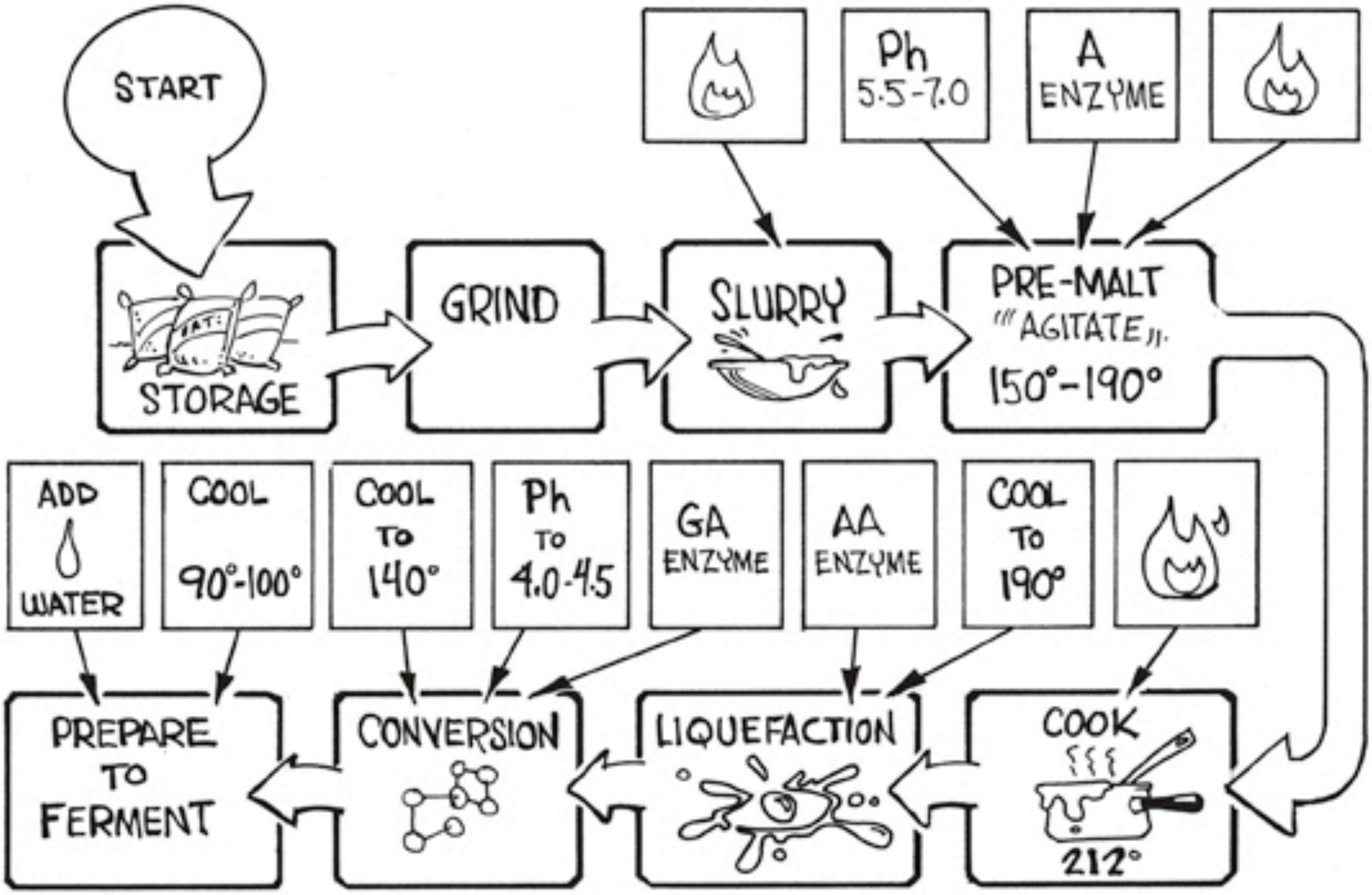


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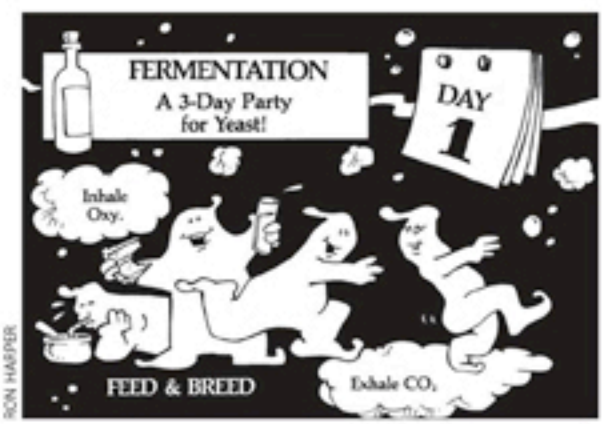
***Fig. 7-19 Starch cooking flow diagram.***

of the yeast and do not become a limiting factor. This new development is a boon to small-scale producers, as well as the big boys.

## THE KEY TO FERMENTATION: YEAST

While you may feel justifiably proud of having mastered two enzyme steps in converting starch to sugar, yeast is going to sail through 11 enzyme and co-enzyme steps in converting sugar to alcohol, without even giving it a thought. And the little creatures are going to love every minute of it. From the moment you introduce them to your wort until a moment one to three days later when they die, drunk and exhausted—all they do is eat and reproduce.

During their short lives, yeast go through two distinct phases. The first is called the aerobic phase, during which yeast breathe in oxygen, eat sugar, reproduce like crazy, breathe out carbon dioxide—and don't really produce any alcohol to speak of. Once they've used up all their oxygen, they shift to the **anaerobic** phase, in which they breathe in carbon dioxide, eat sugar, excrete alcohol, and breathe out carbon dioxide—without reproducing. (You might say we run our cars on yeast manure.)

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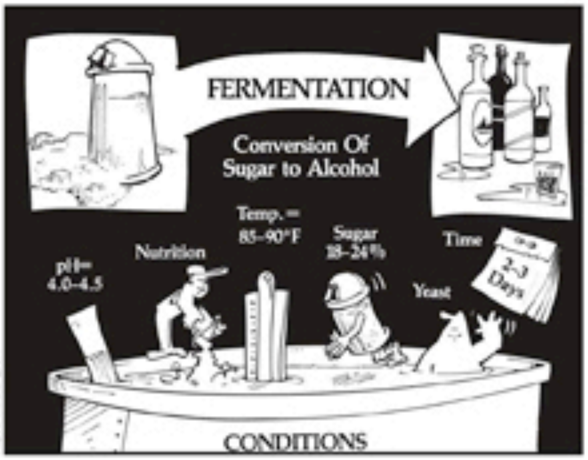
It's important to know just how much alcohol your yeast can stand, in order to figure out how much of a sugar concentrate to feed them. Yeast will use a little over half the sugar to produce alcohol, and almost half to produce carbon dioxide. Different strains of yeast will tolerate different strengths of alcohol before they die. Baker's or brewer's yeast, for instance, can stand a mash of only about 8% alcohol. Distiller's yeast holds its liquor better, tolerating up to 12% alcohol, and some special breeds can handle up to 15%. The top of the line, as you might expect, are the champagne yeasts, which tolerate (under perfect conditions)

17% alcohol. A few of the newer yeasts will go up to 23% alcohol under special conditions, but those conditions are hard to provide in a small plant. As a practical rule, you can expect most good distiller's yeasts to handle about 10–12% alcohol.

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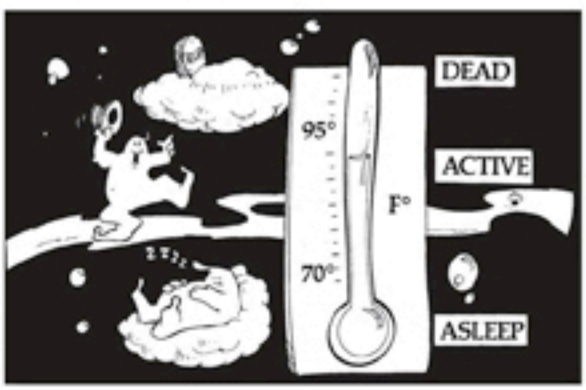
The critical factors to control in order to end up with a 10–12% alcohol mash are (does this sound familiar?) temperature, pH, nutrition, agitation, initial yeast dosages, and contamination.

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### *Temperature*

Optimum operating temperature depends on the strains produced by the yeast company. Most yeast prefer 80 to 90°F. Some good newer yeasts can tolerate 100–105°F. Below 75°F, yeast acts so slowly that it seems as if nothing's happening at all. Bringing the temperature back up often revives yeast activity. Temperatures above their optimum for a long period of time will kill yeast. Clearly, some method of temperature control is in order.

The problem of keeping yeast warm is not nearly as critical as keeping it cool, since its frantic orgy of eating and reproducing generates quite a bit of heat all its own. In fact, it's common for vigorously fermenting batches to get so hot that much of the yeast dies halfway through the process.

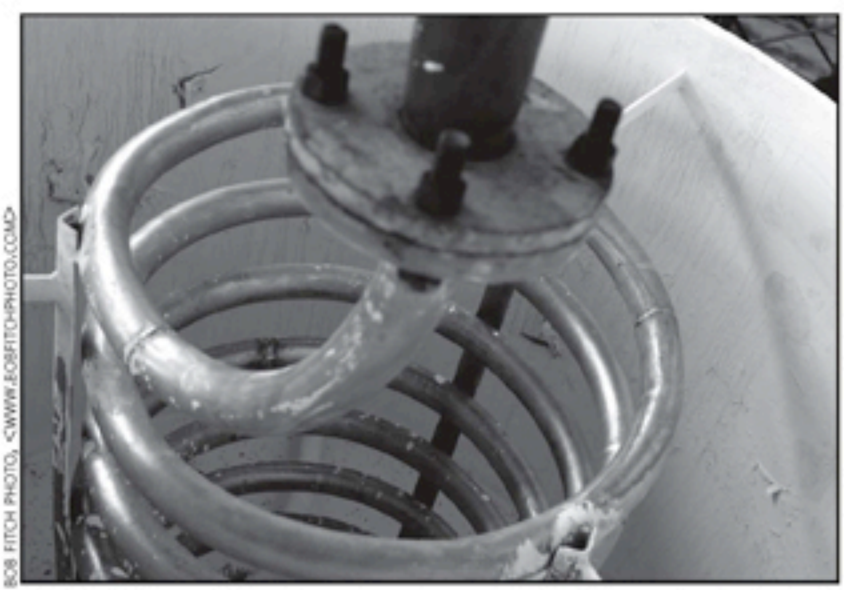
Cooling the mixture can be accomplished with cooling coils or cooling jackets. Some low-tech producers have gotten away with spraying the outside of the tank so that evaporating water cools it. If you're going to try external spraying, it's a good idea to wrap the tank with burlap first to enhance the evaporative effect.

Even better is to pump the mash through an external heat exchanger. With an external heat exchanger, you can inject pH-correcting chemicals into the mash as it passes though the heat exchanger, or bubble in oxygen for the first half hour of fermentation to further stimulate yeast growth.

The main disadvantage of internal cooling coils is that they are harder to clean and decontaminate between batches. The external heat exchanger is disinfected by pumping from a tank full of disinfectant back to the same tank, which is a form of **cleaning-in-place (CIP)** system. Caustic soda is the cleaner commonly used.

Temperature changes in fermentation are generally quite slow and really only need to be checked once or twice a day. The highest rate of heat production will happen between ten and 30 hours. This is when you want to be sure your agitation and heat exchange are at their optimum. If the fermenting mash is agitated, temperature throughout the mash can be kept more or less even throughout the tank, and temperature changes made less often.

If you want to make cooling or heating automatic, it's easy to use a temperature-controlled twin-inlet **solenoid valve** to regulate tank temperature. Plumb hot and cold water to each of the solenoid valve's supply inlets. Set the upper limit



BOB FITCH PHOTO, <WWW.BOBFITCHPHOTO.COM>

***Fig. 7-20 Fermentation cooling coil.*** *This Brazilian alcohol producer used a one-inch-diameter stainless steel coil to absorb heat from the hotter center of this non-agitated fermentation tank.*

of your thermostat for a couple of degrees below the yeast manufacturer's maximum recommended temperature, and set the lower end a couple of degrees below the optimum temperature. The hot or cold water admitted to the cooling coils controls the temperature nicely.

In practice, you will rarely use hot water, and seasonally you may wish to use insulation if too rapid a cool-down becomes a problem. A thermostat will also work to automatically start and stop the pump and **valves** of an external heat exchanger.

The new higher-temperature-tolerant yeast can make quite a difference in plant operation. Depending on air temperature, fermentation tanks may naturally cool themselves enough just through radiation of heat to stay within the temperature tolerance of 100+°F yeast.

### *pH*

Yeast used in making alcohol are very sensitive to pH levels in mash. To operate at top capacity, yeast prefer a pH of 4.0–4.5. This low pH inhibits the growth of most butyric and lactic acid bacteria. But too-low pH will inhibit yeast and reduce your yield. Yeast can tolerate pH between 3.0 and 4.0 for a few hours, and pH 2.0 for less than two hours. Tolerance of low pH drops as the alcohol level in the batch begins to rise. A pH level above 4.5 will cause your yeast to make acids and glycerol out of some of your sugar, rather than alcohol, to bring the pH down to its optimum level. It's always cheaper to adjust the pH yourself than to let the yeast do it.

The pH should always be the last thing you check before you add yeast. You should check it during fermentation, as well, to see if corrections are necessary.

### *Nutrition*

Yeast need a balanced diet of proteins and minerals. Grain mashes almost always provide this balance. Perhaps the best yeast nutrient source is backslop—what you've got left after distillation, the spent mash full of cooked dead yeast—which can provide most of the nutrients that the new living yeast need. Using backslop instead of water for about a third to half of your liquid when preparing your wort takes care of most all of yeast's nutritional requirements.

Backslop is often not a sufficient source of nitrogen, however. For instance, 25% backslop in your mash will add around 15 milligrams of nitrogen per liter, with the corn itself adding about 71 milligrams per liter. The goal is to reach approximately 100 milligrams of nitrogen per liter, so a small amount of fertilizer or malt would need to be added to get optimum results.[11] The batch will still ferment with most grains and backslop without nitrogen supplementation, but it will slow down earlier than if it has enough.

Do not use urea as a nitrogen source, since yeast will make a dangerous byproduct, ethyl carbamate (**urethane**), from it.

Instead of adding fertilizer, you can extract more usable nitrogen from **amino acids** in the mash by using protease enzymes to break protein down into amino acids, which the yeast can use as food. Some companies combine proteases with their glucoamylase (the enzyme used for saccharification of starch just before fermentation), e.g., Rhizozyme.

You can get into problems with not having enough protein or minerals for the yeast when you use straight starch, or waste fast foods, which are relatively devoid of anything other than fat and starch. (Just think—if it doesn't have enough nutrition to support yeast, what are we doing eating it ourselves?)

The type of water you use in fermentation can sometimes affect the mash. Water containing

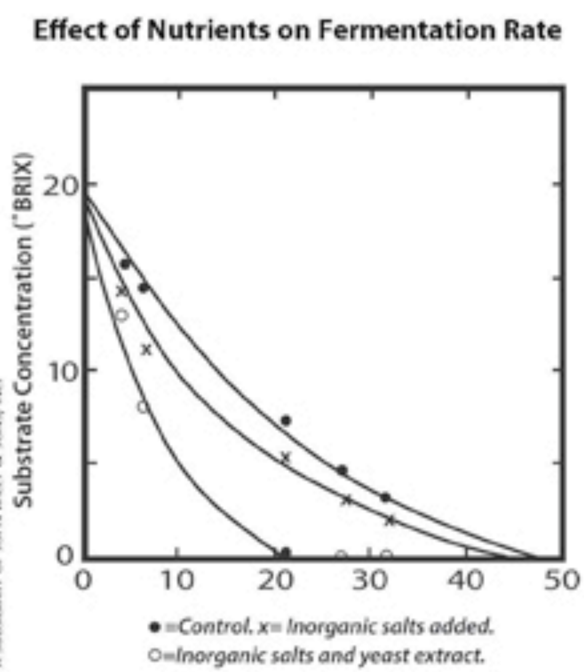





***Fig. 7-21 Effect of nutrients on fermentation rate.***[12]
*As you can see here, the combined benefits of fertilizer (inorganic salts) and yeast extract (which is contained in backslop) result in the least number of hours for fermentation.*[13]