Experiment to Test Two Ancient Methods of Preserving Grape Juice Unfermented

Performed
by Kyle Pope

May 3, 2010 – January 7, 2012
Amarillo, Texas

Experiment to Test Two Ancient Methods of Preserving Grape Juice Unfermented

Background

A number of ancient sources claim that various methods were used in ancient times to preserve "must" (fresh squeezed grape juice) unfermented. Two of these methods were…

1. Boiling: Aristotle wrote about wines in Arcadia rendered so thick that they were scraped off the wineskins and diluted with water to drink later (*Meteorologica* 388b, 6). Virgil described housewives boiling down "sweet must" (*Georgics,* 1.295). The Bible refers to "wine mixed with water" (Isa. 1:22), which was sometimes the way boiled reduced wine was rehydrated. The Hebrew word for "mixed"—*mahol* means "to cut down or reduce"—which could allude to reduction before or after adding water. The Mishnah records debates among Jews about whether boiled or unboiled wine should be used in the heave-offering (*Terumot* 11:1). Discussions on boiled wine are also found in the Babylonian Talmud tract *'Abadah Zarah* 30a-b, and in one of the earliest quotes from the teaching of the second-century AD Jewish teacher Simeon ben Eleazar (*Eruvin* 29a).

2. Filtration: Pliny the Elder wrote that the wine most suitable for all men was wine, "with strength reduced by the filter," going on to describe the difference between "must" and fermented wine (*Natural History,* 23.24). Pliny says this was a linen filter (*Natural History* 14, 28). Plutarch devotes an entire discussion to whether wine should be strained, declaring wine "cleansed" by a strainer, has its "strike and madness taken away" leaving one in a "mild and healthy state of mind" (*Symposiacs,* 693b 3-5). In the Bible, Isaiah 25:6 probably describes filtered wine in its reference to a feast of "wines on the lees well-refined." The word for "well-refined" means, "to purify, distil, strain, refine" (Gesenius). In modern winemaking "lees" refers to sediment from dead yeast cells after fermentation. Yet, both Plutarch and Talmudic sources call "lees" the residue from initial pressing and later stages. Plutarch even writes that filtering lees prevented intoxication (*Symposiacs,* 692c 9-10). The Mishnah mentions the "wine filter" (*Terumot* 8.6), and the Babylonian Talmud records debates regarding whether wine should be filtered on the Sabbath or not (*Shabbat,* 139b).

Storage Vessels. Boiled or filtered wines (like other wines in ancient times) were stored in earthenware vessels or sometimes in animal skins for travel. The Bible frequently refers to "skins" used for carrying water and wine (Gen. 21:12; 1 Sam. 1:24; 10:3; 16:20; 25:18; 2 Sam. 16:1), but also to other "vessels" for storage (Jer. 13:12; 40:10; Hab. 2:15). The University of Pennsylvania holds a two-and-one-half gallon jar that is believed to be the oldest wine jar ever found. It was discovered in the excavation of an ancient kitchen in Hajji Firuz Tepe, Iran. Traces of terebinth resin and red wine have been found on the inner walls (Object No. 69-12-15). This likely indicates that the walls of the jar were coated with this resin to seal it. Cato the Elder (234 BC – 149 BC) claimed that must stored in an amphora coated with pitch and stored thirty days in a water tank could be removed and kept as "must" for the whole year (Cato, *De Re Rustica* 120).

Columella, who was the Roman tribune of Syria in 35 AD claimed the same thing but extended the period during which the amphora was submerged in water to forty days (Colimella, *De Re Rustica* 12.29). Some earthenware vessels were also glazed. A multi-gallon Canaanite wine vessel found at Tel Kabri, near the Mediterranean coast in northern Israel, dated to around 1800 B.C. used to store gallons of red wine was covered with a white glaze (Shapira, Ran. "Ancient wine vessel found in north Israel draws picture of Canaanite banquets" *Haaretz* {Dec. 9, 2012} [online] http://www.haaretz.com/news/national/ancient-wine-vessel-found-in-north-israel-draws-picture-of-canaanite-banquets.premium-1.483537).

Sealing. Earthenware vessels could be sealed with a pitch coated cork (Horace, *Carminum Liber* 3, 8, 9-12), but other methods of sealing were used as well. Columella describes covering an amphora, plastering over the lid, and then covering it with leather (*De Re Rustica* 12.39). In August of 2012 a Roman shipwreck was discovered off the coast of Varraze, Italy believed to date from the First century BC to the First century AD. The ship was had nearly 200 amphora containing wine, oil, grain, and pickled fish with pine caps coated with pitch still sealed and in place (ABC News, Aug. 9, 2012). The ancients recognized that "must" stored in the cold does not ferment (Plutarch, *Natural Questions* 27). When attempting to keep "must" it was generally stored in a cool place and could be kept as sweet "must" for as much as a year (Columella, *On Agriculture* 12.20.1; 12.37.1; 12.29.1).

Dilution. Ancient sources also describe the fact that wine was generally diluted with water. This was as much as 20 to 1 (Homer, *Odyssey* 9.208), 8 to 1 (Pliny *Natural History* 14.6), or among the Jews 2 or 3 to 1 (*Shabbat* 77a). The apocryphal book of 2 Maccabbes goes so far as to claim, "It is hurtful to drink wine or water alone… wine mingled with water is pleasant" (15:39).

Objective

If these techniques were effective, they can be duplicated and tested. This experiment will attempt to duplicate methods used by the ancients as close as possible. I will test variants and document the results for a period of time which would produce fermentation if these techniques were not utilized.

Method

For a control sample, hand squeeze grapes into a container with no filter. Next, hand squeeze grapes through a cloth, filling five containers with juice. In the first container, store the juice that has only been filtered. In a second container, store the juice that has been filtered and boiled, with no reduction. In a third container, store the juice that has been filtered, boiled, and reduced to one third of the original quantity. In a fourth container, store the juice that has been filtered, boiled, and reduced down to one fifth of the original quantity. In the fifth container, store the juice that has been filtered, boiled, and reduced down to one tenth of the original quantity. Seal containers by hand, with no canning or boiling of the container. Allow all six containers to sit under moderately controlled temperature for at least six months then test to see if any of the juice has fermented.

Materials

Figure 1

- 11.5 lbs. of black grapes **(figure 1)**.
- 6 half pint glass jars with metal lids with rubber seals **(figure 2).**
- 2 yards of unbleached 100% cotton muslin (**figure 3).**
- 3 large bowls.
- 1 small sauce pan.
- 1 large sauce pan.

Figure 2

Figure 3

Note: I was unable to find suitable earthenware vessels with corks to seal the contents. Although the jars used are the sort used for modern canning, they will not be boiled to create a vacuum seal. This will more closely approximate the imperfect seal of an earthenware pitch corked container.

First Pressing

On May 3, 2010 I purchased black grapes from Walmart and began the first phase of the experiment. About half of the grapes were washed and then hand squeezed through the muslin cloth folded so as to create four layers of material through which the juice had to pass. A handful of grapes was used at a time. The grapes were crushed through the material, and the juice was slowly squeezed into a large bowl, getting as much liquid as possible out of each pressing **(figure 4).** When this was completed the skins were taken out of the cloth and placed in a separate container **(figure 5).** This process was repeated until half of the grapes were processed. The juice was then filtered again through one layer of the muslin cloth. One half pint jar was filled with juice, sealed, and labeled number 1. The remaining juice was placed into a small sauce pan and reduced over about an hour to approximately 1/3 of its original quantity. This was placed in a second jar and labeled number 3.

Figure 4

Figure 5

Notes: During this first pressing we had some difficulty clearing the pressed skins from the cloth between each pressing. To address this we rinsed the cloth off with water twice during this process. Although I squeezed the water out each time, it became evident during the second pressing that this had allowed some water into the squeezed juice. Another factor that arose from the rinsing process is that it made it much more difficult to keep the clean side and the dirty side of the cloth (where the skins were) separate. It may be that some of the residue from the grape skins made contact with the clean side of the muslin cloth. We tried to wash this off of the cloth, but it is unclear if this will have any affect on the final results.

Second Pressing

Figure 6

On May 4, 2010 I processed more of the grapes. The muslin cloth was laundered overnight to avoid any contamination. As in the previous pressing, the grapes were washed and hand squeezed through the muslin cloth folded to create four layers of material through which the juice had to pass. Once again, a handful of grapes was used at a time. The grapes were crushed through the material, and the juice was slowly squeezed into a large bowl, getting as much liquid as possible out of each pressing. When this was completed the skins were taken out of the cloth and placed in a separate container. This was repeated until the remaining grapes were processed. As before, the juice was filtered through a single layer of the muslin cloth **(figure 6).** All of the juice was placed into a small sauce pan and brought to a boil **(figure 7).** One half pint jar was filled with juice, sealed, and labeled number 2. The remaining juice was reduced over about an hour and a half to approximately 1/5 of its original quantity. This was placed in a second jar and labeled number 4.

Figure 7

Notes: To avoid the difficulty I encountered during the first pressing regarding cleaning the grapes from the muslin cloth, greater caution was used between each pressing. A spoon was used to scrape the skins off the cloth into a separate container and the depleted skins were not allowed to make contact with the clean side of the cloth. In addition no water was used to rinse the cloth. This produced a visible difference in the appearance of the juice. Even before boiling, the juice was much darker than the first pressing.

Third Pressing

On May 5, 2010 I created the control sample. A small quantity of grapes was lightly rinsed and then hand squeezed into a jar labeled number 0 **(figure 8)**. No filter was used, and no attempt was made to filter out, or limit contact with the crushed skins. Visible portions of the skins which dropped into the juice were removed, but no filtering or boiling was applied to this sample.

Figure 8

Notes: The juice produced from this pressing was darker than any of the previous initial pressings.

Figure 9

Fourth Pressing

On May 6, 2010 the final pressing was done. Enough grapes to fill a large bowl were washed **(figure 9).** The muslin cloth, having been laundered, was folded to create four layers of material through which the juice had to pass. A handful of grapes was squeezed at a time. The grapes were crushed through the material, and the juice was slowly squeezed into a large bowl, getting as much liquid as possible out of

each pressing. When this was completed the skins were taken out of the cloth and placed in a separate container. This was repeated until all the grapes were processed. Finally, the juice was filtered through a single layer of the muslin cloth. All of the juice was placed into a large sauce pan and brought to a boil. The juice was allowed to reduce until approximately one tenth of the original quantity remained **(figure 10)**. This was poured into a half pint jar and labeled number 5.

Figure 10

Note: In spite of the further reduction the result (though much darker) was not solid.

Storage

All test samples were stored in the bottom of a dark cabinet in my office which maintains a temperature of approximately 75 degrees Fahrenheit **(figure 11).** This is somewhat warmer than might be preferable, but could easily have been maintained throughout various regions in the ancient world in lofts, cellars, or cisterns.

Figure 11

Sample Overview

Number	0	1	2	3	4	5
Condition	Unfiltered	Filtered	Filtered & Boiled	Filtered, Boiled, & Reduced to 1/3	Filtered, Boiled, & Reduced to 1/5	Filtered, Boiled, & Reduced to 1/10
Date Sealed	5/5/2010	5/3/2010	5/4/2010	5/3/2010	5/4/2010	5/6/2010

Initial Examinations

Sample 0 (Unfiltered). On May 15th the samples were examined for the first time and mold was visible on the surface of Sample 0. On August 13th samples were examined and the amount of mold and residue was about the same as previously noticed, however the lid was rounded and bent (as seen in **figure 12**).

Figure 12

Sample 1 (Filtered). When samples were examined on May 15th, sample 1 was very murky but showed no evidence of mold on the surface. On August 13th the lid of sample 1 was very slightly convex but not as much as sample 0.

Sample 2 (Filtered & Boiled). Sample 2 may have been a little more murky on May 15th than it was when it was first sealed. There was no bend or pressure on the lid. On August 13th this sample was not visibly different from the last time it was checked.

Sample 3 (Filtered, Boiled, & Reduced to 1/3). Sample 3 was not noticeably different on May 15th than it was when it was first sealed. There was no bend or pressure on the lid. On August 13th this sample was not visibly different from the last time it was checked.

Sample 4 (Filtered, Boiled, & Reduced to 1/5). Sample 4 was not noticeably different on May 15th from when it was first sealed. There was no bend or pressure on the lid. On August 13th this sample was not visibly different from the last time it was checked.

Sample 5 (Filtered, Boiled, & Reduced to 1/10). Sample 5 was not noticeably different on May 15th from when it was first sealed. There was no bend or pressure on the lid. On August 13th this sample was not visibly different from the last time it was checked.

Record of Alcohol Testing Performed at West Texas A&M University (March 25, 2011)

Participants: Kyle Pope (Minister, Olsen Park church of Christ, MA. Classics, University of Kansas, 2000); Dr. Pat Goguen (Chemist, Pantex Corporation, PhD. Chemistry, Texas A&M University) **Far right**; Dr. Shiquan Tao (Asst. Professor, West Texas A&M University, PhD. Chemistry, Hiroshima University, 1996) **Far left**; Christian Gulde, (Senior, Chemistry & Biology West Texas A&M University) **Center right**; Stephanie McDonald (Junior, Professional Chemistry) **Center left**.

Figure 13

Procedure: Dr. Tao and his students purchased a breathalyzer such as is used for testing the blood alcohol content (BAC) of a driver's breath. They constructed an apparatus to cover one end with a small cap, into which a small plastic tube was inserted (as seen in **figure 13).** The end of the tube was connected to a syringe into which samples were taken. Various dilutions and proportions of known ethanol and unknown squeezed grape juice produced in May 2010 were taken into the syringe with air. The air was pressed into the breathalyzer in order to determine alcohol content of the samples just as it tests blood alcohol content (as shown in **figure 14).** Numbers and proportions were recorded in order to determine the alcohol content of samples.

Figure 14

Testing Media:

- **Sample 0 (figure 15)**. Grape juice produced from black grapes hand squeezed by Kyle Pope on May 5, 2010 and stored in a sealed glass jar until testing.
- **Cooking Wine (figure 16)** – Labeled "Alcohol by volume 17%." At the suggestion of Dr. Goguen, Kyle Pope prepared a dilution of 1 part cooking wine to 4 parts water (identified henceforth as "Cooking Wine Dilution" CWD) in order to provide a control sample of a known labeled content.
- **Sangria (figure 17)** – Labeled "Alcohol by volume 7-10%" provided by Christian Gulde.
- **Pure Ethanol (figure 18)** provided by Dr. Tao.

Figure 15

Figure 16

Figure 17

Figure 18

Testing Data:

Cooking Wine Dilution:

Test Number	Dilution Proportions	BAC Reading
1	CWD (no additional dilution)	.12
2	CWD (no additional dilution)	.12

Sangria:

Test Number	Dilution Proportions	BAC Reading
1	sangria (no additional dilution)	.12
2	sangria + 2ml ethanol	.12

Ethanol:

Test Number	Dilution Proportions	BAC Reading
1	1 ml ethanol / 19 ml water	.12
2	1 ml ethanol / 39 ml water	.11
3	1 ml ethanol / 79 ml water	.08
-	Air Test	.00
4	1 ml ethanol / 119 ml water	.05

Cooking Wine Dilution:

Test Number	Dilution Proportions	BAC Reading
1	10 ml CWD / 20 ml water	.05
2	20 ml CWD / 20 ml water	.08
3	20 ml CWD / 100 ml water	.000

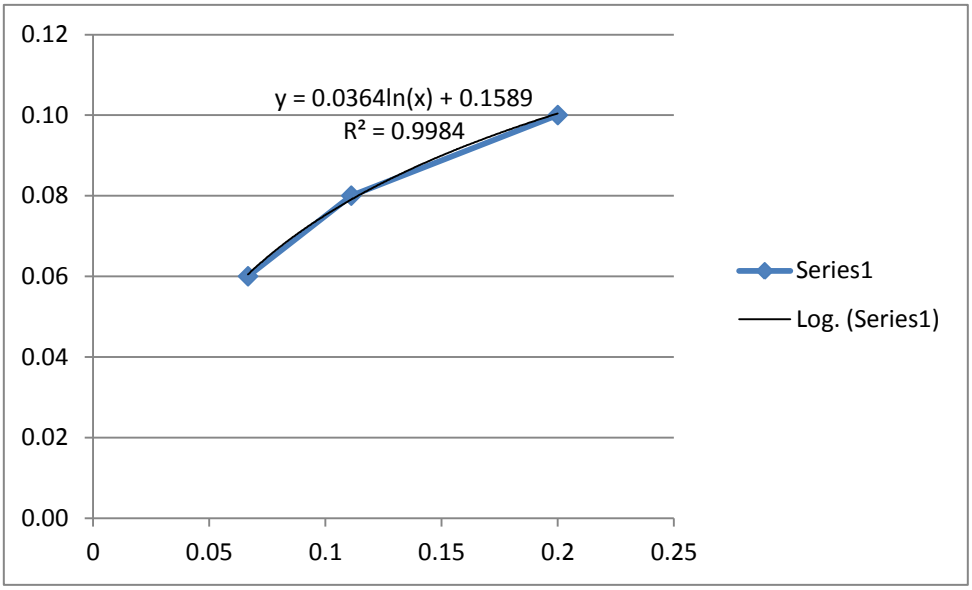
Sample 0:

Test Number	Dilution Proportions	BAC Reading
1	sample 0 (no dilution)	.12
2	10 ml sample 0 / 10 ml water	.09
3	10 ml sample 0 / 20 ml water	.09
-	Air Test	.05
-	Air Test	.00
4	10 ml sample 0 / 20 ml water	.05
5	10 ml sample 0 / 40 ml water	.09
-	Air Test	.02
-	Air Test	.00
-	Air Test	.00
6	10 ml sample 0 / 40 ml water	.09
-	Changed caps for breathalyzer	-
-	Air Test	.00
-	Air Test	.00
7	10 ml sample 0 / 40 ml water	.08
-	Air Test	.05
-	Air Test	.00
-	Air Test	.00
-	Changed needle	-
8	10 ml sample 0 / 40 ml water	.05
-	Air Test	.00
9	2ml ethanol / 20 ml sample 0 / 80 ml water	.11
10	2ml ethanol / 20 ml sample 0 / 130 ml water	.03
11	2.5 ml ethanol / 20 ml sample 0 / 130 ml water	.02
12	2.5 ml ethanol / 20 ml sample 0 / 130 ml water	.12
-	Air Test	.02
-	Air Test	.00
13	10 ml sample 0 / 40 ml water	.10
14	10 ml sample 0 / 90 ml water	.08
-	Air Test	.02
-	Air Test	.00
15	10 ml sample 0 / 140 ml water	.06
-	Air Test	.00
16	.5 ml ethanol / 10 ml sample 0 / 140 ml water	.06
-	Air Test	.05
-	Air Test	.00
17	1 ml ethanol / 10 ml sample 0 / 140 ml water	.11
-	Air Test	.00
18	.5 ml ethanol / 10 ml sample 0 / 140 ml water	.10

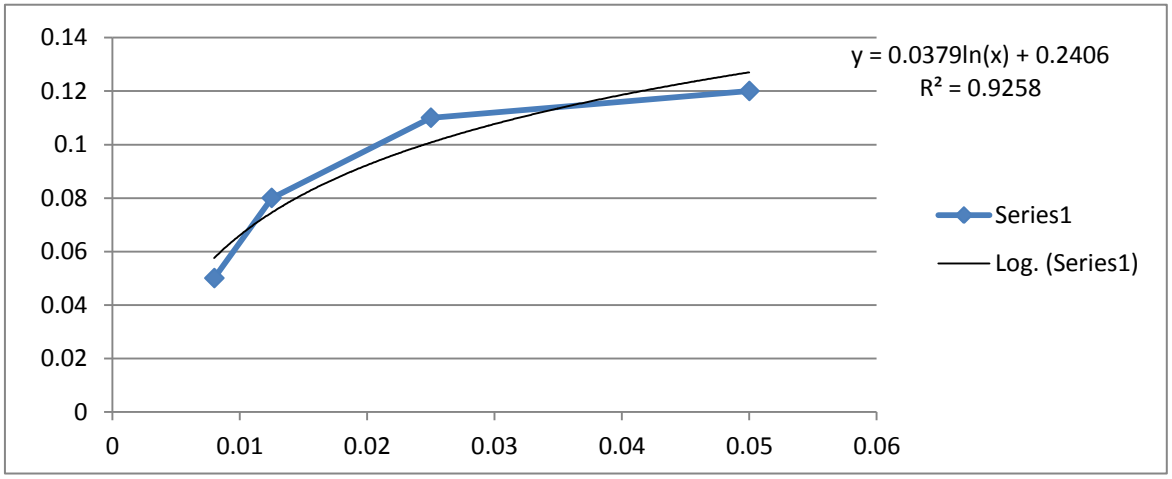
Analysis: Dr. Tao, Dr. Goguen, Mr. Gulde and Miss McDonald graphed and analyzed data and estimated alcohol content of sample 0 at 12%.

Sample 0

Ratio	%	BAC	X	eX	
1 to 5	0.2	0.10	-3.78378	0.022736	0.113682
1 to 9	0.111111	0.08	-4.32432	0.013242	0.119182
1 to 15	0.066667	0.06	-4.86486	0.007713	0.115693
plus .5mL		0.11	-3.51351	0.029792	11.6186
plus 1mL		0.10	-3.78378	0.022736	



95% Ethanol in Water (%)	BAC
0.05	0.12
0.025	0.11
0.0125	0.08
0.008	0.05



Additional Testing of Sample 0

After lab testing was completed Kyle Pope tested Sample 0 and the cooking wine in his home with a vinometer. This device is used by winemakers to measure alcohol content. A vinometer allows fluid to pass down an open column in the device and stops at a graduated marks in the column based on alcohol content (as shown in **figure 19).** Winemakers claim that this method is fairly reliable for measuring so-called "dry wines," but not as reliable for sweet wines. According to Dr. Goguen, a device such as this relies upon density or viscosity as a way to measure alcohol content. Additional sugar content would thus affect both factors. Some winemakers add food coloring to test samples to make the reading more visible. In testing Sample 0, this appeared to affect the results. Sample 0 was strained through a paper towel to eliminate solid matter and three tests were done.

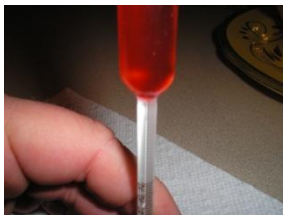


Figure 19

Testing Data:

Test Number	Substance Tested	Vinometer Reading
1	Sample 0 with food coloring	4%
2	Sample 0 without food coloring	5%
-	Sample 0 without food coloring (after tapping the vinometer)	6%
3	Cooking wine (with no dilution)	10%
-	Cooking wine (with no dilution) – (after tapping vinometer)	10%

External Literature:

Dr. Gary Calton, Scuentific Director Calwood Nutrinonals, PhD. Organic Chemistry, Biochemistry and Microbiology, Texas A&M University, 1971, in his unpublished "A PRIMER FOR WINE AND ALCOHOL PRODUCTION IN ANCIENT TIMES" offers some claims which may call a reading of 12% into question. Calton writes:

> An amateur wine maker will not usually get above 6% alcohol content even with all of the information and yeast cultures available to him today. This is probably (no one knows for sure) equivalent to strong drink in the Bible. The maximum alcohol content of a wine is 15.5%, however, this is with a very specially selected strain of yeast for alcohol for fuel production with optimized sugar content. Most yeasts are killed when the level of alcohol reaches 12 %. In contrast with that, the distilled beverages that are sold today contain up to 95% alcohol.

Concluding Results for Sample 0.

The breathalyzer test performed at West Texas A & M University found that after ten months the alcohol content by volume of Sample 0 was 12%. The vinometer test found that after ten months the alcohol content by volume of Sample 0 was 6%. We may conclude that without any artificial measures being taken, grape juice will ferment producing an alcohol content by volume of between 6-12%.

Testing of Remaining Samples

Dr. Tao had originally planned on testing of the remaining samples in the laboratory at West Texas A&M University through the breathalyzer method used on Sample 0, but was ultimately unable to do so. This demanded that another method be utilized. One of the most common methods used by wine makers to determine alcohol content by volume involves testing the specific gravity of juice before and after fermentation. Specific gravity is measured by a device known as a hydrometer (**figure 20**). This device measures the density of liquids. Fresh squeezed grape juice has a high density because of its initial high sugar content. A hydrometer placed in fresh grape juice floats high in the liquid. As fermentation takes place, the conversion of sugar to alcohol changes the density of the liquid, causing a hydrometer to float lower. Ideally, initial readings are done at the time juice is extracted, and then final readings are taken after a period of time. However, the same principles can be utilized and measured by considering specific gravity, and weight readings after a period of time, then boiling off any alcohol present, rehydrating the sample and taking weight and specific gravity readings of the resultant liquid. The remaining samples were tested by a mass testing method analyzed by Dr. Pat Goguen and a specific gravity method designed by Dr. William Honneyman. Note: See **Appendix One** for Dr. Honneyman's procedure.

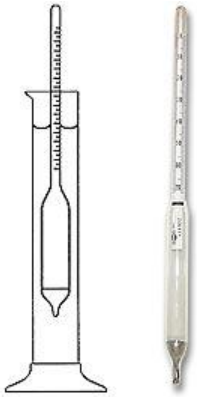


Figure 20

Record of Alcohol Testing of Remaining Samples By Specific Gravity and Mass Testing Methods (January 3, 5, 7, 2012)

Equipment

- Triple-beam scale (**figure 21**).
- One graduated plastic cylinder.
- One clear glass cylinder.
- Two hydrometers of differing ranges.
- Paper coffee filters.
- Distilled water (**figure 22**).
- Small saucepan (**figure 23**).

Figure 21

Figure 22

Figure 23

Procedure

1. Take room temperature and record readings.
2. Open container.
3. Filter sample using a standard coffee filter to remove solids.
4. Do an initial test with the vinometer and record readings.
5. Measure 100 ml of sample.
6. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
7. Take a specific gravity reading with the hydrometer and record readings.
8. Boil sample down to one half (50 ml) or until volume of sample no longer changes.
9. Add 50 ml of distilled water.
10. Weigh the sample (subtracting weight of graduated cylinder) and record readings. (Note: For a 10% alcohol sample (by volume), your weight difference will only be about 2.1g, so don't expect a huge weight difference here).
11. Take a specific gravity reading with the hydrometer and record readings.
12. Do a final test with the vinometer and record readings.

Samples 3-5 should also be tested in rehydrated form. To test in rehydrated form:

Sample Three

1. Repeat steps 1-3 above.
2. Measure 33 ml of sample and add 67 ml of distilled water.
3. Do an initial vinometer reading and record readings.
4. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
5. Take an initial specific gravity reading with the hydrometer and record readings.
6. Boil sample down to one half (50 ml) or until volume of sample no longer changes.
7. Add 50 ml of distilled water.
8. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
9. Take a specific gravity reading with the hydrometer and record readings.
10. Do a final test with the vinometer and record readings.

Sample Four

1. Repeat steps 1-3 above.
2. Measure 20 ml of sample and add 80ml of distilled water.
3. Do an initial vinometer reading and record readings.
4. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
5. Take an initial specific gravity reading with the hydrometer and record readings.
6. Boil sample down to one half (50 ml) or until volume of sample no longer changes.
7. Add 50 ml of distilled water.
8. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
9. Take a specific gravity reading with the hydrometer and record readings.
10. Do a final test with the vinometer and record readings.

Sample Five

1. Repeat steps 1-3 above.
2. Measure 10 ml of sample and add 90 ml of distilled water.
3. Do an initial vinometer reading and record readings.
4. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
5. Take an initial specific gravity reading with the hydrometer and record readings.
6. Boil sample down to one half (50 ml) or until volume of sample no longer changes.
7. Add 50 ml of distilled water.
8. Weigh the sample (subtracting weight of graduated cylinder) and record readings.
9. Take a specific gravity reading with the hydrometer and record readings.
10. Do a final test with the vinometer and record readings.

Test One

Figure 24

On January 3, 2012, **Sample 0** (unfiltered) and **Sample 1** (filtered) were tested. Sample 0 was reopened (**figure 24**). There was not enough of this sample left to do specific gravity and mass testing, but another vinometer reading was taken resulting in a reading of 6.6% alcohol content by volume. Next, Sample 1 was opened for the first time since May 3, 2010. There was thick residue on the bottom, but the juice was clear on top (**figure 25**). There was no smell of ferment. The juice had a fruity smell and a sweet taste. Two tests were conducted following the procedure outlined above (see **figures 26-30**). Data was recorded and charted (as recorded in **Chart One** below). Mass testing analyzed by Dr. Pat Goguen (as recorded in **Chart Two** below), determined an alcohol content of less than 1% alcohol by volume. Specific gravity testing, based on the procedure designed by Dr. William Honneyman (as recorded in **Chart Three** below) determined an alcohol content of 0% alcohol by volume.

Figure 25

Figure 26

Figure 27

Figure 28

Figure 29

Figure 30

Note: There was some discrepancy between the first and second test results of Sample 1. This likely resulted from my own failure to make exact measurements. Efforts were made on the remaining samples to make more precise measurements.

Test Two

Figure 31

On January 5, 2012, **Sample 2** (filtered & boiled) and **Sample 3** (filtered, boiled, & reduced to 1/3)) were tested. Sample 2 was opened for the first time since May 4, 2010 (**figure 31**). The juice was light brown with little residue. It had a fruity smell with no smell of ferment and a sweet taste. Testing was performed following the procedure outlined above, but there was not enough to perform more than one test. Data was recorded and charted (as recorded in **Chart One** below). Mass testing analyzed by Dr. Pat Goguen (as recorded in **Chart Two** below), determined an alcohol content of less than 1% alcohol by volume. Specific gravity testing based on the procedure designed by Dr. William Honneyman (as recorded in **Chart Three** below) determined an alcohol content of 0% alcohol by volume. Sample 3 was also opened for the first time since May 3, 2010. This sample was darker brown than previous sample, as would be expected due to its reduction to 1/3 of its original volume (as seen in **figure 32**). There was only a very small amount of floating residue. When juice was removed, there was a thick hardened ring of residue on the bottom of the jar (**figure 33**). The juice had a fruity smell, although it was less pronounced than in the previous sample. It too had a sweet taste with no smell of ferment. As the first of the reduced samples it was necessary to perform two types of tests on Sample 3 and all of the remaining samples. The first test measured the juice in its reduced state (as outlined above), while the second test measured the juice after it had been rehydrated back to its original volume (as outlined above). Data was recorded and charted (as recorded in **Chart One** below). Mass testing analyzed by Dr. Pat Goguen (as recorded in **Chart Two** below), determined an alcohol content of less than 1% alcohol by volume. Specific gravity testing based on the procedure designed by Dr. William Honneyman (as recorded in **Chart Three** below) determined an alcohol content of 0% alcohol by volume.

Figure 32

Figure 33

Test Three

Figure 34

On January 7, 2012, final testing of the samples was performed. **Sample 4** (filtered, boiled & reduced to 1/5) and **Sample 5** (filtered, boiled and reduced to 1/10) were opened and tested. Sample 4 was opened for the first time since May 4, 2010 (**figure 34**). It was a much darker brown color than the previous sample. It too had a fruity smell like previous sample. There was a much thicker hardened ring of residue on the bottom of the jar (**figure 35**). It also had a sweet taste with no smell of ferment. The thicker consistency of Sample 4 made filtering much more difficult. The sample had to slowly strain through the filter (as shown in

Figure 35

figure 36). This thicker consistency produced a much higher density causing the hydrometer to float higher in the sample (**figure 37**). As with the previous reduced sample, Sample 4 was tested first in its reduced state (as outlined above) and then a second time after it was rehydrated to its original volume (as also outlined above). When rehydrated, there was enough to perform two tests in its rehydrated form. Data was recorded and charted (as seen in **Chart One** below). Mass testing analyzed by Dr. Pat Goguen (as recorded in **Chart Two** below), determined an alcohol content of less than 1% alcohol by volume. Specific gravity testing based on the procedure designed by Dr. William Honneyman (as recorded in **Chart Three** below) determined an alcohol content of 0% alcohol by volume. The final sample, Sample 5 was opened for the first time since May 6, 2010 (**figure 38**). The sample was a dark brown thick syrupy consistency of clumpy jelly-like globs (**figure 39**). This made filtering impossible. Sample 5 had a molasses smell and taste. There was no hardened residue ring on the bottom of the jar. As in the previous sample, this even thicker consistency produced a much higher density causing the hydrometer to float higher in the sample. As with the previous reduced sample, Sample 5 was tested first in its reduced state (as outlined above) and then a second time after it was rehydrated to its original volume (as also outlined above). When rehydrated, there was enough to perform two tests in its rehydrated form. Data was recorded and charted (as seen in **Chart One** below). Mass testing analyzed by Dr. Pat Goguen (as recorded in **Chart Two** below), determined an alcohol content of less than 1% alcohol by volume. Specific gravity testing based on the procedure designed by Dr. William Honneyman (as recorded in **Chart Three** below) determined an alcohol content of 0% alcohol by volume.

Figure 36

Figure 37

Figure 38

Figure 39

Note: The thicker density of the reduced state of Sample 4 and Sample 5 made both tests on the reduced state anomalous. There was obviously a high amount of sugar still present in these thick samples that did not convert to alcohol.

Additional Testing of Samples 1-5

As outlined in the procedure above, during the testing performed on January 3, 5, and 7, 2012 on Samples 1-5, vinometer tests were also done on all samples before and after boiling and rehydration (**figure 40**). As noted above in discussing the vinometer testing on Sample 0, winemakers utilize vinometers to perform simple testing on so-called "dry wines" but acknowledge that vinometers are not as reliable on "sweet wines." This was seen in our testing as well. As noted in the data recorded on **Chart One** below, the higher sugar content of samples 1-5 produced anomalous vinometer readings. For example, in

Figure 40

one test of Sample 1 initial vinometer readings showed an alcohol content of 2% by volume, but final readings registered less than 0% alcohol content by volume. On the other hand, tests on the rehydrated forms of Sample 3 originally registered readings of less than 0% alcohol by volume, while the final readings after boiling and rehydration registered 1% alcohol content by volume. It is likely that the higher sugar content of these samples caused this inconsistency.

Chart One: Hydrometer, Weight and Vinometer Testing Data

Number	0	1		2	3		4			5		
Condition	Unfiltered	Filtered		Filtered & Boiled	Filtered, Boiled, & Reduced to 1/3	Sample 3 Rehydrated		Filtered, Boiled, & Reduced to 1/5	Sample 4 Rehydrated		Filtered, Boiled, & Reduced to 1/10	Sample 5 Rehydrated	
Date	1-3-2012	1-3-2012		1-5-2012	1-5-2012	1-5-2012		1-7-2012	1-7-2012		1-7-2012	1-7-2012	
General Appearance	Murky with a strong smell of ferment.	Thick residue on bottom, clear on top. No smell of ferment. Fruity smell, sweet taste.		Light brown with little residue. Fruity smell with no ferment smell. Sweet taste.	Darker brown than previous sample. Very small amount of floating residue. Thick hardened residue on bottom ring of jar. Fruity smell, though less pronounced than previous sample. Sweet taste. No ferment smell.			Darker brown than previous sample. Fruity smell like previous sample. Thicker hardened residue on bottom ring of jar. Sweet taste. No ferment smell.			Dark brown thick syrupy liquid. No hardened residue ring on bottom but clumpy jelly-like globs. (Filtering was not possible). Molasses smell. Molasses taste.		
Room Temperature	75.2° F	79.3° F		73.9° F	77.2° F	77.2° F		69.8° F	69.8° F		75.9° F	75.9° F	
Initial Vinometer Reading	5	4	2	Less than 0	2.5	Less than 0	Less than 0	Less than 0	Less than 0	Less than 0	Less than 0	0	Less than 0
Initial Weight	43.6 gm (Only 44ml left)	104.45gm	105.10gm	105.5gm	111.0gm	103.00gm	102.65gm	118.85gm	102.95gm	102.1gm	130.3gm	101.2gm	101.25gm
Initial Specific Gravity Reading	Not enough left to take a reading	1.07	1.09	1.11	1.15	1.05	1.05	1.2	1.05	1.05	1.31	1.02	1.02
Final Weight	43.2 gm	(37ml left) 105.6gm	(53ml left) 103.8gm	(64ml left) 105.3gm	(59ml left) 110.7gm	(59 ml) 102.75gm	(58 ml) 102.4gm	(54ml left) 116.95gm	(59 ml) 102.95gm	(60 ml) 102.45gm	(52 ml left) 119.4gm (reduction stuck to pan)	(48 ml) 101.5gm	(50 ml) 101.1gm
Final Specific Gravity Reading	Not enough left to take a reading	1.05	1.05	1.09	1.15	1.05	1.05	1.17	1.05	1.05	1.17	1.02	1.02
Final Vinometer Reading	6.6	(Missed Reading)	Less than 0	Less than 0	Less than 0	1	1	Less than 0	Less than 0	1	Less than 0	Less than 0	Less than 0

Chart Two: Mass Testing Analyzed by Dr. Pat Goguen

Sample	1	1	2	3	3 rehydrated		4	4 rehydrated		5	5 rehydrated	
Initial mass	104.45	105.1	105.5	111	103	102.65	118.85	102.95	102.1	130.3	101.2	101.25
Final mass	105.6	103.8	105.3	110.7	102.75	102.4	116.95	102.95	102.45	119.4	101.5	101.1
% ethanol (v/v)	-1.45754	1.647655	0.253485	0.380228	0.316857	0.316857	2.408112	0	-0.4436	13.81496	-0.38023	0.190114
										stuck		
initial density	1.07	1.09	1.11	1.15								
final density	1.05	1.05	1.09	1.15								
% ethanol	-2	-4	-2									
0.789 = density of ethanol												
1.00 = density of water												

Chart Three: Specific Gravity Testing

Based on Procedure Designed by Dr. William Honneyman

	1		2	3			4			5		
	Filtered		Filtered & Boiled	Filtered, Boiled, & Reduced to 1/3	Sample 3 Rehydrated		Filtered, Boiled, & Reduced to 1/5	Sample 4 Rehydrated		Filtered, Boiled, & Reduced to 1/10	Sample 5 Rehydrated	
Initial SG	1.07	1.09	1.11	1.15	1.05	1.05	1.2	1.05	1.05	1.31	1.02	1.02
Final SG	1.05	1.05	1.09	1.15	1.05	1.05	1.17	1.05	1.05	1.17	1.02	1.02
Difference	-.02	-.04	-.02	0	0	0	-.03	0	0	-.14	0	0
Alcohol % by volume	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Concluding Analysis

Final Results of Samples:

Number	0		1	2	3	4	5
Condition	Unfiltered		Filtered	Filtered & Boiled	Filtered, Boiled, & Reduced to 1/3	Filtered, Boiled, & Reduced to 1/5	Filtered, Boiled, & Reduced to 1/10
Date Sealed	5/5/2010		5/3/2010	5/4/2010	5/3/2010	5/4/2010	5/6/2010
Date Opened	WT Test 3/25/2011	1/3/2012	1/3/2012	1/5/2012	1/5/2012	1/7/2012	1/7/2012
Condition	Strong smell, mold on top, abundant residue	Murky with a strong smell of ferment.	Thick residue on bottom, clear on top. No smell of ferment. Fruity smell, sweet taste.	Light brown with little residue. Fruity smell with no ferment smell. Sweet taste.	Darker brown. Very small amount of floating residue. Fruity smell, though less pronounced than previous sample. Sweet taste.	Darker brown than previous sample. Fruity smell like previous sample. Sweet taste. No ferment smell.	Dark brown thick syrupy liquid. Clumpy jelly-like globs. Molasses smell. Molasses taste.
Alcohol Content	12% (5-6% vinometer)	6.6% vinometer	0%	0%	0%	0%	0%

The objective of this experiment was to test two methods that ancient writers claimed were utilized to impede the fermentation of grape juice in order to test the validity of their claims: 1) **filtering** and 2) **boiling.** This experiment utilized methods and material that could have easily been utilized by ancient peoples in light of the resources and technology available to them. There is no question that grape juice naturally ferments at a rather high rate. With no manipulation or addition of yeasts or sugars juice produced from common black grapes fermented to a level of at least 6% (and possibly even to its maximum natural level of 12%). However, it is also clear that simply by removing much of the fermenting matter contained in the skins of the grapes by means of filtering through common cloth this natural fermentation can be so impeded that an alcohol content of less than 1% can be attained (and possibly 0% alcohol by volume). When boiling is added to this process, either with reduction or without the effect on fermentation is even more pronounced resulting in only microscopic levels of alcohol content by volume, or again 0% alcohol content by volume. This allows us to conclude that the claims of ancient writers that filtering, boiling, and rehydration of reduced wines rendering the product free of any intoxicating effect are in fact valid. It should be noted that this evidence does not infer that juice filtered or boiled could not later ferment if left unsealed. However, it is clear that sealed juice that has been filtered or filtered and boiled does not ferment to the same degree that unfiltered or unboiled juice of the same type does.

APPENDIX ONE:

Procedure For Testing the Alcohol Content of Wine After Fermentation Utilizing Specific Gravity Measurements

Measuring Alcohol Content:

Tools:

- Narrow Range Hydrometer - 0.990 to 1.120
- 1 pint or 1 litre glass or enamel pan for boiling

The following method measures the alcohol content by volume of any wine, spirit, or beer, uses no instruments except the hydrometer, and is as accurate as the ebullioscope. The method, simplified here for amateur use, is based on the researches of William Honneyman, B.Sc.,Ph.D.

1. Measure the SG of the wine you wish to test. We will call this figure SG-1.
2. Measure out exactly one litre or pint of the wine. We will call this the sample.
3. In an enamelled or glass pan, boil the sample down to about half it's original volume. This drives off some of the water, but all of the alcohol, because alcohol boils at a lower temperature than water. The sample now consists of water, residual sugar, colouring matter, acids and proteins-that is, all the non-alcoholic constituents of the wine.
4. With distilled water make the boiled-down sample up to exactly a litre/pint again. Tap water is not recommended because, in some areas, it has a considerable dissolved mineral content that may affect your results.
5. Cool the sample down to 60o-F, or what ever temperature your hydrometer is calibrated for.
6. Read the SG of the sample, we will call this reading SG-2.You will find it higher than SG-1 because you have removed the alcohol and replaced it with water.
7. Subtract SG-1 from SG-2. The difference is called the Spirit Indication.
8. Read the alcohol strength from the following table on the right.

Spirit Indication	Alcohol Strength % by volume
1.5	1.0
2	1.3
3	2.0
4	2.7
5	3.4
6	4.1
7	4.9
8	5.6
9	6.4
10	7.2
11	8.0
12	8.8
13	9.7
14	10.5
15	11.4
16	12.3
17	13.2
18	14.1
19	15.1
20	16.0
21	17.0
22	18.0
23	19.0
24	20.0
25	21.0
26	22.0

As an imaginary example:

SG-1 (SG of original wine) = 0.995
SG-2 (SG of sample at stage 6) =1.011
Spirit Indication= 1.011 - 0.995 = 16
Alcohol strength= 12.3 % by volume.