An Analysis of Mead, Mead Making and the Role of its Primary Constituents (reprinted with permission from the authors)

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From the bonny bells of heather,
They brewed a drink long-syne,
Was sweeter far than honey,
Was stronger far than wine.
They brewed it and they drank it,
And lay in blessed swound
For days and days together
In their dwellings underground.
R.L. Stevenson
Heather Ale

PART 1: AN ANALYSIS OF HONEY

Since such a tremendous part of the character of mead is derived from the honey we use, we thought that we should first take a look at honey, and then concentrate on those variables and components that we can control which might improve our mead making.

For the purposes of brevity, when we discuss the values of honey, those values are based on averages determined in an analysis of 490 samples of honey conducted by the Honey Investigations Unit of the Plant Products Laboratory of the U.S.D.A. This information was collected and published by Dr. Jonathan W. White[1,2], who was the chief of the Plant Products Lab, and to whom we owe credit for most of the information here. Certain floral varieties of honey may differ markedly from these averages, and we will make an effort to note when those differences should have noticeably good or bad effects on your mead making efforts.

OVERVIEW

Honey is obviously the product of the collection of nectar by honeybees. Not much is known about nectar. Perhaps the government does not think that it is worth the effort to collect it the way it pretty much has to be collected: one bee-full at time. Nectar is a complex sugar blend consisting primarily of sucrose, as well as levulose and dextrose. The bees add enzymes, and transfer the nectar to a honey stomach from which it is regurgitated into cells in the comb when they return to the colony. Additional enzymes are added, the cells are hermetically sealed, and the honey is then permitted to "ripen," meaning that the enzymatic activity occurs which gives the honey its final sugar blend. Bees do also collect pollen, which provides the protein portion of their diet, but pollen is not integral to the production of honey. The nectar source determines most of the variable characteristics about honey, including sugar balance, color, scent and flavor. The F.D.A. holds that a plant or blossom must serve as the chief floral source in order for the honey to be labeled as such.

The vast majority of beekeepers fall into the hobbyist/part time beekeeper category, with fewer than 25 hives. These apiarists account for 50% of the colonies in the country, and about 40% of domestic production. The average colony produces just under 70 pounds of honey per year. An estimated 3.2 million colonies produced roughly 250 million pounds of honey with a value of about $124 million.[3] Others, and probably more important when one wishes to obtain a single source honey, are professional pollenators. These are individuals who provide a valuable service to fruit growers by bringing their bees which pollinate their trees and plants. A by-product of this pollenation is a single source honey.

Honey is quality graded into four classes which are based on a combination of flavor, clarity, absence of defects and moisture content. For our purposes, we would recommend using only Grade A (Fancy) or Grade B (Choice).
This will be expanded on this later.

Honey is color graded into seven categories by the U.S.D.A., and these do not have any bearing on quality. Honey should not be judged on the basis of color, as some of the most distinctively and strongly flavored honeys, such as basswood, are very light, while very mild and pleasant honeys such as tulip poplar can be quite dark. Honey color is based on the Pfund Scale in millimeters; the common names for the range of standards from lightest to darkest are: Water White, Extra White, White, Amber, Amber, and Dark Amber. Honey has an average specific gravity of 1.41, which gives it a weight of about 11 pounds, l2 ounces to the gallon. Although the sugars in honey have more sweetening power, due to moisture content, honey matches the sweetening power of sucrose (table sugar) pound for pound.

COMPOSITION AND ORGANOLEPTIC EFFECTS

WATER

The moisture content of honey plays a critical role in its quality. Honey is very hygroscopic, which means that it will absorb moisture from the air. Honey, on the average, contains 17.2% water by weight. Grades A and B must not have more than 18.6% moisture. Grade C honey can contain up to 20% water, and we do not recommend it for mead making.

The reason that the moisture content of honey is important is that all unpasteurized honey contains wild yeasts. Due to the high sugar concentration, these yeasts will pose little risk in low moisture honey because osmosis will draw sufficient water from the yeast to force them into dormancy. In honey that has a higher proportion of water, the yeast may survive and cause fermentation to begin in storage.

SUGAR

Honey is comprised of many sugars, and their percentages and ratios are dynamic dependent on floral variety and storage. The primary sugars[4] contained in honey are shown below on Table 1.

Table 1. Average Sugar Content of Honey

Levulose (d-fructose)3	8.2%
Dextrose (d-glucose)e	31.3%
Sucrose (table sugar)	1.3%
Maltose (& other disaccharide)	7.3%
Other higher sugars	1.5%

The "other higher sugars" which have been identified in honey are considered to be the by- products of enzymatic activity. Since enzymatic activity begins at collection and continues from the sealing of the comb through the extraction and storage process, these sugars will inevitably be present to some degree. They include erlose, kojibiose, maltotriose, isomaltose and a host of others. Virtually all of the sugars found in honey are fermentable.

ACID

Honey's acidity is masked by its sweetness, but it is considerable. The pH of honey ranges from 3.4 to around 6.0, with the mean and mode both being around 3.9. It is important to note that the pH of honey does not directly reflect the total acid content, but rather reflects the buffering action of the inorganic cation constituents on the organic acids present.

The primary acid in honey is gluconic acid, and acids account for 0.57% of honey. Other acids include citric, malic, succinic, formic, acetic, butyric, lactic, pyroglutanic, and various amino acids. Acid content and variety in honey is very important to its flavor profile.

PROTEINS, SOLIDS AND MINERAL CONTENT

Proteins, and other solids make up 0.26% of honey, and include all of the nitrogen that your honey provides for the yeast nutritional requirements other than that which they synthesize themselves. The number and nature of the protein content is very complex with at least 19 proteins present in addition to albumin.[5,6] Protein varies widely between that honey varieties. Total nitrogen averages 0.043%. Mineral/ash content contributes 0.17% by weight, and while the mineral content is not substantial, darker honeys have been shown to be substantially richer in minerals than lighter honeys, particularly potassium, chlorine, sulfur, sodium, iron, manganese and magnesium.

ENZYMES

Enzymes[7] are very critical ingredients in honey. The sucrose contained in floral nectar is converted into dextrose and levulose (the invert sugars) by the enzyme invertase, also known as saccharase or sucrase. Invertase activity is believed to begin in the bee, and continues indefinitely barring excessive heat exposure. Diastase is also present in honey, along with glucose oxidase, catalase and phosphatases.

COLLOIDS

Colloids are suspended materials in a given medium, in our case honey. They do not settle out, and are not readily filtered. Colloids must be assumed to have appreciable affect on honey flavor, and consist of proteins, waxes, pentosans and inorganic constituents. They appear to originate both in the bee and from the floral source.

FLAVOR AND AROMA SUBSTANCES

Sadly, the finest reference materials available on honey are inconclusive on the actual flavor causing substances in honey[8]. It has been well documented that honey will take on many of the flavor and aroma characteristics of the floral source from which it is produced. Obviously, the predominating flavor of honey is the complex sweetness arising from the blend of levulose, dextrose, maltose and other sugars. This blend can vary substantially by floral source; the range of maltose runs from below 4% to above 12%, and the higher sugars ranged from 0.13% to 8.6%. These variances will have an impact on the fermentation process and its by-products in mead.

Additionally, the range of mineral content is equally wide. While there are exceptions to the rule, the higher mineral contents are paired with darker color and higher pH readings. The mineral content may actually provide valuable nutrients for the yeast during its activity. In general darker honey has been described as being stronger in flavor, and this may be the result of that higher mineral content. Sulfur, for example has been shown to exceed aroma thresholds in dark honey. To further compound the situation, sodium (a flavor enhancer) has been shown to reach 400 ppm in the darker honeys, and to be greater than 4-fold higher than that of lighter honey. The averages for potassium are more than 8-fold higher in dark honey than in light.

Other potentially influential flavor components would include the acids and their ratios, tannins, and glycoside or alkaloid compounds contributed to the mix by the floral source. Another known and recognized flavor contributor is 5-hydroxymethylfurfural, or HMF. It is a by-product of the decomposition of sugars in the presence of acids. and is a detrimental to honey flavor at higher concentrations. HMF should be below 40 ppm.

The information on aroma substances is far more complex . It leans toward the phenyl alcohols and carbonyls. ten Hoopen[9] isolated dinitropenylhydrazones by chromatography, including formaldehyde, acetaldehyde, acetone, isobutyraldehyde and diacetyl. Cremer and Riedmann[10] identified phenylethyl alcohol, propionaldehyde and acetone, and later n-pentanol, benzyl alcohol and 3-methyl-1-butanol. These compounds were present in all of the honeys which they found to be organoleptically recognizable as honey. Phenylethyl alcohol oxidizes down to phenylacetic acid, and nearly all phenylacetic esters have been described as having a honey taste and odor.

Other aroma constituents identified include the carbonyls butyraldehyde, Isovaleraldehyde, methacrolein, and methyl ethyl ketone. Alcohols include isopropanol, 2-butanol, ethanol and beta methylallyl alcohol. Esters identified were methyl and ethyl formate.

The compounds dominating the list are phenolic in nature, and could account for some of the phenolic character attributed to meads, particularly young meads. Most of these compounds have boiling points below 180 F, and would be subject to rapid blow-off during boiling. It would also stand to reason that the character which these compounds create would also be bound to the colloidal substances held in suspension in unheated and unfiltered honey.

INHIBINE

Since ancient times, the antibiotic effects of honey have been recognized by the medical community. - In 1937 Dold[11] and others measured and documented
the effect, and called it "inbibine". 25 years later, Dr. Jonathan White and others isolated the exact cause of the anti-bacterial effect: the glucose oxidase in the honey produces hydrogen peroxide as it acts on glucose to produce gluconolactone (gluconic acid). This enzyme is heat sensitive, and concentration varies with floral type.

VARIATION OF COMPOSITION BY FLORAL VARIETY

The variable composition factors which affect honey and fermentation are: Moisture content (lower moisture means higher percentage of sugar content), Percent dextrose (lower dextrose means lower crystallization), Complexity of sugar blend (higher concentrations of maltose and other sugars make for more complex flavor and aroma variations. This usually also corresponds to lower dextrose levels), pH (affects fermentation and flavor profile), Total Acid content (flavor), Ash (mineral content - affects aroma, flavor and fermentation) and nitrogen content (fermentation). This data is presented on Table 1.

Total acids are expressed as millequivalent/kilogram; it reflects amount of cationic charge produced by the acids in the solution. The average for the 490 samples was 29.12; we have weighted our assessment of each honey's acidity against that value.

Table 1. Honey constituents by variety expressed as a percentage[1]

	Citrus	Clover	Fireweed	Mesquite	Rasp.	Sage	T.Pop	Tupelo
Moisture	16.5	17.7	16.0	15.5	17.4	16.0	17.6	18.2
Levulose	30.9	37.9	39.3	40.4	34.5	40.4	34.6	43.3
Dextrose	32.0	31.0	30.7	36.9	28.5	20.2	25.9	26.0
Sucrose	2.8	1.4	1.3	0.95	0.5	1.1	0.7	1.2
Maltose	7.2	7.7	7.1	5.4	5.7	7.4	11.6	0.0
High.Sug.	1.4	1.4	2.1	0.35	3.6	2.4	3.0	1.1
pH	3.84	3.77	3.03	4.20	4.04	3.51	4.45	3.87
Total acid	30.34	26.53	26.77	16.33	39.19	29.10	42.99	36.59
Ash	0.073	0.071	0.108	0.129	0.471	0.108	0.460	0.128
Nitrogen	0.014	0.039	0.032	0.012	0.07	0.037	0.076	0.046

Citrus: By analysis of the numbers, citrus honey appears to be an excellent candidate for brewing. While the dextrose level is a bit high, moisture is low, pH is in the middle, and ash content is very low. The low nitrogen content might dictate higher than normal yeast nutrient use. Citrus honey of any blend is marketed as "Orange Blossom," and is light in flavor and very aromatic. Micah Millspaw has made some excellent mead from orange blossom honey.

Clover: The values shown here are for sweet clover honey, and the U.S.D.A. has several dozen specimens profiled in their bulletin. Moisture levels tend to run on the high side, making clover honey a candidate for quick use. As with most of the lighter flavored honeys, ash content is low, as is total acid content, which would contribute to a softer flavor profile. It looks like a great case honey for flavored meads.

Fireweed: Other than slightly lower than normal total acids and ash, fireweed honey looks like a very average honey. Fireweed honey did not express a dramatic nose or flavor, and doesn't seem to create much of a stir as a mead.

Mesquite: Not one of our experimental honeys, but a good candidate by the numbers. High pH is due to lack of total acid, not high ash buffering. This honey should ferment well with a healthy dose of nitrogen and no pH adjustment. Low moisture and acid content make for higher sugar content by weight. Low ash should mean light color and minimal offensive odor or flavor. Might require some acid before bottling for balance, especially in sweeter meads.

Raspberry: Very high ash content may make this honey somewhat suspect, although it expresses a dynamite nose and flavor out of the jar. Very interesting sugar blend should create complexity, and high nitrogen should benefit fermentation.

Sage: Another low ash, middle-of-the-road sugar blend honey. Known to be light in flavor with a delicate and inviting aroma. One to be explored.

Tulip Poplar: Tulip Poplar honey is a very distinctive honey in aroma, and although one of the darker honeys, has a mild and appealing flavor. Tulip poplar honey has a high maltose content, lending to its complexity, and, like other dark honeys, is high in ash content. Tulip poplar honey is widely available from the north to the south throughout the midwest.

Tupelo: White tupelo is the primary source for the light unblended honey sold as tupelo honey. It has a very high levulose content, low dextrose and high maltose count, which make it attractive to brewers. Low ash, high Acids and moderate pH.

Wildflower: The range of honeys sold as "Wildflower" is too great to he characterized by one broad brush statement. The U.S.D.A. included 57 "blend of floral source" honeys in its study, with pH values from 3.67 to 5.30, ash contents from .054 to .615, and other swings in other categories. Our experience with the wildflower honey in our batch was not particularly favorable, and I suspect too much mineral content, but some of the honeys had values which looked very conducive to good mead. Caveat Emptor.

Commercially Blended Honey: The drawback to much commercially blended honey
is that it has been heat pasteurized, albeit at temps in the 145 F range.
The upside is that the honey is generally buffered through blending to a pH around 3.9, is light amber in color and therefore free of excessive mineral content, and has been blended to have a neutral palate and nose. It makes a good base honey, frequently providing quality grading which assures low moisture content, and color grading for ease of use and good record keeping.

Other Interesting honeys Several other honeys stood out in the study as having interesting characteristics.

Japanese Bamboo: High Maltose, higher pH, low to medium ash, high nitrogen.

Alfalfa: high dextrose, low ash, low nitrogen.

Blackberry: High pH (5.0), high Maltose (11.3%), high ash, high nitrogen.

Blueberry: High Maltose, low acid, higher pH, high nitrogen.

Chinquapin: Low moisture, low dextrose, high maltose, very high other sugars, very high ash (.761%).

Gallberry: Low acid, higher pH (4.2).

Black Locust: High maltose, very low acid (15.54), very low ash (.052%), low nitrogen.

Peppermint: High pH (4.7), high acid, very high ash (.473)

Prune: High moisture, high maltose, pH 6.0!, acids very low (11.80), ash .694%

Sourwood: dextrose low, maltose very high, pH 4.53, acids 16.95, ash slightly high. Very interesting candidate. Highly respected among honey authorities.

Vetch, hairy: Average sugar values, low pH, low total acids, very low ash, low nitrogen.

SOURCES OF HIGH QUALITY, FRESH HONEY

Due to the unstable nature of honey, the finest honey for brewing will be honey which is fresh, and which has been extracted and packaged by a beekeeper who is concerned with the parameters of moisture content and attention to floral variety documentation which will allow you to be consistent with your recipe formulation. With more than 200,000 small scale beekeepers in the country, the likelihood of finding one in your area should be very high. If you have a local beekeepers supply retailer, he should be able to give you the names of reputable local beekeepers. We also suggest that you call your state's agricultural extension service. They can provide information on potential honey suppliers, as well as information on beekeeping clubs, which can in turn provide information on varietal honey production in your area[12].

Beyond that, however, there are other methods of securing fresh varietal honey in bulk at reasonable prices. Farmers' markets generally have at least one quality honey provider; Detroit's Eastern Market has four. If you develop a relationship with a packager, he will frequently be more than happy to keep you up-to-date on what is fresh, and which honeys are particularly attractive at which time of the year. Many beekeepers will have a first extraction of water white premium honey during the spring, and we have found this to be an excellent source of brewing stock.

Local suppliers are unlikely to provide a full range of floral varieties, and for that you will need to contact a good packer.

The National Honey Board has a Honey Suppliers Directory which provides tremendous information. Good bulk suppliers would be the Bees Knees Honey Factory in Portland, Oregon or the Glorybee Sweetener Company in Eugene; Dutch Gold Honey in Lancaster, Pennsylvania; Sandt's Honey in Easton, Pennsylvania; McClure's Honey and Maple products in Littleton, New Hampshire; Highs Hill Honey in Crossville, Tennessee, and Drapers Super Bee Apiaries in Middleton Pennsylvania. We are sure there are others, but all of these companies list good selections of varietal honey.

We also suggest you check out the WORLD HONEY JAR, which is the American Head Association's publication on high quality varietal honey sources. The A.M.A. is reachable at PO. Box 17511, Boulder, CO 80308.

STORAGE AND STABILITY

Honey is not widely considered to be a fragile substance, but for the purposes of brewing, it should be considered as such. The volatility of the aroma constituents makes pasteurization an unappealing option, and there are a number of other problems which can result from age and improper storage.

>From the time the honey is produced by the bee, its constitution is in a constant state of change. Invertase is continually working on the sucrose content to convert it to levulose. There is additional evidence to indicate that as much as 9% of the dextrose may be converted to more complex sugars, thus changing the balance of levulose to dextrose.1 Additionally, gluconic acid is a primary by-product of the invertase conversion process, and other acids may be added to the blend as the result of additional enzymatic activity. Some honeys have an appreciable increase in acid content during storage. Diastase, due to its own instability, will tend to decrease in storage, and color in virtually all honey stored at room temperature will darken.

Perhaps the most hazardous of all storage problems is granulation or crystallization. Honey granulates by building up dextrose around a "crystal nucleus" of a dextrose crystal, dust particle or pollen grain, and will crystallize most rapidly when stored at temperatures between 50 F and 60 F, (the optimal temperature for initialization of crystallization is 41 F to 45 F). Crystallization is particularly hazardous to unpasteurized honey because the concentration of solids around the crystal creates a higher moisture content (above asthe critical 18 - 19% level) in the residual uncrystallized honey. This in turn promotes fermentation, resulting in alcohol and, in the presence of oxygen, the alcohol will break down to acetic acid and water. If crystallization is present, and a distinct separation of solids and liquids is apparent, your honey is at distinct risk of fermentation. The end result is honey which is sour and definitely not conducive to premium mead creation. The moral of the story is, don't buy your honey in August, put it in the basement at 55 degrees for months, and then haul it and brew with it when its old and crystallized. Unless it's there and the only option is tossing it.

All of these problems can be avoided through immediate use of fresh honey, or through proper storage of your honey. The ideal temperature for long term storage is 0 F or below, as honey kept at very low temperatures, even for prolonged periods, shows little or no degradation of flavor, color, aroma or its other physical properties. If freezing is not an option, short term storage between 61 F and 80 F is the best option, and storage above 80 F will cause particularly rapid deterioration of color, flavor and enzyme content.

SANITATION METHODS

Heat

There is a continuing battle over the practice of eliminating risk of infection by a full boil or by heating to a lower temperature for a prolonged period. The Pros of boiling include guaranteed elimination of biological contaminants and the proverbial "hot break" which will remove protein and other colloidal materials in the honey, and the potential for using your heat to sanitize fruit or other potentially infecting ingredients. The negatives include the driving off of all volatile aroma compounds, which give fresh honey its distinctive aroma.

On the other side of the debate is "super-heating," which is generally agreed to be effective if done to the 190 F range for 10 to 20 minutes. I have used this method with good results, however there is evidence to indicate that the wisdom regarding superheating may not be correct. Initially, I would state that the hygroscopicity, low pH and hydrogen peroxide content make honey a poor candidate for bacterial infection. Therefore the biggest danger of infection comes from the wild yeasts which are present in honey, especially that honey extracted from combs which spent a long period of time unsealed or stored in the hive, such as honey from the previous growing season. Yeast counts can range from 0.1/gram to 100,000/gram, making yeast control a major consideration.

Minimum Conditions Required to Kill Yeasts in Honey

The temperatures and exposure times needed to kill yeasts in honey have been proven to be far lower than we mead makers have been using. Dr. White has noted that honey heated at 145 F for thirty minutes will be free of yeast contamination. The actual time required to kill yeast is 22 minutes at 140 F, and drops well below 5 minutes at 150 F and above. Using temps in the 145 F range will preserve many of the aroma compounds, and cuts down on time, fuel usage and the hazards of dealing with large volumes of boiling-hot concentrated sugar water. As shown in the following graph, sufficient pasteurization may be achieved in as little as 1 minute at 155F. (Data taken from White, J.W., The Hive and The Honey Bee, pp 513.)

Sulfites

The use of Sulfites to produce quality meads has the advantage of ease and lack of heating (avoidance of driving off desirable aroma compounds, no color change). The minimum threshold for adequate sanitation is 70 ppm, which equates to 0.4 grams per gallon at pH 3.5. We have seen and tasted many superior meads produced by this method; Dr. Bill Pfeiffer, a past A.H.A. National Homebrew Competition Head Maker of the Year swears by it, and his meads are wonderful.

Nothing

No sanitation at all is one of the experimental efforts which we intend to pursue, but if you are interested in using this method, we would recommend that you make an effort to obtain honey which you know was produced and capped by the bees in short order. This could be accomplished by finding a local beekeeper who is using his hives for pollination of high nectar producing species such as citrus or tupelo.

Sterile Filtration (Ultrafiltration)

We have had the chance to taste some of the meads produced by Dr. Robert Kime, Cornell University. He is the foremost advocate of ultrafiltration[13], which involves filtering with a 50,000 molecular weight filter to eliminate not only bacteria and yeasts, but all colloidal materials and some proteins as well. This has produced meads of astonishing clarity which are absent of virtually any flavor or aroma defects. His data indicate that meads produced by this method are preferred by 80% of a tasting panel when compared to meads produced by more conventional techniques.

The drawback of this process, by our subjective analysis, is that some and perhaps many of the distinctive and appealing honey characteristics are also removed. Granted these meads are smooth and pleasant in a very short period of time, but some of the character seems scrubbed out. True, Dr. Kime did win Best-of-Show in the First Mazer Cup, but the winner was a pyment of Vignoles grapes, which was very pleasant and vinous, but not dominated by honey character. This would lend credence to the argument that the colloidal content of the honey has dramatic and important effects on flavor and aroma. We believe that Dr. Kime's offerings certainly have commercial potential, but in much the same way that most commercial wines have established markets in the U.S.

GENERAL MEAD REFERENCES

Brewing Mead, Gayre, R. & Papazian, C.
All About Mead, Andrews, S.W.
Making Mead, Acton, B. & Duncan, P.
Making Wines Like Those You Buy, Acton, B.
Zymurgy
American Mead Association
Mead Lovers Digest

PART 2: AN ANALYSIS OF MEADMAKING

INTRODUCTION

Honey is a remarkable liquid. Made by humble insects, it is far more than a simple mixture of sugars. Honey contains, in addition to a rather complex mixture of sugars, enzymes, proteins, organic compounds and trace minerals. It is these interesting compounds, present in minute quantities that give honey its distinctive flavor and characteristic aromas. Many of these are carried over into a mead produced from these honeys and lend a similar, recognizable distinction to the finished mead. To produce a high quality, complex beverage from honey it is our aim to preserve as much of these distinctive flavors and aromas as is possible.

The subtle nature of honey allows a great deal of latitude in additives designed to enhance the character and complexity of mead. We have experienced a great number of fruits, vegetables, herb and spices added to a basic mead with both overt and subtle results. Thus the addition of various materials leads to a subset categorical divisions. Show mead is defined as a beverage produced by the fermentation of honey alone. Nutrients and additive are allowed, but no additional spices, fruits or herbs. In traditional mead small amounts of fruits, spices and herbs are allowed, but they must never overpower the honey flavor and aroma. These additives are to play a supportive role at or below the taste threshold. Pyments, Cysers and Melomels are meads which include the addition of grapes, apples and other fruits respectively. Metheglin is a mead to which spices have been added. Hippocras refers to a spiced pyment, and finally Braggot is a concoction consisting of honey and malt sugars. Clearly there can be many subclasses of these categories, and therein lies the challenge in judging a mead competition. For instance, how and in what category should one judge a cherry braggot,or who determines the threshold levels of a spice?

The history of honey and the making of mead is a long and rich one, but unfortunately outside of the scope of this article. An excellent source by Gayre[14] has been recently published and is highly recommended reading.

HONEY

Many authors recommend the use of fresh honey that has undergone the least processing possible. With this information we heartily concur. Honey blends may be consistent, a good base honey for fruit meads, and offer repeatable results, but it is our contention that far more interest, variety and complexity can be achieved through the use of pure honey sources. These can then be blended by the meadmaker to adjust deficiencies, dilute over range constituents or add pleasing aroma and flavor combinations.

WATER

Water for mead making varies both due to the source and to the composition of the mead. Honey contains quite variable concentrations of minerals and ash, water contains quite variable concentrations of minerals. The secret lies in selecting a honey/water combination hat provides an acceptable balance in the finished mead. High mineral waters clearly are not desired in high ash honeys. Conversely, since yeast requires a certain amount of minerals to prosper, a low ash mead and a low mineral water would also prove unacceptable.

NUTRIENTS

Yeast require nitrogen in the respiratory phase of growth. Since honey is a poor source of nitrogen mead fermentations without adequate nutrition are notoriously slow. The addition of yeast nutrients (diammonium phosphate), yeast energizer (diammonium phosphate, magnesium sulfate, yeast, folic acid, niacin, sodium pantothenate and thyamine) or yeast hulls is very important to promote complete fermentation. These materials are readily available and their use is encouraged.

ACID

The use of acids citric, malic, tartaric, acid blend, or lemon juice has been recommended by many authors to balance any residual sweetness in the finished mead. We agree that some sweet /acid balance is desirable, but feel that it is optional. Furthermore, the addition of acids pre-fermentation can reduce the pH of the honey must, resulting in a sluggish fermentation. The pH of honey is already low, and since there is very little buffering capacity, when fermentation commences, the pH drops to a range at which the yeast slows. We will expand on this point in the following section. It has been our experience that addition of acid to a finished mead is a more reliable method to achieve the desired sweet/sour balance.

TECHNIQUES

Among the more controversial topics in mead production is that of treatment of must prior to fermentation. We will discuss the benefits and drawbacks of many of the methods available to the small scale producer. These methods include boiling, sulfiting, pasteurization, sterile filtering and no treatment whatsoever. Many excellent texts are available that provide step-by-step methods to produce high quality meads.[15]

Many authors have advocated boiling the must. While this technique does possess some distinct advantages as far as coagulation and subsequent protein removal is concerned, resulting in a more rapid clarification, there are valuable losses of aroma components that are driven off in the boil. A technique in which the must is briefly boiled, just long enough for the coagulated protein to be removed then rapidly chilled, offers a good compromise. This method is simple and straight forward and the authors continue to recommend it to beginning mead makers with good success.

The use of Sodium metabisulfite or Campden tablets offers the distinct advantages of no heating and thus no aroma volatilization. This method is also the most rapid in that the honey may be simply mixed with water and then sulfated. Yeast may be pitched the following day. Major disadvantages are that some people are sensitive to these compounds, proper adjustment of addition requires both an accurate scale and an accurate pH meter and these compounds tend to bleach fruit. Another disadvantage is that the proteins are not removed and the meads may require fining to clarify.

The pH of the must effects the amount of free SO_2 present, thus must be taken into account. Table 2 shows the recommended levels of SO_2 to treat white wine and these values may be directly substituted in a mead. Although these values represent the optimal levels of sulfite, the authors tend to err on the short side of the equation, adding at most 1 Campden tablet/gallon. Each Campden tablet contains 0.44 grams of sulfite, so for those that have an accurate balance the weight in grams of sodium or potassium metabisulfite may be calculated from the table.

Table 2. pH effect on sulfite additions[16]

pH of must	ppm SO_2	tablets/gallon
3.0	40	2/3

3.2	60	1 1/3
3.4	70	1 1/2
3.6	80	1 2/3
3.8	120	2 1/2

Pasteurization is the method recommended by the authors. It is safer, more rapid and less equipment dependent than other methods and offers a compromise between sanitization and loss of aroma compounds. A disadvantage is that the proteins are not removed and the meads may require fining to clarify. For the experimental batches made in preparation for this article we simply brought the water to a boil and added the honey, allowing the temperature to settle at approximately 160F. In retrospect, this may have been somewhat higher than needed as data from White3 suggests that as little as 22 minutes at 140F is sufficient to kill wild yeasts.

FERMENTATION

A major issue in mead fermentations is the notoriously long time it can take to reach completion. Fermentation rate is dependent to some extent of the honey variety, but through proper selection of yeast strains, agitation during fermentation, yeast nutrition and control of pH, one can dramatically increase the fermentation rate. Therein lies another controversy; clearly, commercial operations are interested in rapid fermentations. As small scale mead makers, perhaps the economics of capital tied up in fermenters is not so problematic. Of more significance is the effect on flavor. There are some that find the flavor of mead that has had a long, slow fermentation on the yeast objectionable due to the taste associated with autolysis. Others find the taste familiar and similar to that of a fine sur lie Champagne in which the toasty/yeasty flavor of autolysis is a welcome and integral part of the taste profile. The authors prefer a more relaxed approach which favors long fermentations, although recently we have been experimenting with accelerated methods.

The single most significant factor effecting the rate of mead fermentation is yeast health. This may be ensured by providing adequate nutrients in the form of yeast energizer and yeast nutrients well as careful monitoring of the pH throughout the fermentation. Most of the required nutrients are available in the commercial preparations, but other additional nutrients that may be helpful such as biotin, pyridoxine and peptone. Morse[17] found that the most rapid fermentations were achieved when a balanced salt, buffer and nutrient additive was used. They report fermentations to 12% alcohol in less then 2 weeks by using 6.75 g/L of formula 1 and 0.25 g/L of formula 2 as shown below on Table 3.

Table 3. Nutrient Mixtures for Mead Fermentations.

Formula 1 Component	Weight/gr.	Formula 2 Component	Weight/mg
ammonium sulfate	1.0	biotin	0.05
K3PO4	0.5	pyridoxine	1.0
MgCl2	0.2	mesoinositol	7.5
NaHSO4	0.05	Calcium pantothenate	10.0
citric acid	2.53	thiamin	20.00
sodium citrate	2.47	peptone	100.0
		ammonium sulfate	861.45

The pH of honey is naturally low and since it is poorly buffered, upon fermentation the pH may drop to a point at which the yeast is unable to ferment efficiently. The addition of a basic buffer helps greatly by holding the pH to 3.7-4.0 throughout the course of the fermentation. The authors have had success fermenting a mead to completion in 2 weeks simply by providing adequate nutrition (yeast energizer), oxygen saturation of the cooled must and the addition of calcium carbonate to hold the pH above 3.7. Other salts that may be used include potassium carbonate and potassium carbonate.[18] Care must be exercised because all of these salts can add a bitter/salty flavor if overused and therefore minimum use of these compounds is recommended.

YEASTS

A large number of yeasts are now available to the small scale meadmaker for conducting the fermentation. Most wine yeast strains will perform nicely, and indeed some are very good at fermenting low nutrient musts. There are several commercial sources for high quality mead yeasts and most of these are now available as pure cultures on slants, thus eliminating bacterial contamination commonly encountered in the dry yeast packets. We have discovered, however, that bacterial contamination is a minor issue in mead fermentations. Of far greater consequence is the potential for post-fermentation contamination during processing or storage with acetobacter species that may result in the production of honey vinegar. Most of these problems can be prevented with good sanitation practices, prevention of aeration during transfer or preventing oxygen from reaching the mead by keeping carboys or barrels filled.

Since meads generally start out with high sugar content (on the order of 20%) it is prudent to pitch a large volume of yeast, we recommend pitching the slurry from a starter prepared that is 10% of the volume of the main fermentation.

THE EXPERIMENT

On May 2nd 1993 we made 65 gallons of mead in a single, long afternoon. All yeast was obtained through Yeast Lab or The Yeast Culture Kit Company, and all were pure cultures from slants or normal production runs in the case of Yeast Lab M61 and M62. All honey was obtained locally or by mail order and in each case we attempted to purchase the least processed form. In many cases this was unfiltered and unprocessed therefore we were handling crystallized bricks rather than liquids. All meads except batch 13 were made to the same recipe: 2.5 lb/gal honey, 0.4 t/gal malic acid, 0.4 t/gal tartaric acid, 0.4 t/gal yeast nutrient and 0.2 t/gal yeast energizer. OG fell in the range of 1.092 to 1.094, pH 3.55-4.0, TA 0.2-.25. For the blended batch (13) we added all the remaining honey leftovers and then diluted with water to obtain an OG of 1.130. The procedure was the same for all batches: we brought the proper amount of acid treated water to a boil, added the honey and allowed it to pasteurize for 15 min. at 160-170F, cooled to 70F and ran it out into a carboy.

Here is an outline of the project:

#	gal	Honey Variety	Yeast
1	5	Clover	Yeast Lab M61-dry mead
2	5	Clover	Yeast Lab M62-sweet mead
3	5	Clover	Yeast Culture Kit Co.-Riesling
4	5	Clover	Yeast Culture Kit Co.-Epernay
5	5	Clover	Yeast Culture Kit Co.-Prisse de Mousse
6	5	Clover	Yeast Culture Kit Co.-Tokay
7	5	Wildflower	Yeast Lab M61-dry mead
8	7.5	Fireweed	Yeast Lab M61-dry mead
9	5	Orange blossom	Yeast Lab M61-dry mead
10	5	Snowberry	Yeast Lab M61-dry mead
11	5	Wild Raspberry	Yeast Lab M61-dry mead
12	5	Starthistle	Yeast Lab M61-dry mead
13	7.5	Blended	Yeast Lab M61-dry mead

We used four 15.5 gal stainless steel kettles equipped with either propane or natural gas burners. Crystallized honey proved to be difficult to work with on the 60 lb scale. The only other minor problem aside from slight confusion during visitation by neighbors (what ARE you doing?), friends (so what is the OG, TG, TOH, style of beer, of this batch?), daughters (Daddy PLAY with me), wives (explicative deleted) and occasional hungry hornets (Yikes), was a live ant that was fished out of the cooled honey must. After a short dinner break at 8PM (we barbecued chicken at the same time), we had everything washed by 9PM. All carboys were carried down into the basement and the yeast cultures pitched at 9:30. Arranging and re-arranging the carboys on the floor so they sat on an insulation of Styrofoam, produced a pleasing array of hues that ranged from almost water-white (starthistle) to amber (wild flower). After pausing to ponder and admire the magnitude of our work, we parted, very tired but very satisfied.

Fermentations were all active within 12 hours and were allowed to proceed at ambient temperatures until the following Spring. The ambient temperature ranged from 50 to 70F depending on the season and was complete by the end of the summer. We made no attempt to achieve a rapid fermentation in this experiment. Two of the batches spontaneously cleared at 7 months: those clover meads fermented with Eperney and Prisse de Mousse yeast. All were treated with Bentonite and racked to secondary the following winter. No further clarification was seen, therefore Sparkeloid was added to all of the carboys. Absolute clarity was observed within 4 days in all batches.

The individual batches were racked to a kegs, blanketed with CO2 and allowed to condition at cellar temperatures. We have done some taste tests on the finished meads and will share the analysis and the meads at the 1994 AHA National Conference.

1. White, J.W.Jr.,et al., Composition of American Honeys, USDA Technical Bulletin #1261, 1962.
2. White, J.W.Jr., Honey, Adv Food Res., 24:287-374, 1978.
3. Humann, M., Honey Industry Facts, National Honey Board, Longmont, CO. 1991.
4. White, J.W.Jr., The Hive and the Honey Bee, .
5. Marshall, T., Williams, K.M., Electrophoresis of honey: characterization of trace proteins from a complex biological matrix by silver staining, Anal Biochem., 167(2):301-3, 1987.
6. Bergner, K.G., Diemair, S., Proteins in honey. I. Separation and concentration of proteins in honey, Z Lebensm Unters Forsch, 157(1):1-6, 1975.
   Bergner, K.G., Diemair, S., Proteins in honey. II. Gel- chromatography, enzymatic acitivity and origin of honey-protein, Z Lebensm Unters Forsch, 157(1):1-6, 1975.
7. Stadelmeier, M., Bergner, K.G., Proteins of bee honey. VI. Isoelectric focusing of amylase in various kinds of honey, Z Lebensm Unters Forsch, 182(1):25-8, 1986.
8. Crane, E., Honey, A comprehensive Survey, Heinemann, London, 1979.
9. ten Hoopen, T., From Crane, E., Honey, A comprehensive Survey, Heinemann, London, 1979.
10. Cremer, From Crane, E., Honey, A comprehensive Survey, Heinemann, London, 1979.
11. Dold, From Crane, E., Honey, A comprehensive Survey, Heinemann, London, 1979.
12. Who's Who In American Beekeepimng, Gleanimgs In Bee Culture, 3-7, 1992.
13. Kime, R., McLellan, M.R.&Lee, C.Y., Ultra-filtration of Honey for Mead

Production, Agricult. Research, 15:517, 1991.
14. Gayre, R., Wassail in Mazers of Mead, Brewers Publications, Boulder, CO, 1986.
15. Papazian, C., Brewing Mead, Brewers Publications, Boulder, CO, 1986.
16. Cox, J., From Vines to Wines, Garden Way Publishing, Pownal,Vermont, 1985.
17. Morse, R.& Steinkraus, K.H., Wines from the Fermentation of Honey, In: Honey.
18. Moorhead, D., The Relationship of pH and Acidity in Wine, In: The Complete Handbook of Winemaking, G.K.Kent, Ann Arbor, MI, 1993.

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