid bacteria and any undesirable organisms. After cooling the wort is run into fermentation tanks and inoculated with a pure yeast culture of sufficient size. The wort is then aerated by passing in compressed air either through bottom or side inlets. The oxygen of the air bubbling through the wort stimulates the growth and reproduction of the yeast cells.

When the growth of yeast has reached the desired extent, the cells are separated from the fermenting wort in the third set of operations. The ordinary equipment for this purpose is identical in action with the familiar centrifugal cream separator. The heavy cream of separated yeast is cooled, further water is removed by means of a filter press. The press cake is churned, squeezed in hydraulic presses, packed, and stored in a refrigerator.

**Distillers' Yeast.**—Each manufacturer of distilled spirit prepares the yeast for carrying on the production of alcohol in a manner generally similar to that just described. The start is usually made by reserving a portion from each completed fermentation. The yeast in this reserved portion is propagated in a small special mash made often from equal amounts of barley malt and rye. In other distilleries only malt, either rye or barley, is used; or possibly a mixture of one of these malts with a ground, unmalted cereal such as wheat, barley or rye. In any case, the object is to produce yeast cells which are young, vigorous and
so active that they will rapidly reproduce and will have a high sugar splitting or fermentive capacity, to the end that the highest possible yield of alcohol will result. A flow sheet of this process is shown in Figure 7. It will be noted that it corresponds quite closely to the main steps in the manufacture of ordinary yeast.

The ground rye is first scalded with water of about 170° F. temperature. Then it is stirred, the ground malt added and the whole mash kept for about two hours at a temperature of approximately 150° F. Its sugar content should be about 22 to 25 per cent as indicated on the Balling hydrometer.

The mash is now cooled and soured. Sometimes a pure culture of lactic acid bacteria is added to speed up the souring process. Cooling reduced the temperature of the mash about thirty degrees, or to 120° F. When no lactic acid bacteria are added it is kept at this temperature for about forty-eight hours and souring is usually completed by that time. The addition of bacteria reduces the time for souring to about eighteen hours, or a little longer.

The souring process not only helps in the development of a nutritive medium for the yeast but also the lactic acid formed
prevents, or retards, the development of unfavorable micro-
organisms during fermentation, notably acetic acid bacteria.

As in commercial yeast manufacture, the lactic acid bacteria
are killed by heating the mash again; this time to 170°F. After
holding it at this point for about twenty minutes the temperature
is brought down to about 85°F. and the seed yeast is added.
Fermentation commences and the temperature is gradually low-
ered about five degrees. When the sugar content of the mash has
dropped to about 8 per cent Balling it is added to the main mash
where it represents about 5 per cent of the total volume. Heating and cooling in all cases is obtained by the use of coils
for the circulation of hot or cold water in the tanks.

**Wine Starters.**—Grapes ordinarily will produce a must which
contains sufficient yeast to carry on the fermentation. Unfortu-
nately, the must is also almost certain to contain many varieties
of unfavorable micro-organisms. Hence, especially in the manu-
facture of white wines some purging or sterilizing process is neces-
sary. The process ordinarily used is called defecation. This
consists of treating the must with sulfurous acid and is ordinarily
accomplished by pumping it into sulfurized casks (as described in
chapter on wine making). In from twelve to twenty-four hours,
the must is purged, and all its gross impurities, including micro-
organisms, dust and solid particles derived from the skins, stems,
pulp and leaves have settled to the bottom. It may be slightly
cloudy or nearly clear. It should then be drawn off into clean
casks and fermentation started. Sometimes it is sterilized by
Pasteurization following defecation, but this is not a very satis-
factory operation from the flavor standpoint; it is costly and is
generally dispensed with. In defecating must to eliminate un-
favorable micro-organisms the wine maker, unfortunately also
removes the true yeasts. The more perfect the process the more
necessary it is to add wine yeast. It is, therefore, necessary to
add a starter.

**Natural Starters.**—One method of producing such a starter
is to gather a suitable quantity of the cleanest and soundest ripe
grapes in the vineyard, crush them carefully and allow them to
undergo spontaneous fermentation in a warm place. An addition
of a quarter to a third of an ounce of potassium meta-bisulfite per hundred pounds of grapes is of great assistance in promoting a good yeast fermentation in the starter. Perfectly ripe grapes should be selected and the fermentation allowed to proceed until at least 10 per cent of alcohol is produced. If imperfectly ripe grapes are used or the starter used too soon, the principal yeast present may be *S. apiculatus*. Towards the end of the fermentation *S. ellipsoideus* predominates. From one to three gallons of this starter should be used for each hundred gallons of crushed grapes or must to be fermented. Too much should not be used in hot weather or with warm grapes, as it may become impossible to control the temperature.

This starter is used only for the first vat or cask. Those following are started from previous fermentations, care being taken always to use the must only from a vat at the proper stage of fermentation and to avoid all vats that show any defect.

*Pure Yeast Starters.*—An improvement on a natural starter of this kind is a pure culture of tested yeast. There are two ways of using these yeasts. One is to obtain, from a pure yeast laboratory, a separate starter for each fermenting vat or cask. All the wine-maker has to do is to distribute this starter in the grapes or must as they run into the vat. If the starter is used when in full vigor this method is simple and effective. Unfortunately, it is difficult to have it on hand in just the right condition at the right moment. If the starter is too young, it will not contain enough yeast cells; if too old, the cells will be inactive or dead. The usual starter is in full vigor for only a few days at the most. Recent improvements in the methods of preparing pure yeast starters are said to overcome this difficulty and to produce starters which maintain their full vigor for weeks or months.

The other method is for the wine-maker to obtain a small culture of pure yeast from a reliable source and from this to make his own starter.

To do this he prepares an inoculum of two or three gallons of must defecated with sulfurous acid and sterilized by boiling. This, on cooling, is placed in a large demijohn plugged with
sterilized cotton and the pure culture of yeast added. The demijohn must be placed in a warm place (70° to 80° F.) and thoroughly shaken several times a day to aerate the must. In a few days a vigorous fermentation occurs.

When the fermentation is at its height in the demijohn, which will be when the must still contains 3 or 4 per cent of sugar, it is ready to use to prepare a bulk starter. This is best prepared in a small open vat or tub, varying in size according to the amount of starter needed daily. Into this tub are poured twenty to fifty gallons of well-defecated must extracted from clean, sound grapes. It is not necessary to boil it, as the few micro-organisms it may contain will be without effect in the presence of the vastly more numerous yeast cells introduced from the pure culture in the demijohn.

The whole of the pure culture is poured into the tub of must, the temperature of which should be between 80° and 90° F. This temperature is maintained either by warming the room or by occasionally placing a large can full of boiling water in the tub. This can should, of course, be tightly stoppered in order that none of the water may get into the must. The must should be well aerated several times a day to invigorate the yeast. This is done by dipping out some of the must with a bucket or ladle and pouring it back into the tub from a height of several feet or by the use of compressed air. The tub should be covered with a cloth to exclude dust, and everything with which the must comes in contact should be thoroughly cleaned with boiling water.

In a day or two the must is in full fermentation and may be used as a starter. From ten to thirty gallons of starter are used for every thousand gallons of must or crushed grapes. The cooler the grapes the more should be added. Too much added to warm grapes may make the fermentation so rapid that it will be difficult to control the temperature. Moldy or dirty grapes require more than clean, because there are more injurious germs to overcome.

Every twenty-four hours, nine tenths of the contents of the starter tub can be used and immediately replaced with fresh defecated must. The yeast in the remaining tenth is sufficient to
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start a vigorous fermentation and multiplication of yeast. Two things must be watched with special care if the starter is to maintain its vigor. The temperature must be kept above 80° F. and thorough and frequent aeration must be given.

With care, a starter of this kind will remain sufficiently pure to be used continuously throughout the vintage.
CHAPTER VII

MALT

In one very important respect the manufacture of spiritous liquors from a grain base differs from that commencing with a fruit juice base. This difference is that the fruit juices contain preformed sugar directly available for fermentation while the cereals contain starch and proteins in a relatively insoluble form. It was stated in previous chapters that by suitable processes this insoluble starch and proteins can be converted into soluble forms which are then fermentable. The processes by which this conversion is accomplished are the subject of this chapter.

There are two general means by which starch and proteins are solubilized (hydrolyzed) for the purpose of fermentation. These are by the action of suitable enzymes or by treatment with acids. Of these the former is much more common in the liquor industry. For the production of suitable enzymes the natural changes which occur in the sprouting of seeds are used. The employment of this natural chemical process is called malting, and the product, malt.

Malt.—Malt may be made from any cereal but is commonly made from barley and unless otherwise specified, the term "malt" is understood to refer to barley malt. The general preference for barley is due to its high enzyme productivity, its ability to retain its husk in threshing (husk subsequently serving as a filtering material in the mash-tun) and the responsiveness of its endosperm during growth to modifications and mellowing.

The following Figure 8 shows an enlarged cross-section of a barley grain.

A grain of barley, or other cereal, consists essentially of two parts, the main starchy portion, known as the endo-sperm and a smaller part at one end of the corn known as the embryo. The
embryo is the rudimentary plant. From it rootlets eventually develop which extract nourishment from the soil for the development or growth of the plant. The rootlets do not appear in the first stages and it is necessary for nature to provide some means of feeding the embryonic plant. The nutrient media provided by nature are principally starch, and smaller amounts of proteins and other products. The nutrient materials are contained in the endo-sperm and are insoluble and therefore non-diffusible through the cellular structures to the germ where they are needed. Nature has adjusted for this situation by providing that the plant secretes certain substances, namely enzymes, very actively as soon as germination commences. The enzyme, cytase, attacks the cellular wall structures and its action makes it possible for the enzyme, diastase, to act upon the starch, changing it into a soluble form and therefore rendering it diffusible, assimilable and available to the germ as food. A portion of the insoluble proteins is also acted upon and changed into soluble, diffusible and chemically simpler substances, e.g., peptones, proteoses, and amino acids. This change, commonly called proteolysis, is thought to be brought about by other enzymes in the plant but little is definitely known with respect to these agents, the action partly resembling that of trypsin and partly that of pepsin or peptase. The actual mechanism by means of which cytase enables the other enzymes to reach the starch and proteins is also not definitely known; i.e., it is not known whether the cytase dissolves the cellulose or whether its action is merely a softening one whereby the cellulose
MALT

is rendered permeable. Figure 9 is a diagram of the various changes which take place within the grain during the malting operation.

This is the process on which the maltster relies, but his endeavor is to keep the consumption of starch as low as possible and hence when the action has proceeded to a point where he judges the starch rendered soluble and the enzymes developed to
the most useful point the process is arrested and the plant killed by drying the germinating grain in the malt kiln. This calls for considerable judgment and experience on the part of the maltster, but, in a general way, the end point may be said to have been reached when the plumule has grown almost to the length of the grain or corn. At this stage the starch should be in the proper degree of conversion into sugar and the enzymes developed to such a point as to be able to act upon and saccharify not only the starch of the malt but also the starch of the unmalted cereal with which it is often mixed in the mash tun. Since the yield of alcohol is dependent upon the yield of starch converted to sugar it is important to develop a malt of maximum diastatic properties. It is also economical because it eliminates the necessity of converting all of the cereal to malt.

Generally speaking, American malts have high diastatic (starch-converting) power and are mixed with other cereals in proportions ranging from 10 to 15 per cent of the whole for the production of lower grade whiskies and from 20 to 50 per cent for the higher grades. The United States Dispensatory requires that malt shall be capable of converting not less than five times its weight of starch into sugars. Distillers’ malt, however, is usually capable of accomplishing the conversion of nearly fifteen times its weight.

Malt is used, either alone or in combination with unmalted cereals, as a raw material in the manufacture of whiskey, gin, vodka and kornbranntwein. It is also used as a raw material in the manufacture of beer. It is, therefore, one of the most important products used by the liquor industry.

The finished product may be light yellow, yellowish-brown or blackish-brown in color depending upon the intensity of the heat treatment received in processing. Caramel malts are yellowish-brown and are so called because they have been made from ordinary malt submitted to a secondary process consisting of steeping, drying and progressive heating until the sugar formed at the lower temperatures is finally caramelized. Black malts are those of the darkest color and are the product of comparatively high temperature drying.
The malting operation offers several distinct advantages. It assists in the development of the enzymes diastase, cytase and peptase which are of great importance. It influences the solubility of the albumen, starch and phosphates in the grains and affects the condition of the starch for subsequent conversion in the mashing operation.

Practical Malting.—The malting operation consists in: 1. cleaning the grain, 2. adding water and steeping, 3. germinating, 4. drying, 5. cleaning and crushing. The sequence of these steps is shown in the flow sheet, Figure 10.

Equipment and processes for cleaning, steeping and drying are more or less standardized but various methods are available for carrying out the germinating operation.

Steeping.—This consists of soaking the cereal in water for approximately 48 hours. Allowance must be made for variables such as kind and condition of barley, water temperature, hardness of water, humidity of air, etc. Float or ladle off skimmings. Change the water every 12 hours the first day and every 24 hours thereafter. When loading have tank half full of water and then
add barley, allowing water to stand 1 to 2 feet above the barley when full. When cereal is properly steeped drain off water.

Germination.—There are three methods available for carrying out the germinating operation on a large scale. These are respectively known as the floor, compartment, and drum systems. The floor method was the first used, the other two representing the contributions of modern chemical engineering. They are commonly referred to as pneumatic malt and are based on mechanical as compared to hand turning over the grain and on subjecting it to a flow of conditioned air either intermittently or continuously during the raking or tumbling. Pneumatic malting is of great assistance to the patent still distilleries; it permits all-year-round malting.

Floor system.—In this method the damp cereal is spread upon the floor and is periodically shovelled over to aerate the germinating mass and keep its temperature below the scorching or burning point. The right air temperature is about 60° F. and the grain temperature should be about 75° F.

This part of the process must be watched closely and its success depends on the judgment and experience of the maltster who varies the depth of the grain at each working over. He will usually start with a depth of about 8 to 10 inches and then alternately and gradually increase and reduce it from a maximum of 14 inches to a minimum of about 5 inches.

Germination proceeds and in a few days reaches a point where further growth must be arrested. This is usually when the leaf or acrospire has grown to the length of the kernel. The germination is stopped by drying the green malt in the kiln. Manchurian barley reaches this point in about five days while the two-rowed and Bay Brewing types take about eight days.

Drum system.—These are large drums of the rotating, tumbling type found in many chemical and other industrial plants. They are arranged for continuous admission of conditioned air and their speed can be varied to suit operating requirements.

It is customary to revolve the drums very slowly at first but, as germination proceeds, the speed of rotation is gradually stepped up. No definite operating rules can be set up since germinating
conditions are never absolutely standard, but the following procedure may be used as a guide: twelve complete revolutions every twenty-four hours for the first three days, then change to a full revolution every hour and a half for the next thirty-six hours and thereafter speed up to one revolution every forty minutes until germination reaches the arrestation point in about twelve hours more.

Compartment system.—This consists of an oblong tank with perforated bottom, usually of galvanized steel. The conditioned air can be either top or bottom delivered. A carriage fitted with revolving helices for stirring the grain travels across the top of the tank and a sprinkling device is usually provided for moistening the grain as it is turned over. Unloading is accomplished by means of a scraper which draws the grain to one end of the tank where an automatic device is located for feeding the germinating mass to a conveyor.

Kiln drying.—This is carried out in a three-storied building fitted with a suction fan on the top floor and a furnace on the ground floor. The furnace is fed with smokeless coal and air and the hot gases are sucked up through the floors and exhausted from the top of the building by the fan. The grain is spread on the top floor and given a preliminary drying. It is then dropped to the second floor where it is gradually subjected to higher temperatures. This is an operation of some delicacy, and considerable care and experience are required in order that the malt may be dried gradually and not spoiled by scorching. Exposing the green malt to too high temperatures at the beginning of the drying operation will reduce its diastatic strength. For the first 24 hours 90° F. is about right and it should then be dry to the touch; thereafter the heat is gradually increased until a temperature of 120° to 130° F. is reached in the 40th to 48th hours. The maximum diastatic properties of the malt are obtained when the drying is stopped at about 123° F. and this is an important point for the distiller of mixed mashes. Malts dried at temperatures no higher than this point are usually referred to as green malts.

On the other hand, where high diastatic power is not so
essential, as at all-malt distilleries, it is better to continue drying to a higher temperature. This gives the following advantages: (1) a more friable product, easier to grind, (2) more suitable for storage and (3) better fermentations and superior flavoring properties. Offsetting these favorable characteristics is the fact that green malts are more nourishing to yeasts and have about ten times more diastatic power. Barley gives a malt of the highest diastatic power with rye, wheat, oats and corn following in the order named.

**Yield.**—After the malting and kilning operations the accreened malt produced will weigh approximately 20 per cent less than the green grain, but, taken by measure, the malt will exceed the original grain by 6 or 7 per cent. This is to say, the malt produced is bulkier but less dense than the original green grain.

**Acid Conversion.**—The theory of the acid conversion of starch into sugars was discussed in Chapter I. Practically, this method finds some use in the preparation of cereal raw materials prior to fermentation although probably less in this country than abroad. In the United States the hydrolysis of starch for fermentation is almost invariably accomplished by the diastatic action of malts. These malts are mixed with unmalted grain (the starch of which has been pastified by prior cooking) and the conversion to fermentable sugar carried to completion by a subsequent operation called "mashing."

In Great Britain there is more variation in the means employed to secure a completely fermentable mash. There is first of all the common process in which all of the diastatic action comes from malt. Then there are two processes for making mixed mashses. In the first of these, mixtures are made of malt and unmalted grain, the starch of the latter having been completely converted by the acid process. In the second process the action of the acid on the unmalted grain is halted before completion and a small proportion of malt added to finish the task of hydrolysis. The preparation of these mashses will be discussed again under the general subject of the whiskies prepared from them.
Definitions.—Distillation is defined as the separation of the constituents of a liquid mixture by partial vaporization of the mixture and separate recovery of the vapor and the residue. The more volatile constituents of the original mixture are obtained in increased concentration in the vapor; the less volatile remaining in greater concentration in the residue. The apparatus in which this process is carried on is called a still. Generally speaking, the essential parts of a still are: 1. The kettle in which vaporization is effected, 2. the connecting tube which conveys the vapors to 3. the condenser in which the vapors are liquefied. Modifications involving the addition of other parts to the still are introduced for various purposes such as the conservation of heat and to effect rectification. Rectification is a distillation carried out in such a way that the vapor rising from a still comes into contact with a condensed portion of the vapor previously evolved from the same still. A transfer of material and an interchange of heat result from this contact, thereby securing a greater enrichment of the vapor in the more volatile components than could be secured with a single distillation operation using the same amount of heat. The condensed vapors, returning to accomplish this object, are called "reflux." (The above definitions are substantially based on "The Chemical Engineers' Handbook" by Perry, p. 1107-8.)

In less precise language, a simple distillation is a means of separating a volatile liquid from a non-volatile residue. A fractional distillation is a means of separating liquids of different volatility. This latter process rests on the fact that no two liquids of different chemical composition have the same vapor pressure at all temperatures, nor very often the same boiling point.
On the other hand, while its actual amount may be almost vanishingly small, every liquid or even solid substance has a definite vapor pressure at any given temperature. Furthermore, that vapor pressure is unchangeable at a fixed temperature by any external means, but only by a change in the composition of the liquid. From this it seems probable that the vapor pressure depends partly on the nature of the liquid molecules and partly on their mutual attraction. We have neither need nor space here to develop the proof of this theory. Its application is as follows: The molecules of water (B. P. 100° C.) and of alcohol (B. P. 78.3° C.) do possess a strong attraction for each other as shown by the contraction which is readily observed when the two liquids are mixed. The effect of this on the vapor pressure and hence on the boiling point is shown in Figure 10a. From this diagram, the proportions of which are exaggerated, it will be noted that a mixture containing approximately 95% of alcohol to 5% of water by volume has a lower boiling point (i.e., higher vapor pressure) than either pure compound. From this it follows that alcohol higher than 95.57% cannot be produced by distillation and also that in a simple still, starting with a mixture of alcohol and water of relatively low alcoholic strength, the first distillate will be higher in alcohol content and as the distillation continues the alcohol content of each succeeding portion of distillate will be lower until finally pure water comes over. The relation between the alcohol content of the first vapors and distillate and that of the original boiling liquid as determined by
Sorel (Distillation et rectification industrielle, 1899) is shown in Figure 10b.

If the first portion of distillate were condensed and redistilled, the new distillate would be still richer in alcohol. For instance, if the liquid being distilled contained 10% of alcohol, the first distillate would contain 48.6% and this if condensed and redistilled would contain 69-70% alcohol. Obviously, a practical operation cannot be conducted in this manner. What is done, therefore, is to introduce into the head of the still a number of plates in each of which a portion of the vapor is condensed, yielding a liquid somewhat richer in alcohol than the original liquid, and this is again partly evaporated so that as we ascend the column each plate is progressively of higher alcoholic strength. It is possible by the application of experimental results such as Sorel's (loc. cit.) to these considerations to calculate the number of plates required, and the proportion of condensate return required, to produce alcohol of any desired strength from a given dilute supply. In general it can be seen that there is an inverse ratio between the number of plates and the amount of reflux so that as a practical matter it is advisable to increase the number of plates as far as economically feasible in order to economize fuel.

The fact that it is difficult to secure alcohol concentrations in excess of 12-14% by fermentation alone, requires that for the
production of stronger liquors the process of distillation be applied. The increase in alcohol concentration which can be achieved thereby depends on the effectiveness of the rectification and the completeness with which it is desired to recover all the alcohol. It can range up to a recovery in excess of 99% and alcohol of 95% strength by volume. The type and size of still

![Diagram of a distillation apparatus]

Fig. 11.—Simple pot still used in liqueur manufacture.

actually employed in the distilled liquor industry depends on the industrial development of the country in which the process is being applied, upon the beverage being made, the raw materials used, and the amount of material being processed at one time. The various types may be classified as pot stills, Coffey or patent stills, vat stills and continuous stills.
Pot Stills.—The simplest form of pot still is used in the manufacture of liqueurs both on account of the small lots which are worked and the method of manufacture. Such a still is shown in Figure 11. “A” is the kettle; “D” is the “swan’s neck” for conveying the vapors to “R” the condenser; and “S” is the worm. The mode of operation of this apparatus is obvious from an inspection of the figure.

Fig. 12.—Pot still used in French brandy manufacture.
C is the chauffe-vin used for pre-heating the wine fed to the still.
R is the condenser.

Figures 12 and 13 illustrate the addition of another part to the simple pot still as used in France for the production of brandy. This is the device marked “C,” called in French the “chauffe-vin,” from its function of pre-heating the wine which is fed to the kettle “A.” This pre-heating is a mode of conserving some of the latent heat of the vapors by passing them through the feed
to the kettle before leading them to the condenser. The types of still illustrated are specially designed for brandy manufacture and their peculiar adaptation for this purpose will be found in the chapter on Brandy.

**Improved Pot Still.**—In Great Britain the chief distilled liquor is whiskey. Some of this continues to be made in pot-stills of somewhat improved design and considerably larger size as shown in Figure 14. The pot stills used for this purpose are divided into two classes, wash stills and low-wines stills. The mash in which fermentation is complete, now called "wash," is distilled in the former. The distilled product, low wines, is approximately a third of the volume of the original wash and

![Figure 13: French brandy still fitted with chauffe-vin.](image)

- **A** is the kettle.
- **C** the chauffe-vin.
- **R** the condenser.