Meads and Their Lactones
A Cautionary Tale for Mead Makers
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The operative question for the Meadmaker is "how can this help me make better mead"?

Among the many factors winemakers take into account in making a well balanced and flavorful wine, acidity ranks among the highest. A wine with insufficient acidity is said to lack zip and zing, causing medium bodied or sweet wines to become cloyish. Acid, measured as TA (total acidity) and pH (active acidity), is carefully assessed and care given to the type of acid(s) present in the wine when considering acid additives.

Tartaric acid is the primary acid found in wine grapes and imparts a strong and sour taste. Malic acid is more frequently associated with apples and ciders. Citric acid is found in citric products, giving a sour and lemony flavor to a fruit or country wine. Gluconic acid is the primary acid found in honey and, of course, in mead but stands apart from the other organic acids due to its unique properties. Although these properties are well known to honey analysts and the honey industry, oddly enough the literature on meadmaking is silent on the subject. This is all the more striking given the highly complex reactions of gluconic acid in the chemical makeup and flavor profile of mead.

The easiest route to outlining acidic properties in honey is to briefly look at how honey bees make honey. The process by which honey bees convert flower nectar to honey is truly amazing and only understood within recent decades, after much painstaking research.

Invertase and glucose oxidase, enzymes secreted from the hypopharyngeal glands of the bee, work on the sucrose sugars in flower nectar, "inverting" the sugar to glucose and fructose, and then oxidizing glucose to hydrogen peroxide and gluconolactone, the lactone product of gluconic acid. In the next step of honey production, gluconolactone partially hydrolyses to September 2002 gluconic acid, leaving both the acid and the remaining gluconolactone co-existing in a pH dependent relationship that helps to buffer against changes in acid content. If the pH of the honey is stable, gluconic acid and gluconolactone remain unchanged. If the acid is neutralized, raising the pH, more of the gluconolactone in the honey hydrolyses into gluconic acid, thus lowering the pH again. The rate of the lactone reaction is also dependent on the pH of the honey. The higher the pH, the faster the reaction takes place.

The lactone reaction causes persistent problems in honey analysis by interfering with analytic procedures using any form of acid base titration method. Long recognized as the "fading endpoint problem," honey researchers were aware that it was difficult to measure or analyze certain components of honey up through the 1940's but it wasn't until a 1958 publication by John W. White Jr. that the lactones in honey were identified as the source of the unstable pH in acid base titrations. White ran a series of experiments demonstrating the presence of the lactone reaction and devised a special method for measuring total acid content that could be used in honey analysis. This article was a critical step in identifying the complex acid properties in honey.

Home winemakers are usually interested in the more practical aspects of oenology and chemical analysis. The operative question for the meadmaker is, how can this help me make better mead? Measurements of total acidity and pH are the important parameters for acidity in home wine making, giving the winemaker a good idea of the needed counterbalance to residual sugar as well as ensuring quality of flavor profile. Meadmaking calls for use of these acid measurements, however, the lactone reaction in honey has not been examined or even considered in honey fermentations. first series of experiments. The need for a show mead was to minimize factors that could potentially skew the experimental results, such as various acids and salts from yeast nutrients. The second series was conducted with a strawberry melomel (i.e., a mead made with fruit), made with nutrient additives and yeast. The purpose of the second series was to show that the lactone reaction, once identified in the show mead, continues to persist even in the presence of other chemical factors. Both the show mead and the strawberry melomel used different honeys, orange blossom and wildflower honeys respectively. As White showed in his 1962 analysis of 490 honeys, the ratio of lactone to acid varies according to the type of honey. For this reason, it should be expected that the lactone reaction will vary somewhat according to the type of honey used in the mead.

A simplified outline of the chemical reactions are as follows:

Glucose Oxidase
$C_6H_{12}O_6 + O_2$ $C_6H_{10}O_6 + H_2O_2$
Glucose + Oxygen Gluconolactone + Hydrogen Peroxide

Hydrolizes to:
$C_6H_{12}O_6 + H_2O$ $C_6H_{12}O_7$
Gluconolactone + water Gluconic acid
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The experimental series were quite simple and can be duplicated in any home with ease. All that is required is a standard wine making acid titration kit, an electronic pH meter, mead of course, and a watch with a second hand. A solution of 0.1 N sodium hydroxide was used to raise the pH of the meads to the desired levels, then monitored with the pH meter.

Three different starting pH levels were used for each mead and the results recorded. It is important to add a measured amount of sodium hydroxide all at once, stirring it into the mead quickly in order to reach the desired pH level. The lactone reaction occurs very rapidly and may not be observed if the sodium hydroxide is added slowly. For the show mead, the pH was raised for each of the three series to 7.8, 8.8, and over 9.0 The strawberry melomel was raised to pH 5.2, 7.0 and 8.8. The results are presented in tables 1 and 2.

The trial results clearly show that for each time the pH of the mead was brought close to neutral or above, the pH dropped again to acid levels, duplicating White's 1958 observations of the action of honey lactone. In this Instance, it is the lactone present in the mead changing to gluconic acid that accounts for the drop in pH following the addition of sodium hydroxide. The rate of the lactone reaction at high pH levels made observation difficult, so difficult, in fact, that the attempt to raise the show mead to pH 9.0 was impossible to accurately record until the pH dropped to 6.4.

TABLE 1: FIRST TRIAL: SHOW MEAD

Starting pH 3.1

pH	Time (sec)	pH	Time (sec)	pH	Time (sec)
7.8	0	8.8	0	9.0	0
7.1	15	7.8	15	6.4	30
7.0	30	6.6	30	6.3	60
6.9	60	6.3	45	6.2	2 min
6.9	90	6.1	60	6.2	30 min
5.9	2 min				
5.8	30 min				

TABLE 2: SECOND TRIAL: STRAWBERRY MELOMEL

Starting pH 3.3

pH	Time (sec)	pH	Time (sec)	pH	Time (sec)
5.2	0	7.0	0	8.8	0
4.8	10	5.1	5	7.8	5
4.7	60	5.1	30	7.2	15
5.1	60	6.9	30		
5.1	30 min	6.8	60		
6.8	30 min				

The observed results of the lactone reaction in honey are simple and dramatic, in spite of the complexity of the chemical processes that are involved. Essentially what happens is that whenever the acids in a honey solution are chemically neutralized, the lactone content reacts and the solution once again becomes acidic. The reaction is well known in honey and requires altered procedures in order to perform standard chemical analytical techniques such as measuring total acidity (TA) or free amino nitrogen(FAN). The persistence of the lactone reaction in a finished mead calls for similar considerations.

As can be seen in the trial series charts, the lactone reaction in mead interferes with the titration method used in standard wine making acid kits, skewing the results and making them unreliable for measuring total acidity (TA) in mead. This is of serious practical consequence for meadmakers. Many home meadmakers will add acid to a finished mead in order to improve the flavor profile, measuring total acidity(TA) and calculating the amount of acid to add to the mead based on the results of the TA measurement. Given the unreliability of measuring TA in mead because of the lactone reaction, and especially with the wide variations in lactone content among varietal honeys, this can be a very uncertain undertaking. This is probably part of the reason why the advice given in meadmaking circles for adding acid has shifted from adding set amounts, to adding acid only to taste, if a tall. The palate was proving to be more reliable than TA measurements, even though the cause of the difficulties was unknown.

Honey has long been considered to be poorly buffered against pH changes, however, this question needs to be reconsidered in light of the lactone reaction. It seems that many of the observations regarding the poor buffering of honey fermentations were made prior to White's 1958 publication, with the assumption maintained for long afterwards in meadmaking circles. The late Roger Morse's Masters thesis, titled "The Fermentation of Diluted Honey” submitted to Cornell University in 1953 is an example of this. On page 45 he noted "Honey is a weakly buffered sugar solution which is unable to maintain a fixed pH within a few tenths of a pH unit when a small amount of acid or base is added to it." This statement was made five years prior to White's 1958 article and consequently does not take into account the lactone reaction's effects on the pH of a honey solution. Honey may or may not be poorly buffered, but this cannot be accurately affirmed without using analytical procedures that take the lactone reaction into account, and without keeping in mind the wide variations in composition among varietal honeys, including lactone content.

One of the most far reaching consequences of recognizing the lactone reaction in mead is the realization of how unique mead is in comparison with other fermented beverages. Honey as a biochemical food product stands apart from others due to a number of unusual properties. The more we learn about how bees make honey, the more we understand how amazingly fine tuned the process is. Honey is far more than an exotic sweetener to be used from time to time in place of sugar, and its use in meadmaking likewise makes mead a beverage as unique as honey.

RESOURCES

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