by Ken Schramm

Optimizing Honey Fermentation

The challenge of making mead is achieving the perfect honey fermentation—clean, with zero or absolutely minimal off flavors. It optimizes the character of a spectacular honey, yielding aromatics and flavor reflecting its finest properties.

Simply, it comes down to a series of steps: pitching a vigorous, healthy yeast population, low lag times, effortless and robust yeast reproduction, successful competition or K-factor activity, and a steady, healthy ferment to completion.

Reference texts for wine production, brewing, and yeast performance and technology for the beer and wine industries number in the dozens, but at present there are none for mead. But we can begin to piece together a plan for moving mead fermentations to quality levels reserved for the finest wines and most consistent beers.

Yeast requires nutrients to grow, to metabolize sugar into ethanol and to stay healthy in the process. Everything gets into or out of the yeast cell through the cell wall, and the plasma membrane is the barrier that can disrupt fermentation or damage the cell. Membrane health is critical to maintaining healthy functions from start to finish. Keep that bugger fat and happy, and life (and your mead) is good. Fail to meet the membrane's needs, and everything deteriorates in a hurry.

Growth nutrients include carbon, nitrogen, phosphate and sulfate. Carbon is available from the sugars in the medium. Nitrogen and phosphate are problematic in mead musts.

While it has been accepted that mead musts are low in free amino nitrogen (FAN), I have been curious to know exactly "How low is low?" I set out to determine

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the FAN content of musts from four preferred meadmaking honeys. I bought Florida Tupelo and Orange Blossom from my local farmers market, and Clover (Kroger) and Buckwheat (Private Selection) from my local grocery. I contacted Dr. Ben Gavitt at the Cornell University/New York State Agricultural Extension Service Wine Lab and arranged to have the musts analyzed as well as a sample of pure cherry juice and a finished bottle of mead.

The Procedure

To approximate a standard gravity mead must, I measured 100 milliliters of honey into a sanitized Pyrex vessel, and diluted that to 400 milliliters with steam distilled water. I dissolved the mixture by stirring with a sanitized spoon, and transferred 100 milliliters of the mixture to a sterile vial. I used the remainder of the liquid to measure and record the specific gravity of all of the samples. The samples were shipped via FedEx to NYSAES Lab.

Analyses

Sample 1, the Tupelo, received a FAN analysis along with a sterility check. The other must samples received only FAN analysis. The finished mead received residual sugar analysis, ETOH, sterility check and a microbial analysis.

Gavitt reported that all samples arrived in good condition, and showed no signs of

Photo courtesy of the National Honey Board

fermentation. He indicated that while there may be variances in FAN levels due to testing regimens, the numbers are accurately representative of FAN levels in mead musts.

Results

The Florida Tupelo must had an OG of 1.110, and contained 10 parts per million FAN. The sterility check showed >1 x 10^6 yeast/100 milliliter, typical of *Saccharomyces*, but most importantly, 0 Viable Bacteria/100 milliliter. That finding indicated that the practice of preparing traditional mead musts without heat or the use of sulfites may be capable of producing a good medium for clean fermentations.

Sample 2, the Florida Orange Blossom, had an OG of 1.110, with 5 ppm FAN. The must from Pure Clover (Sample 3) also registered an OG of 1.110 and 14 ppm FAN. Sample 4, the Buckwheat, had an OG of 1.106 and 21 ppm FAN, reinforcing the widely held belief that darker

musts contain more nutrients. Still, 21 ppm is a long way from the 300 ppm most winemakers seek from a wine must destined for more than 12-percent alcohol.

Obviously, the amount of FAN in these musts is well below what is needed for a healthy fermentation. The actual FAN compounds in the honeys I had analyzed were not determined, but there is some information on amino acids in honey from Dr. Jonathon White's "Composition of Honey," published in "Honey, A Comprehensive Survey," edited by Eva Crane, Britain's master authority on honey.

TARGET NITROGEN LEVELS

Brix range of must	S. G.	Target YANC* Level
21	1.087	200 ppm
23	1.096	250 ppm
25	1.106	300 ppm
27	1.115	350 ppm

REFERENCE: Bisson and Butzke
SG Conversions: USDA Tables

*YANC is Yeast Available (assimilable) Nitrogen Content, which combines all available nitrogen from both organic (amino acids) and inorganic (ammonia or urea) sources.

Sample 5 was pasteurized cherry juice from Swanson's Juice Mill in Bear Lake, Mich. Its OG was 1.047, and it contained 262 ppm FAN, above the level of 200 ppm commercial winemakers would consider adequate for a lower gravity must. That said, most meadmakers would not use more than 1 and perhaps 2 gallons of juice in 5 gallons of must, and that dilution would leave the available nitrogen levels below the optimal range.

White documents a number of important amino acids in honey, including compounds with high yeast uptake levels such as lysine, methionine, isoleucine, leucine, and glutamic and aspartic acids. While the variety of amino acids is largely positive, their concentration in a must dilution is perilously low. Interestingly, the most prevalent amino acid in honey, proline, cannot be assimilated by yeast.

Vitamins and Minerals

As the yeast population makes the transition from growth to fermentation, its needs change to include the sugar that it will gather from the must, and vitamins and minerals to conducts its metabolism. The most critical of the vitamins is biotin, but the yeast needs thiamine, niacin, pantothenate, and the minerals magnesium, calcium, manganese, potassium, zinc, iron and copper. Many of these micronutrients are utilized in the process of transamination, in which amino acids are broken down and then reassembled by the cell to build the lipid layers in the plasma membrane. Nitrogen is also a metabolic need. During the fermentation, nitrogen is used in transporters that move sugars across the plasma membrane against the concentration gradient.

"Biotin takes part in all major biochemical reactions that involve protein synthesis, in nucleic acid synthesis, in carbohydrate metabolism, and in the synthesis of fatty acids. Its deficiency is clearly shown by poor growth and damaged plasma membranes." (Yeast Technology, Reed and Nagodawithana).

Reed and Nagodawithana document biotin levels in average beer wort of .56µg/100 ml. Levels in undiluted honey are quoted by Kitzes, et al, at .066µg/100g, which would represent one-quarter to one-third of the levels found in a honey must. Thiamine (vitamin B1) is used by yeast in amino acid synthesis. It is also needed in the sugar-to-pyruvate-to-ethanol pathway. The same two sources note levels in wort of 60 µg/100 ml, and levels in honey of ~5/6 µg/100 g. Honey musts will likely be low in pantothenate, key to the production of serine and methionine—amino acids used in the plasma membrane. Pantothenate deficiency causes yeast to produce high levels of H2S and its characteristic rotten egg smell. Lastly, riboflavin, another key vitamin, is present in wort at 33-46 µg/100 ml and in ~5/6 µg/100 g of honey.

Minerals important for growth and metabolism in a healthy yeast population include

calcium, magnesium, potassium, phosphorus and zinc, which are present in honey in minor to absolutely negligible quantities. The exception may be potassium.

Minerals are also a large part of the buffering capacity of must. Clayton Cone notes that potassium levels above 300 ppm are critical to maintenance of pH levels. Haydak, et al, reported levels from 100 ppm in light honeys (not enough) to over 4700 ppm in darker honeys (more than enough). The average of 205 ppm for light honeys, however, would predict a substantial shortfall when diluted with water at ratios of 3:1 or 4:1. When potassium levels drop below 300 ppm, pH levels in the cell can drop below 2.7, and metabolic activity will virtually cease. Especially in the case of traditional and show meads, early monitoring of the pH is a wise preventative measure. Bisson also comments on the need to establish potassium levels early, as well as the strong possibility that potassium plays a role in strengthening the plasma membrane's resistance to ethanol toxicity.

As the fermentation progresses, environmental and metabolic stress on the plasma membrane increases. Several key functions rely heavily on good membrane health, including:

1. Transport of a declining supply of sugar from the medium into the cell.
2. Transport of ethanol and CO_2 through the membrane out of the cell.
3. Maintaining resistance to ethanol absorption into the cell through the membrane against an increasingly hostile concentration gradient.
4. Absorption of ongoing metabolic nutritional needs and survival factors.

Thus it is important to build healthy cell wall mass during lag and growth phases, and to maintain it during the entirety of the stationary phase.

Fermentation Protocols

I have been utilizing staggered additions of a combination of 1 gram diammonium phosphate (DAP) and 0.5 gram Fermaid K (Lallemand's micronutrient blend) at pitch and at 24-hour intervals for three days. Fermentation times have been reduced, and the resulting meads have been of very high quality, requiring less aging to reach drinkable maturity.

Lallemand recommends rehydration of the yeast in water supplemented with the organic nutrient Go-Ferm. The yeast membranes are devoid of a number of micronutrients needed to develop the yeast biomass required for high gravity musts and the subsequent stress of higher alcohol levels later in the fermentation.

Cone stresses the importance of keeping the yeast in the growth phase. "Yeast produce 33 times as much alcohol per cell during the growth phase than it does in the stationary phase. So there is an advantage to keeping the yeast growing as long as possible. There is also an advantage to adding the DAP in as many increments as possible. This keeps the yeast growing as long as possible and also keeps a fresh supply of N available for the yeast to metabolize and build up its protein content." The yeast will also continue to absorb and utilize oxygen in the growth phase. For winemakers, the practice of pumping over would get that oxygen into the fermenting must.

The goals are to prolong the growth phase as much as possible without overfeeding the yeast, to provide a source of micronutrients and to supplement potassium levels, in particular the lighter-colored honeys with lower mineral levels. For traditional 5-gallon mead fermentations with a gravity above 1.120, the keys are:

1. Rehydration at 104º F with Go-Ferm or other organic rehydration nutrient at a rate of 1.25 grams nutrient per gram of yeast. In all cases, addition of nutrients by weight will be more accurate than by volume. Volumes are included for the convenience of those without the benefit of gram measurement devices. This equates to 3.0 lbs/1,000 gallons.
2. Addition of 3 grams (approximately 0.75 teaspoon) Fermaid K, plus 4 grams (1 teaspoon) DAP per 5 gallons of must with a vigorous aeration at the end of the lag phase (six to 12 hours, at the start of obvious fermentation activity). This equates to 21 ounces Fermaid K plus 28 ounces DAP per 1,000 gallons. For gravities above 1.125, increase these amounts by an additional 25 percent.
3. Addition of 1 gram (0.25 teaspoon) DAP, plus 1 gram (0.125 teaspoon) Fermaid K with a vigorous aeration at 12-hour intervals until 50 percent sugar depletion or five days, whichever occurs first (7 ounces DAP plus 3.5 ounces Fermaid K per 1,000 gallons).
4. Supplementing the potassium levels to a minimum of 300 ppm with a potassium source. Food grade potassium hydroxide is an option for commercial meadmakers, but its handling and use would be problematic on smaller scales. For home meadmakers, potassium bitartrate or potassium phosphate are viable options.

Role of pH in Better Detail

Drs. Roger Morse and Keith Steinkraus established many years ago that low pH in a fermenting mead must can lead to a slowdown in fermentative activity and a prolonged and unhealthy fermentation.

Bisson explains the phenomenon in her text on fermentation for her course at UC-Davis. Movement of amino acids across the cell membrane (by transporters, or trans-permeases) is coupled to proton movement *into* the cell. Those protons must then be transported out of the cell by ATPase pumps (at the expense of one ATP > ADP hydrolysis per transport). When the pH drops, additional protons enter the cell due to passive proton flux. If the number of protons inside the cell wall exceeds the capacity of the ATPase pumps in the membrane to evacuate them, amino acid uptake slows and fermentative activity is reduced.

Bisson also notes that fermentations that falter and stick can be extremely difficult to restart, making the maintenance of an appropriate pH all the more important.

No-Heat Methods, Melomels and Metheglins, and Microorganisms

In *The Compleat Meadmaker*, I make the case for preparing mead musts without the use of any heat or must sanitation processes beyond the requisite rigorous adherence to equipment sanitation. Although traditional mead musts may be largely devoid of competitive microflora, the application of that method to melomels and metheglins creates a window of opportunity for any organisms that come to the must through fruits or spices. That fruit can bring a load of microflora is obvious; less obvious is the fact that the environs in which spices are harvested—and the processes by which they are prepared for market—are rife with poor sanitary practice and opportunity for exposure and contamination.

The threat from microflora on fruit appears to be backed up by the analysis of the finished raspberry mead I sent to the Cornell lab.

Sample 6: Raspberry Mead
15.0 lb (6.8 kg) Michigan raspberries
15.0 lb (6.8 kg) Raspberry Blossom Honey
0.5 tsp DAP
0.25 tsp Fermaid K at pitch, 24, 48 and 72 hours.

Original Gravity: Unknown
Final Gravity: 1.002 (corrected to 1.009 post lab)

Analysis Data:
ETOH: 14.1%
Residual sugar: 3.7% (w/v)
Glucose: 25.6 g/l
Fructose: 11.9 g/l
Viable yeast/100 ml: 5
Viable bacteria/100 ml: >1 x 106
Comments: "Yeast typical of *Saccharomyces* strains. Bacteria are long rods forming short chains (*Lactobaccillus*)."

The bacterial population in this sample is considerable. Several possible sources of contamination include process, equipment (racking cane, bottles, cork, which receive the same sanitation practices as the "clean" sample) and the lead suspect, fruit. Possibilities are airborne and bird- or insect-carried bacteria and yeast, bug parts or extraneous plant matter. Data aside, this mead was very tasty, and was well received by different audiences at several tastings.

Fruit and spices will add organisms that compete with your yeast population, not only for food, but also for nutrition. The growth needs of bacteria and wild yeast strains are in most cases almost identical to those of your chosen/pitched yeast strain—nitrogen, oxygen and B-vitamins. If the competing microflora are at phases that allow them to consume and utilize the available must nutrients, they will have a huge advantage in their war to dominate the environment and compromise your fermentation.

My initial conclusion from this data was that the use of sulfites might be preferred to minimize bacterial contamination. On further thought, however, the recommended procedure is to prepare and initiate fermentation in a smaller honey must. For a 5-gallon batch of a fresh fruit melomel, start with 2.5 gallons of water and 8 pounds of honey. Rehydrate yeast with Go-Ferm or equivalent and water at 104º F. Aerate the must thoroughly and pitch. When the must has moved through the lag, add 3 grams Fermaid K (1.5 teaspoons). When the must is fermenting vigorously (two to three days), add the fruit or pressed fruit juice and the remainder of the honey. This will create a healthy yeast population to compete with any bacteria or wild yeast present on the fruit. Continue with staggered additions of DAP at 1 gram or 0.25 teaspoon every 12 hours, plus 0.5 gram Fermaid K (0.125 teaspoon) until 50 percent sugar depletion. These numbers can be scaled to commercial volumes.

It is important to note that microflora may be present and capable of activity beyond the point at which the yeast ceases fermentation. *Especially* in musts that may finish with considerable residual sugar because the yeast has reached ethanol tolerance, or those that finish with low alcohol levels (below 10 percent), or both, it is critically important that the amounts of nutrient used do not exceed that which will be consumed by the yeast during growth and fermentation. Excess nutrient at that point will simply serve to nourish organisms that may harm your mead.

Ken Schramm is author of *The Compleat Meadmaker.*