The Manual for the Home and Farm Production of Alcohol Fuel

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Chapter 6

PROCESSING STEPS SPECIFIC TO SACCHARINE MATERIALS

GENERAL DESCRIPTION

As stated earlier, saccharine materials require the least processing of any of the ethanol feedstocks. Referring to Figure 4-1, it can be seen that molasses and other sugar-containing syrups need only to be diluted and pH adjusted prior to fermentation. Other materials, such as grapes and other fruits, need to be either crushed or extracted to make the sugar readily accessible to the yeast enzymes.

In addition to extraction, the requirements of pH control, dilution, backslopping, and cleanliness as discussed in Chapter 5 also apply. Recipes for specific materials are contained in Chapter 10.

EXTRACTION

Prior to fermentation, saccharine materials, such as fruits, beets, etc., are usually put through an extraction process. This means that the sugar-containing juice is separated from the rest of the material . This is usually done in a press like those used for crushing grapes or making cider. Extraction, per se, is not absolutely necessary. The materials can also be simply crushed to expose the juices for the fermentation process. However, with most distillation equipment, the solids will have to be removed prior to going into the still.

There are certain problems and considerations associated with either extraction or crushing. Extraction in a press, at best, leaves an appreciable amount of fermentable material behind. Typically, only 75% of the sugars can be extracted from apples and about 80% from grapes. One technique that can be used with press extraction to increase the yield is to take the residue from the first pressing, soak it in a minimum amount of water to dissolve more of the sugar, and then press it again. However, this method creates additional dilution which lowers the alcohol content of the fermented mash (called "beer") requiring more energy and time in the distillation process. If a fruit juice contains, for example, 10% sugar, the final alcohol concentration going to the still will be about 5%. Any water used to wash additional sugar from the residue will further dilute this final concentration. The lower the alcohol concentration, the more water must be removed from the alcohol during distillation. However, in many instances, the greater total amount of alcohol gained justifies the additional dilution.

Crushing the material instead of extracting it in a press leaves all the sugar available for fermentation, although the material usually must be strained prior to distillation. Again, some of the valuable liquid will be retained in the residue and the only solution is to wash it with a little water. If you are using a simple pot still, such as described in this book, filtering the residue isn't absolutely necessary as long as the still pot is cleaned out after each run. In this case, the crushing method is superior.

Certain materials such as sweet corn stalks, sugar cane, and the like, require heavy hydraulic presses to effectively extract the juice. The alternate process here is to shred the material and then heat it with as little water as possible to dissolve out the sugar. Note that to obtain complete recovery of the sugar, the process described must be repeated several times. Again, a point is reached where dilution offsets the amount of sugar released and some compromise must be made. Note also that two extractions of one gallon each will dissolve more sugar than a single two gallon extraction.

Chapter 7

PROCESSING STEPS SPECIFIC TO STARCHY MATERIALS

PREPARATION OF STARCHY MATERIALS

Starchy materials fall into two main categories: (11) materials, such as grains, in which the starch is encased or protected by grain hulls; and (2) those materials, such as potatoes, where the starch is more readily available. Milling or grinding the material to expose the starch is necessary for the former group, but not the latter. Otherwise, all starchy materials require a certain amount of cooking and conversion of the starch to sugar prior to fermentation.

There are two basic methods of conversion. The first uses malt or an extract of the enzymes contained in malt and the second uses dilute acid in a process called "acid hydrolysis".

MILLING

Grains and similar starchy materials must be milled to expose the starches to the cooking, conversion and fermentation processes. The ideal is to grind the material as fine as possible without producing an excessive amount of flour. This is because fine (flour) particles are difficult to remove if the material must be filtered prior to distillation. Again, if you are using a simple pot still, the material need not be filtered and the presence of fine flour particles is not objectionable.

Large amounts of flour can also make the mash too viscous (thick) and hard to handle. This is only objectionable if it must be pumped from container to container or otherwise handled. If you are doing everything in the same pot, the viscousness can often be tolerated. Otherwise, premalting, as discussed later, will solve the problem.

Almost any kind of grain-milling equipment can be used, or the grain can be milled by your local feed plant. Unfortunately, there is no alternate process, and if you are going to use grain as your feedstock, it will have to be milled.

COOKING

Cooking is necessary for all starchy materials. The object is first to dissolve all the water soluble starches and then, as much as possible, gelatinize them.

In commercial operations, cooking is almost always done with steam, under pressure, and usually in a continuous process. Water boils at 212 deg Fahrenheit at sea level and at a lower temperature as altitude increases. By using pressure cooking equipment, higher temperatures and shorter cooking times can be obtained. At 150 pounds pressure, for example, grain starches can be cooked in six minutes or less. Large scale pressure cooking equipment is expensive and, in this manual, the cooking times for various materials will be given for the "atmospheric" process where temperatures are in the 208-212 deg range. Cooking times for different materials are listed under the individual feedstocks in Chapter 10.

Because a lot of energy is needed to boil the water used in the cooking process, it is best to cook with as little water as possible. Then, after cooking, additional water may be added to dilute the mash to optimum concentration for fermentation. If the additional water is added at a time when it is desirable to cool the mash, for example after cooking and prior to conversion, cooling time is saved. Most grains can be cooked with as little as 15-20 gallons of water per bushel. Note that when cooking with minimum water, special attention must be given to stirring the mash. Otherwise lumping and burning may occur.

New methods of cooking are being developed that help to conserve energy. The most interesting is a method that combines milling and cooking into one operation without the use of water. The process uses heat generated by friction in the milling process to simultaneously cook the grain. It is all done in a specially designed grain mill.

CONVERSION

Conversion is the process of converting starch to fermentable sugars. It can be accomplished either by the use of malt, extracts of the enzymes contained in malt, or by the treatment of the starch (or cellulose) with acid in a process called "acid hydrolysis". Each method is discussed separately.

MALTING

Starch can be converted to fermentable sugars by the action of enzymes in malt. When the seeds of any cereal grain are moistened and allowed to sprout, certain enzymes (amylases) are produced which have the ability to convert starch to a form of fermentable sugar called maltose. All cereal grains produce these enzymes to a greater or lesser degree. However, barley produces by far the most and is usually the most economical to use.

You can either purchase dried, ground barley malt, or you can produce your own from the grain. However, undried or "green" malt, such as that you might produce yourself, will not keep unless dried. On a small scale, it is often better to use the commercial product.

In converting starch to sugar, malt enzymes exert two forms of chemical activity: liquefaction and saccharification. The intensities of these two activities depend on the temperature of the mash. The liquefying power is greatest at about 158 deg Fahrenheit. It begins to weaken at 175 and ceases at about 200. The saccharifying (sugar making) power is strongest between 120-130 deg F. and is destroyed completely at 175 deg. Both of these actions are desirable. Therefore a compromise must be made. The conversion process is therefore usually begun after the cooked mash is allowed to cool to about 150 deg F. The material is held at this temperature for a certain length of time (depending on the material) and then allowed to cool to the optimum fermenting temperature.

The average malting recipe calls for the use of between half to 1 pound of dried malt for each 10 pounds of grain. Again, specific recipes are covered later. The dried malt is usually mixed with warm water at a ratio of about 2.5 pounds per gallon to form a slurry. This slurry should be mixed about an hour ahead of time and added to the mash when it cools to the proper temperature.

Because barley malt is expensive, usually more expensive than the material it is used to convert, it is best to use as little as possible. The minimum amount can be determined after several trial conversions. To do this, make a trial malting using the amounts listed in Chapter 10. Then take a little of the converted mash and filter it through a cheesecloth or some similar material. Place a little of the filtered liquid in a white dish and add several drops of a solution composed of 5 grams potassium iodide and 5 grams of iodine crystals in one quart of (distilled) water. Any blue color produced indicates the presence of unconverted starch. Naturally, if the test indicates no blue color, the next trial should be run with less malt and vice-versa. The test solution can be compounded by your local druggist or the chemicals can be purchased from any laboratory supply house.

PREMALTING:

During the cooking process, the starch in the grain is gelatinized. When the mash is cooled, it may become too thick to be stirred and handled effectively during the malting operation. The technique of premalting cures this problem by taking advantage of the liquefying properties of malt prior to the conversion. To premalt, simply add about 10% of the total malt weight to the mash prior to cooking. This causes sufficient liquefaction to facilitate handling the mash during subsequent operations. It also helps to prevent thermal destruction of the malt enzymes later on and so reduces the production of undesirable by-products. After cooking, the remaining 90% of the malt slurry is added, and the conversion is continued as usual.

PREPARATION OF MALT

The following is a basic process for making malt, for those who prefer to prepare their own.

Any grain can be used to make malt, but as stated before, barley is by far the best.

However, if you are working with corn, for example, you can simply set aside about 20% of the grain, prepare a malt as described below, and use it in the same way you would use barley malt. The same is true of similar materials.

Malt is simply sprouted grain. The basic requirements for sprouting are moisture, warmth, and darkness. Grain can be sprouted in anything from a five-gallon plastic pail to a 55-gallon drum. The container should either have small holes poked in the bottom or, with larger containers, a valve protected by a screen or mesh that will allow water to drain but retain the material being sprouted.

Begin by soaking the grain until the kernels can be crushed between the fingers and the inside is soft. This takes about 8-12 hours for barley and considerably longer for corn. Then drain the water. Thereafter, sprinkle the grain several times a day with warm water. The object is to keep the grain moist but not wet. If too wet, the grain will rot. After a watering, the water will work its way down through the grain and out the holes (or valve) in the container. The sprouting will generate some heat. The optimum temperature for sprouting is about 80 deg F. but the most enzymes seem to be produced at about 60 deg F. When sprouting in large containers, be careful that the grain doesn't get too warm. If it does, it can be spread out on a concrete floor in a dark place and the sprouting continued. Small containers will not have the problem of too much heat.

Sprouting will take about 4 days. The malt is ready when the sprout is about a half inch long.

Prior to use, the malt will have to be crushed. This can be done in a mill or, on a small scale, a heavy duty garbage disposal can be adapted. It is also possible to use an ordinary blender or food processor.

Fresh, undried malt is called "green" malt. it Must be used immediately or dried because it will rot if stored wet. It should be used in the same manner as dried malt, and it is not usually necessary to adjust the recipe to allow for the green malt's moisture content because the green malt is slightly more potent.

ENZYME CONVERSION

The enzymes contained in malt are available commercially from several manufacturers. The procedures for using them are very similar to malt conversion. In addition, the use of enzyme extracts is usually superior to malt.

First of all, the enzyme extracts are usually cheaper. They are also specifically designed for the job at hand, and they generally produce more predictable results and higher yields.

The three basic types of commercially available enzymes are alpha, beta, and gluco amylases. Alpha amylases randomly split the starch molecules to produce a type of sugar called dextrose. Beta amylases act similarly to produce maltose. Together, these two enzymes can convert about 85% of the starch to fermentable sugar. Gluco amylases can reduce the remaining starches, and the use of all three can achieve almost total conversion of the starch.

The two principal manufacturers of enzymes suitable for starch conversion are Miles Laboratories and Nova Laboratories, as listed in the appendix. Enzymes are used in much the same manner as malt. However, because different enzymes require slightly different pH, times, and temperatures, it is best to follow the recommendations of the manufacturer. A typical recipe for the use of Miles Laboratories "Taka-Therm" and "Diazyme L-100" for the conversion of corn is included in Chapter 10.

ACID HYDROLYSIS

Starch (and cellulose) may also be converted to fermentable sugars by the action of acid.

This process is relatively simple, but it requires acid proof equipment, high temperatures, and the handling of acid. For these reasons, it is not really recommended for small scale production.

Basically, dilute mineral acid (usually sulfuric) is added to the grain slurry prior to cooking at a concentration of 1-4% as calculated on a weight/weight basis. The mash is then cooked at a temperature of about 350 deg F.

Cooking and conversion of the starch take place simultaneously. The mash is then immediately neutralized with calcium hydroxide (lime), or some other base, and fermented in the usual manner.

The high temperatures essential in this process are obtained by the use of pressure cooking. The steam pressure required is about 150 pounds per square inch. This, together with the necessity for acid proof equipment, make this process unsuitable for small scale use. However, it is an excellent process for large operations because cooking and fermentation times are short and the method is readily adaptable to continuous operation.

MASH COOLING

Malting is conducted at a temperature of about 145-150 deg F. As is discussed later, fermentation is commenced at an optimum temperature of 70-80 deg Fahrenheit. Between the two steps the mash must be cooled.

One of the biggest problems affecting alcohol yield is bacterial contamination of the mash either before or during fermentation. The chief protection against this is the pH or acidity control of the mashing and fermentation operations. However, even with perfect pH control bacterial infections can set in. This happens mostly during the cooling stage between mashing and fermentation.

If bacterial contamination becomes a problem, the only solution (other than the obvious need for cleanliness) is to shorten the cooling time as much as possible. The less time at the temperatures conducive to bacteria growth the better. Therefore, it might become necessary to make a cooling coil as illustrated in Chapter 13. The cooling coil is the best long term solution, but if the problem only occurs occasionally, as during the summer months, a plastic bag full of ice and suspended in the mash might do the trick. Just be sure the plastic bag doesn't leak and dilute your mash!

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