Post-Fermentation Clarification: Wine Fining Process

A Major Qualifying Project
Submitted to the Faculty of
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In partial fulfillments of the requirements for the
Chemical Engineering Bachelor of Science Degree

Sponsored by:
Zoll Cellars
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Shrewsbury, MA

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This report represents the work of WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its website without editorial or peer review. For more information about the projects program at WPI, please see *http://www.wpi.edu/academics/ugradstudies/project-learning.html*

Abstract

The sponsor, Zoll Cellars, is seeking to improve their current post-fermentation process. Fining is a post-fermentation process used to clarify wine. This paper discusses several commonly used fining agents including: Bentonite, Chitosan and Kieselsol, and gelatin and Kieselsol. The following tests were conducted to compare the fining agents: visual clarity, mass change due to racking, pH, and gas chromatography-mass spectrometry. Bentonite was an effective fining agent when hydrated with water heated to at least 140 ˚F. Chitosan and Kieselsol were also successful with a wait time before racking of at least 24 hours. Gelatin and Kieselsol are not recommended for use at Zoll Cellars because gelatin easily over stripped the wine of important flavor compounds.

Acknowledgements

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Table of Contents

Table of Figures

Table of Tables

Introduction

For thousands of years, humanity has been making fermented beverages. Wine, one of the most common beverages, has been made as early as 6000 BC. Wine is made of fermented grape juice; however the process of winemaking has changed minimally over the centuries. Wine makers follow the process because it works, although very little is known about the chemistry behind winemaking. With modern advancements in science, the chemistry behind winemaking can be further studied to explain why and how different wines are made.

Zoll Cellars in Shrewsbury, MA originally reached out to the WPI Chemical Engineering department in 2013 to understand the chemistry behind the winemaking process in an effort to improve their product. After a successful project in 2013-14, they once again agreed to work with WPI students and became the sponsor to three projects that would improve their product. Zoll Cellars specifically wanted to focus on their dry Riesling and Chardonnay, two of their more popular white wines. The project outlined in this paper focuses on the post-fermentation process.

Background

History behind winemaking

Wine has been a part of humanity for thousands of years. Pottery with wine residue has been found as early as 6000 BC in Georgia. As wine spread to Ancient Egypt, it became an important part of their culture. They used wine in important ceremonies and depicted scenes of winemaking on their tomb walls. As wine was essential to ancient Egyptians, they passed it on to the Phoenicians and Jewish with their contact. The Jewish adopted wine and integrated it in their religion, leading it to become an important part in Christianity. Additionally, the Phoenicians played an important role in spreading wine, as they traded all around the Mediterranean including North Africa, Greece, and Italy.

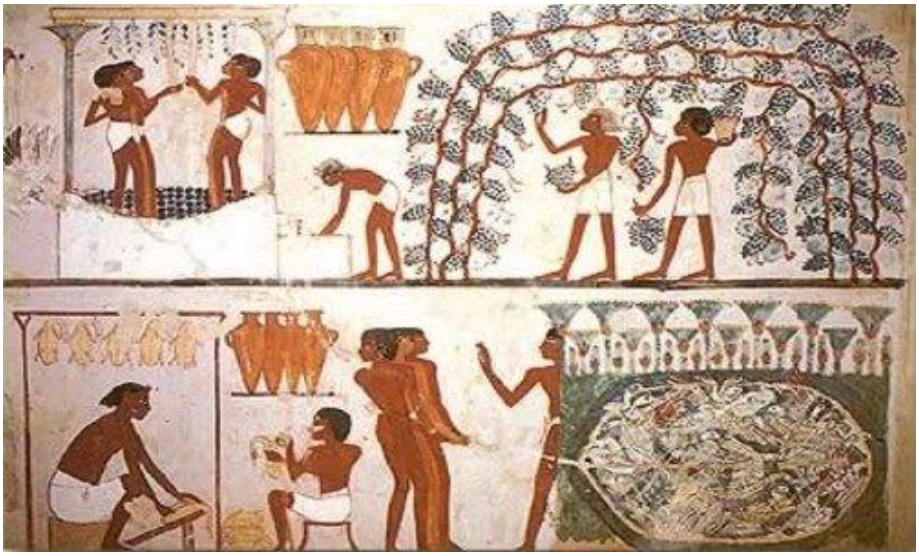

Figure 1- A Winemaking depiction from Ancient Egypt (Wine in Ancient Egypt, 2005)

As wine spread through Europe via trade, the Greeks integrated it into their society. They even had a god of wine, Dionysus. The Greek method of making wine was recorded, and they used a type of fining by adding lime after fermentation to reduce the acidity of the

wine. As the Greek Empire spread, their wine and grape vines spread with them, including to Ancient Rome.

The Roman Empire had a strong impact on the development of wine. Wine became a large part of their culture, and drinking alcohol became more widely accepted. Winemaking became a large business and vineyards emerged all over the Roman Empire. It grew so exponentially that eventually the first wine law was created to limit the number of vineyards. When Rome converted to Christianity, wine became an important part of the church. Wine is a central part of the sacrament, as it is the 'blood of Christ'. The church worked on perfecting winemaking and even had monks specializing in wine. As Christianity spread, so did winemaking. It was soon a staple in France, Italy, Spain, and all over Europe.

When the colonization era began, the empires spread across the globe and brought wine with them. The Spanish Conquistadors brought grape vines to Central and South America, but the winemaking thrived in Chile and Argentina particularly. The Portuguese and British also brought wine to the well-known areas of South Africa and Australia/New Zealand, respectively.

The United States was also an area where colonists tried to produce wine. When missions were established in California, monks brought grapes with them. Winemaking flourished in California, particularly in the Napa Valley region. However, wine production on the east coast was a little more difficult. The first colonists attempted to make wine with local grape varieties, but the wine was distasteful. Eventually, the European grape varieties were brought to the East Coast, but it was soon found difficult to grow the grapes in the ever-changing climate. Adaptations were made, but the changing seasons made some harvests more difficult than others. This brings us to modern day, where vineyards do exist

on the East Coast, but they are not as vast or extensive as the vineyards around the world, especially in California, Europe, and Australia (The History Of Wine Timeline | How Wine Colonized The World).

There is a prejudice that exists in the wine community against American wines as a whole, as they are new world wines. Old world wines are any wines grown in Europe, while new world wines are grown around the world in any other area; this can be seen in Figure 2. Since old world wines are grown in the area that winemaking was originally established, the main argument for this type of wine is that there is a stronger heritage surrounding the winemaking. To protect this heritage, there are also much stricter laws on winemaking including where they can plant, how close grape vines can be, what variety of grapes can be used, and much more. Aside from the regulations and heritage, old world wines tend to be lighter bodied and lower in alcohol content than new world wines.

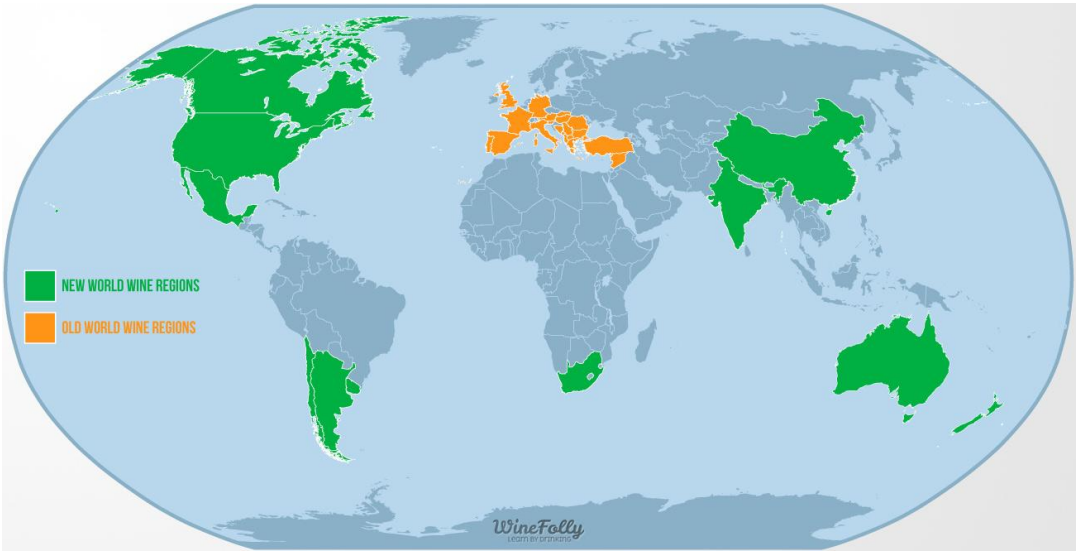

Figure 2-Map of New World Wines vs Old World Wines (New World vs Old World Wine, 2012)

While new world wines are sometimes looked down on, there are many benefits. With the lack of strict regulations, there are a lot more possibilities with winemaking and

wine makers can be more innovative. Wine makers can use technological advancements to make a better wine. They are also able to make blends of wines, which old world wines are not able to do to the same extent. This provides a more entrepreneurial environment, and wine makers are able to be more competitive. Taste wise, new world wines are fruitier and fuller bodied, while having higher alcohol content due to the sweeter wines (Gormann-McAdams).

Winemaking Process

Most wineries specific processes differ but winemaking can be condensed into the five general steps shown below.

Figure 3-Steps of the winemaking process (The Wine Making Process, n.d.)

The first step in the winemaking process is harvesting the grapes. This must be done when the grapes are properly ripe to ensure a suitable tasting wine. The harvest can be done mechanically or by hand, although most vineyards prefer by hand because mechanical harvesters can be rough on the grapes. Next, the bunches of grapes are run through a machine which removes the stems. The grapes are then crushed mechanically. This step differs for red and white wines. To make white wine, the grapes are crushed and the must is pressed, separating the juice from the skins. This prevents unwanted color and tannins from entering the wine and altering the flavor. In the making of red wines, the juice is fermented with the skins to enhance color and flavor (Goode, n.d.). Wild yeasts are typically

present in the air, so natural fermentation will occur within 6-12 hours. Most wineries will add a specific strain of yeast which will allow for a more controlled and predictable fermentation. The fermentation process takes place in barrels or stainless steel tanks. Red wines are often then matured in oak barrels so the wine interacts with the oak and adopts some of the flavor characteristics. After fermentation the wine is often cloudy from dead yeast and tannins. The wine can be racked, which involves siphoning the wine from one barrel to another leaving behind sediment at the bottom of the barrel. Filtration and fining are also used to clarify the wine to produce a bright and clear final product. Fining involves adding a substance to the wine which bonds to unwanted solids and together they sink to the bottom of the barrel or tank. The wine is then racked and ready for bottling (The Wine Making Process, n.d.).

Zoll Cellars

Zoll Cellars is a micro-winery located in Shrewsbury, MA. Frank Zoll has owned and operated the winery since 2008 when he first opened it. Currently, Frank Zoll grows grapes on his property and imports from nearby locations to make his wine. His product line currently includes 10 beverages, with prices ranging from $10 to $25 a bottle. Currently, the wines can be purchased at multiple local retailers, including the Wine Vine on West St and Highland Liquors, at local restaurants, including the Sole Proprietor, and local farmers markets (Zoll Cellars, n.d.).

Post Processing Techniques

After the fermentation of grape juice, the mixture is full of dead yeast and other imperfections, making for a very cloudy wine. Other steps must be taken after fermentation to ensure a clear and appetizing wine. The simplest step is to rack the wine. Racking the wine can clear most of the floating particles, but not all are cleared. The other two more effective post-fermentation techniques are filtration and fining. Filtration is simply running the wine through a filter to remove the particles. Fining agents are materials that bond with different unwanted particles in the wine and sink to the bottom, requiring another racking step.

Filtration

Filtration is the last step in the winemaking process before bottling. Most commercial wines are filtered to produce a clear finished product. Filtration removes dead or unreacted yeast, bacteria, and grape debris. This also makes the wine more stable because there is no longer leftover yeast to react with sugar and continue fermenting the wine. In addition, filtration removes particles, which if left in the wine, may later settle out as sediment at the bottom of the bottle. However, filtering a wine could remove compounds that contribute subtle and complex flavors to the wine. Therefore, filtration has benefits and drawbacks that must be carefully considered (Filtering Wine, n.d.).

There are three different types of filtration systems. A gravity flow filter is the least expensive option. It involves a filter body, which is connected to the bottom end of a siphon tube. The siphoning, which is induced by gravity, causes the wine to pass through

the filter. The wine leaving the filter is then immediately bottled. The drawback of this method is that it is very slow so it is not ideal for high volume. The next type is a hand pumped filtration system. This involves using a hand pump to direct the wine flow through the filter. This method is faster than the gravity flow filter but it requires two people to operate it. One person must pump the wine while the other bottles the wine after filtration. The last type of filtration system is a powered pump unit. There are many powered units but typically they involve a mechanical pump that pushed the wine through a filter or creates a vacuum to pull the wine through a filter. This system is faster than the other two, but it is also much more expensive. There are also various filter pad sizes. The pad depends on the size of the pore, which is typically measured in microns. Common wine filter pads range from 0.45-5.0 microns. The smaller the micron rating, the more particles the filter will remove because it is more selective. Most wineries use 2-micron filters to remove yeast or 0.45-microns to remove bacteria. Filters are also either nominal or absolute. A nominal filter is designed to remove most of the particles that are equal to or greater than the micron size. An absolute filter will remove all of the particles larger than its micron size (Keller, 1997).

Fining

Carbon

Activated carbon is used to remove unwanted odors from wine. Similar to a water filter, carbon absorbs weakly polar molecules, particularly benzene rings. Phenolic compounds, which cause odors, are also frequently absorbed. However, carbon has a

tendency to strip the wine of flavor and color if over used. Extreme care must be taken while using carbon as a fining agent. Carbon is more commonly used in red wines, so it would not be a good choice for the Riesling and Chardonnay wines that are being studied.

Egg Whites

Egg whites are a fining agent that has been used for generations in old world wine. Albumen is an egg white protein that is water-soluble. For fining, egg whites must be added to a salt-water solution first. Egg whites are used to reduce astringency and tannins. They are typically implemented during barrel aging of red wines, therefore would not be a good option for the white wines being studied.

PVPP

PVPP is a synthetic molecule, poly-vinyl-poly-pyrrolidone. It is used as a vegan substitute of gelatin. PVPP reduces tannins in white wines while also removing oxidizing agents from wine. It affects the colors of wine as it reduces browning. However, PVPP is difficult to get in small quantities and is expensive, so we did not include it in our tested agents.

Insinglass

Insinglass is a gentle fining agent; it is made to be a final polish to a wine, and is not used for heavily clouded wines. Insinglass will not change the color or characteristics of the wine, and will just produce a thin layer of sediment. It is produced from collagen found in

fish swim bladders. Since the wines studied were very cloudy, it was decided that it would not be a good fining agent to test in this project.

Blood

Before modern winemaking, wine makers used blood as a fining agent. It is used to reduce tanins, and is more commonly used in red wines. However, in many countries, including the United States and France, blood is illegal to use as a fining agent in wine. Therefore, it would not be an acceptable fining agent for Zoll Cellars.

Sparkalloid

Developed by Scott Labs, Sparkalloid is a name brand fining agent made of skeletons of algae. It can be used for clarifying juices or wines. It is gentle and creates an exceptional wine if used in moderation. In regards to other fining agents, it is easy to prepare. However, because it is a name brand fining agent, it was difficult to order online in small quantities. Because of this, we decided not to study this agent.

Bentonite

Bentonite is arguably the most frequently used fining agent. It is a volcanic clay discovered in Wyoming. When hydrated, it can grow 20 times its size. Bentonite must be hydrated before being added to the wine, otherwise it would just sink to the bottom and absorb all parts of the wine and not just the particles intended. After hydration, Bentonite is able to attract positively charged particles because it has a negative charge itself. As a

fining agent, it is an effective first fining step. This was the first of the three fining agents we chose to study since it is commonly used in white wines.

Chitosan/Kieselsol

Chitosan is a commonly used fining agent. It is used in conjunction with Kieselsol, as Chitosan is positively charged and Kieselsol is negatively charged. This is to avoid over stripping the wine, as leftover Chitosan particles can bond with Kieselsol and sink to the bottom of the tank as sediment. Chitosan is derived from shellfish, so it is important to consider during the labeling process of wine, since people with shellfish allergies will not be able to drink the wine. Kieselsol is added first to the wine, and an hour later the Chitosan is added. This combination is especially effective on white wines, as it is gentler and removes most suspended proteins and solids from the wine. Because Chitosan and Kieselsol are inexpensive and easy to use, this combination of fining agents were studied.

Gelatin/Kieselsol

Gelatin is another common fining agent. When used in red wines, it is a powerful clarifying agent and significantly reduces tannins in the wine. For white wines, gelatin is also effective for reducing bitter tastes caused by tannins. Although, it is necessary to also use Kieselsol when using gelatin with white wines because using gelatin alone can over strip the wine and remove important flavor compounds in the wine. Similar to Chitosan and Kieselsol, gelatin is a positive charge so the two work together to remove particles from the wine that are unwanted. Kieselsol is negatively charged so it bonds to excess gelatin to prevent over stripping of the wine. However, gelatin is an animal protein.

Because it is from an animal, it is important to label that the wine is no longer vegan as there were animal products in the wine production. We chose this as our final fining agent because it would be beneficial to compare to Chitosan since they work similarly but gelatin is more aggressive with its fining of the wine (Chorniak).

Gas Chromatography

Gas Chromatography (GC) is a common and effective method for profiling the chemical compounds in alcoholic beverages. This method of analyzing wine usually requires an extraction step before injection into the column to avoid water contamination. When combined with a mass spectrometer, gas chromatography can detect and report the chemical compounds found in a sample. Wine contains many subtle compounds, therefore gas chromatography is a popular method for analyzing wine profiles (Baldock, 2005).

Methodology

Many fining agents require specific preparation before they can be added to the wine. Bentonite, Chitosan and Kieselsol, and gelatin and Kieselsol all mandated different preparation techniques. Once the fining agents were prepared, they were added to the wine in specific amounts and sat for a period of time before racking. After racking, a variety of analysis techniques were used to compare the difference between the fining agents and determine their effectiveness in clarifying the wine.

Bentonite

Bentonite was the first fining agent that was studied. Bentonite is volcanic clay that is available in a dried powder. It was purchased from Homebrew Emporium in West Boylston, MA for $3.95 for one pound. The instructions on the packet said to use 1-2 tsp for 5 gallons of wine, so this one-pound bag would clear a large amount of wine.

On the Internet, there were a large variety of instructions for using Bentonite. As a chemical, all brands of Bentonite are the same, but it was interesting that each website and distributor had different instructions on how to use it. It was decided to follow the directions on winemakersacademy.com because they were the most specific of the sites and the most thorough (How to use Bentonite to Clarify Wine). After reading through their directions, it was decided that it would be most effective to study three variables within the directions: the temperature of the water when the Bentonite was added, the ratio of the Bentonite slurry to wine, and the wait time before racking. The following steps were taken:

1. The Bentonite was first rehydrated. The directions said to add 2 teaspoons to half a cup of water, but converted to metrics 10 mL of Bentonite was used and 120 mL of water. The water was at one of the different trial temperatures (which was monitored with an electric thermometer) when the Bentonite was added- 125° F, 140° F, or 155° F. 140° F was the suggested temperature, but we wanted to see if the different temperatures would make a difference in the wine. The mixture was stirred vigorously until it was a consistent texture.
2. The Bentonite slurry was transferred to an airtight container and sat overnight.
3. The next day, 100 mL of wine was measured out. For the Bentonite trials, the Riesling wine was tested.
4. Different amounts of slurry were added to the wine based on the trial ratios- 0.27 mL of slurry to 100mL of wine, 0.54 mL of slurry, and 1.08 mL of slurry. The wine was then stirred, but not so vigorously that oxygen was introduced into the wine.
5. The wine sat in closed mason jars for the time lengths based on the different trial times- 4, 7, or 10 days.
6. The wine was racked after the set wait time.

The following is a table of the different variables for each of the trials, and the trials names.

Trial Name	Temperature of water when Bentonite was added (Fahrenheit)	Ratio of slurry:wine (mL:100mL of wine)	Trial Wait time (day)
B1	125°	0.54	7
B2	140°	0.54	7
B3	155°	0.54	7
B4	140°	0.27	7
B5	140°	1.08	7
B6	140°	0.54	4
B7	140°	0.54	10

Table 1- Bentonite Trial Variables

Chitosan and Kieselsol

Chitosan and Kieselsol was the second fining agent tested. The brand that was used was Super-Kleer KC fining kit. The packet was $1.95 and can clear 5-6 gallons of wine. The chardonnay was used with these fining agents. The directions for the packet were very specific, since it was a brand of Chitosan and Kieselsol. The variables that were studied were the Chitosan to Kieselsol ratio, the amount of Chitosan and Kieselsol, and the wait time before racking the wine. The following steps were taken to clear the wine:

1. 100 mL of chardonnay was measured out.
2. The trial specific amount of Kieselsol was added to the wine and stirred for one minute.
3. The Kieselsol and wine mixture sat for one hour.
4. The Chitosan packet was added to 30mL of warm water (115° F) and stirred.
5. The trial specific amount of Chitosan was added to the wine and stirred for one minute.
6. The wine was sealed in a mason jar and sat for the trial specific amount of time.
7. The wine was racked after the set wait time.

Trial	Chitosan:Kieselsol	Amount of Chitosan (mL)	Amount of Kieselsol (mL)	Wait time (Hours)
C1	3:1	0.24	0.08	24
C2	2:1	0.24	0.12	24
C3	1:1	0.24	0.24	24
C4	2:1	0.2	0.1	24
C5	2:1	0.3	0.15	24
C6	2:1	0.24	0.12	12
C7	2:1	0.24	0.12	48

Table 2- Chitosan and Kieselsol Trial Variables

Gelatin and Kieselsol

The last fining agents tested were gelatin and Kieselsol. The gelatin was purchased at Homebrew emporium and cost $1.50 for a one ounce bottle. The suggested usage on the label was one teaspoon of gelatin for 5 gallons of wine. The same Kieselsol packet used in the Chitosan and Kieselsol runs was also used for these trials. The trials were performed with the chardonnay from Zoll Cellars. The gelatin was first added to warm water in the recommended proportions of 2g gelatin for 50mL of water. The variables tested were the amount of gelatin, the amount of Kieselsol, and the wait time before racking the wine. The process used to clarify the wine is described below:

1. 100 mL of chardonnay was measured.
2. 30 mL of water was measured and heated to 112 °F
3. 1.2g of gelatin was added to the water and stirred for one minute.
4. The trial specific amount of gelatin and water mixture was added to the wine.
5. The trial specific amount of Kieselsol was then immediately added to the wine and stirred for one minute.
6. The wine was sealed in a mason jar and sat for the trial specific amount of time.

7. The wine was racked after the set wait time.

Below is a table illustrating the specific conditions for each of the gelatin and Kieselsol trials.

Trial	Amount of Gelatin (g)	Amount of Kieselsol (g)	Wait time (Days)
G1	0.01	0.04	10
G2	0.018	0.04	10
G3	0.025	0.04	10
G4	0.018	0.02	10
G5	0.018	0.04	10
G6	0.018	0.06	10
G7	0.018	0.04	7
G8	0.018	0.04	16

Table 3- Gelatin Trial variables

Wine siphoning

After the wine sat for the specified time period, it was necessary to rack the wine. At the bottom of the wines was a layer of sediment composed of the fining agents and other unwanted solids. The most common and simple method found online was siphoning the wine. The wine was placed on an elevated surface, and the second container was placed on the ground. A rubber tube was placed in the wine. On the other end, one person began sucking air out of the tube so that gravity started pulling the wine through the tube. The other person took the tube out of the original wine container, to end the siphoning, when the sediment started to be close to entering the tube. In the small-scale process we dealt with, siphoning was perfect for our needs. In the first attempt, we used 3/8th inch tubing to siphon the wine. It was discovered that this tubing was much too large, and all the

sediment was stirred up the piping and into the second vessel. When we updated the process, we tried using 1/8th inch tubing instead. The 1/8th inch tubing was successful, and was used for all the trials.

Data Collection

Mass Collection

The first data collection method was how much mass was taken out of the wine from the fining process. First, 100mL of the Chardonnay and Riesling were weighed, without the mass of the mason jar they were in. After the fining process was completed, and the wine was siphoned, the finished product was once weighed again, subtracting the weight of the mason jar.

Visual/Clarity

The clarity and visual representation of the wine was observed both before and after the addition of the fining agents. When the trial specific wait time was concluded, we took a picture before and after siphoning. The clarity of the wine resulting from the different fining trials was compared to the wine before fining. In addition, the difference in wine clarity between the various fining trials was observed.

pH Testing

The pH values of the wines before and after the addition of the fining agents were also studied. An electronic pH meter, provided by the WPI Chemistry department, was used

to test the different wines. Before it could be used, the meter had to be calibrated. The meter was calibrated first in a solution with a known pH of 7.0, and then subsequently in a solution with a known pH of 4.0. Once the meter was calibrated, it was placed in the different wine trials to measure the pH.

GC Testing

Gas chromatography was used to profile the various wine samples and allow for comparisons to be made between the different profiles. A sample containing water cannot be run through the GC so an extraction method was used to isolate the wine analytes. This method was developed based on the method used by Justin Lagassey in his Major Qualifying Project from 2013. The initial extraction method required 3mL of wine, 7 mL of water, 2.25 g of NaCl, and 0.4 mL of dichloromethane in a centrifuge tube (Lagassey, 2014). This method did not yield a successful separation so various alterations of the above method were tested until one yielded proper separation. The final method used for all the wine samples involved 10 mL of wine, 10 mL of water, 4.5 g of NaCl, and 10 mL of dichloromethane. The samples were shaken by hand for 10 minutes. The samples were left for one day to allow separation time. A micropipette was used to extract 1mL of wine analytes from the bottom of the centrifuge tube. The extracted liquid was sealed in a GC sample vial.

The gas chromatography parameters were originally developed by Justin Lagassey. The following parameters were used to run all the wine samples in the GC. The AOC-20i auto sampler was used to inject 0.5 µL of analyte in splitless mode. The injection port was set to 230°C. The carrier gas was kept at a constant pressure of 80 kPa. The column oven temperature profile was set as follows: hold at 50 °C for 2 minutes, ramp 10°C/min for 20

minutes to 250°C, hold for 3 minutes. The following mass spectrometer settings were used: interface temperature 230°C and ion source 200°C, detection window beginning at 3 minutes to the completion of the run at 25 minutes (Lagassey, 2014).

New York vs Massachusetts

In addition to testing the Zoll Cellar's Massachusetts trials to compare the trials to one another, the wines were also compared to two New York wines. Two Salmon River Run wines were chosen, one was a Riesling and one was a Chardonnay. However, it should be noted that the New York Riesling was not a dry Riesling, like the Riesling from Zoll Cellars. The two wines were compared using the GC test and the pH testing.

Results

In order to effectively compare the different fining agent trials the following tests were conducted. Visual clarity observations were recorded, the pH was tested, the mass change due to racking was recorded, and gas chromatography tests were conducted.

Visual Observations

Pictures of the wines were taken before and after wine siphoning. The full photo set can be seen in Appendix A. One trial, B5, is shown below in Figures 3 and 4. This trial is shown because one clearly can see the layer of precipitate at the bottom of the jar in the before picture, while the after picture is very clear. Ideally, this is how the wine should look before and after siphoning. This trial had the largest ratio of slurry: wine, so it used the largest amount of Bentonite and was the clearest wine out of the seven trials. An important trial to consider is B1, which is shown below in Figures 5 and 6. B1 has a layer of precipitate at the bottom with a slight haze, but after siphoning, the wine is very murky, and not clear at all. This trial is not ideal as the wine remained cloudy. What is interesting is that this trial used the lowest temperature of water, 125 °F, to dissolve the Bentonite. The water was likely not warm enough to fully dissolve the Bentonite, causing solid bentonite particles to remain suspended when added to the wine. Winemaking websites even warn to not add pure Bentonite to wine, as it will cause hazy wines.

Figure 3- Trial B5 Before

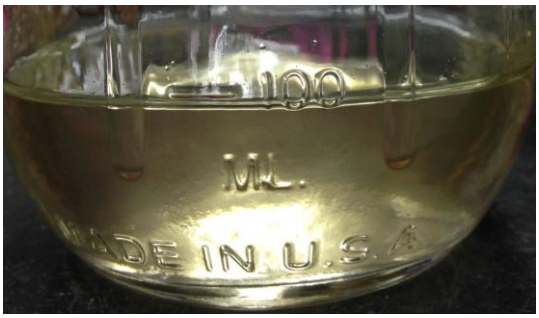

Figure 4- Trial B5 After

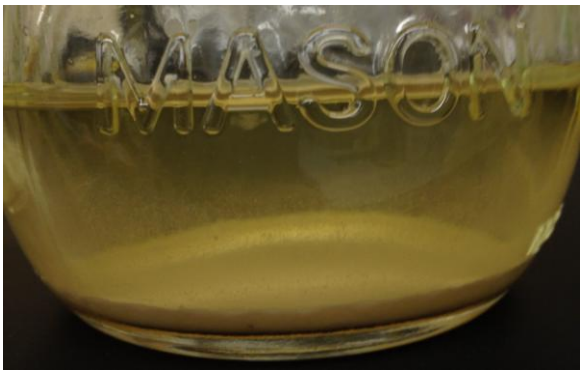

Figure 5- Trial B1 Before

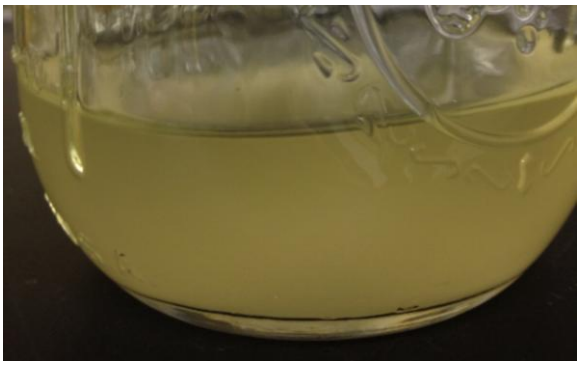

Figure 6- Trial B1 After

Similar to Bentonite, pictures of the wine were taken before and after siphoning for the Chitosan and Kieselsol trials. The full photo set can be found in Appendix B. Trial C4 is shown below in Figures 7 and 8. C4 is the haziest trial. This can be explained because this trial used the least amount of fining agents. Trial C5 is shown below in Figures 9 and 10. This was the clearest trial. This can be explained because this trial used the most amount of fining agents.

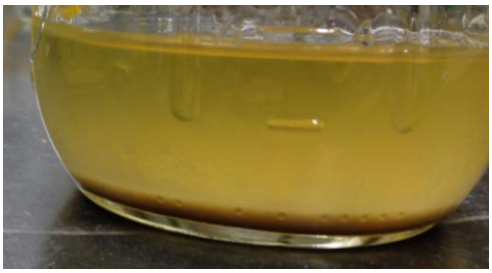

Figure 7- Trial C4 Before

Figure 8- Trial C4 After

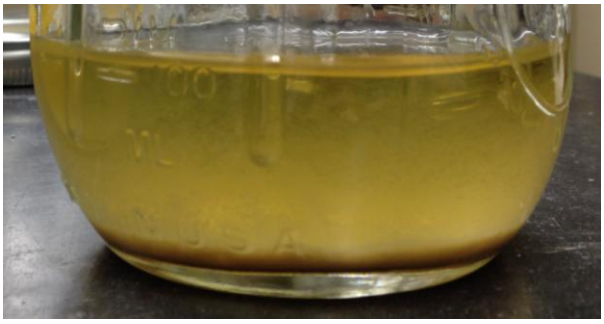

Figure 9- Trial C5 Before

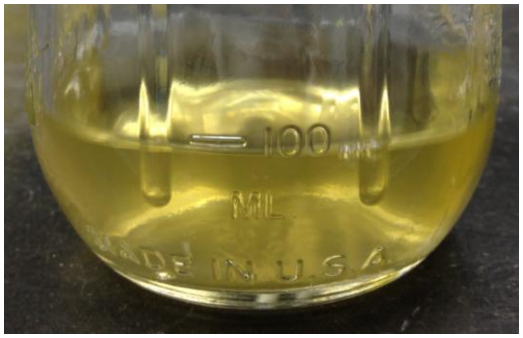

Figure 10- Trial C5 After

Similar to Bentonite and Chitosan, the pictures were studied before and after siphoning for the gelatin and Kieselsol trials. The full photo set can be found in Appendix C. Trial G3 is seen below in Figures 11 and 12. G3 happened to be the haziest trial after fining. This is important to note because the largest amount of gelatin was used in this trial, and the ratio of gelatin: Kieselsol was the largest. This haze could be excess gelatin suspended in the wine, as it is warned to not over use gelatin. Trial G6 is also shown below in Figures 13 and 14. G6 was the clearest trial after fining. This trial used the most amount of Kieselsol and had the smallest ratio of gelatin: Kieselsol. Finally, trial G8 can be seen below in Figures 15 and 16. The wait time before racking for this trial was 16 days, which was the

longest of all the trials. As shown, the wine is much lighter in color. The gelatin stripped the wine of its color, which was a warning in using gelatin.

Figure 11- Trial G3 Before

Figure 12- Trial G3 After

Figure 13- Trial G6 Before

Figure 14- Trial G6 After

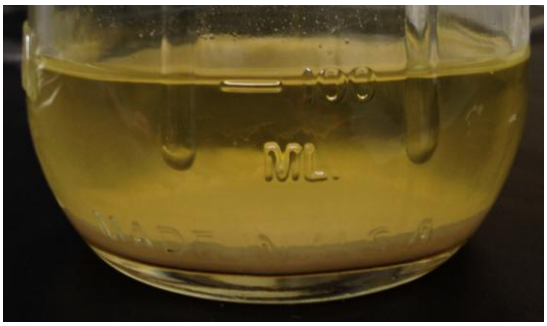

Figure 15- Trial G8 Before

Figure 16- Trial G8 After

Mass Results

The weight of the wine was measured before the addition of fining agents, and after the wine was siphoned. The change in mass in the Bentonite trials can be seen below in Figure 17. The largest change was trial B3. This was one of the first trials siphoned, so there was still a learning curve on how to properly siphon. Extra precaution was taken to avoid taking the precipitate with the wine, so excess wine was left behind. Trial B4 was also important to note since it had the largest mass change with the exception of B3. The precipitate was less solid than in other trials and was more difficult to remove, so more wine was left behind. This is explained because this trial used the least amount of fining agent. Trial B5, on the other hand, used the most amount of fining agent, and the precipitate was more compact and a greater amount of wine could be siphoned out.

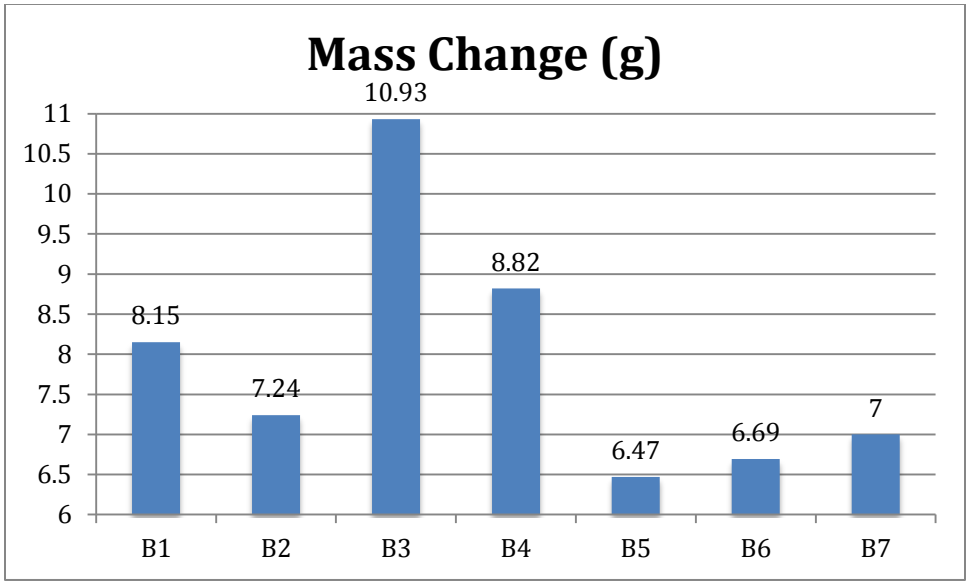

Figure 17- Mass Change of Bentonite Trials

The mass was also compared for the Chitosan and Kieselsol trials. The change in mass can be seen below in Figure 18. As shown, the mass changes are much larger than in

the Bentonite trials, with the exception of trial C2. This trial was the control trial since the variables were all set in the middle, so it should not have been this much of an outlier. The reason concluded was because of human error. Besides this error, the trial with the least amount of mass change was trial C5. This trial had the most amount of fining agents so the precipitate was the most solid, and less wine was left behind. The trial with the most amount of mass removed was trial C6. This trial had the smallest wait time before siphoning so the precipitate had less time to settle.

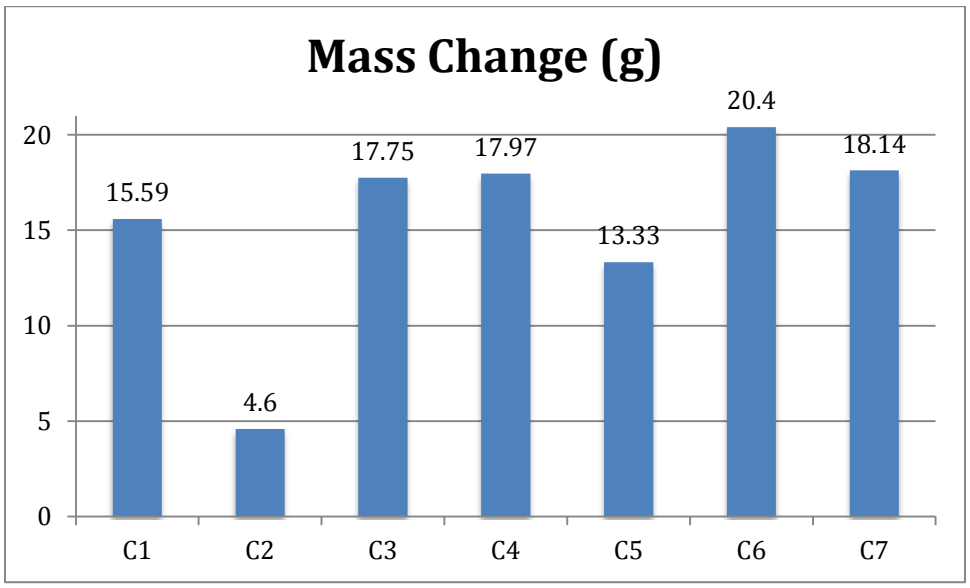

Figure 18- Mass Change of Chitosan Trials

Finally, the mass change was compared for the gelatin and Kieselsol trials. The change in mass can be seen below in Figure 19. G3 removed the least amount of mass. Trial G8 removed the most amount of mass. These results did not follow any obvious trend.

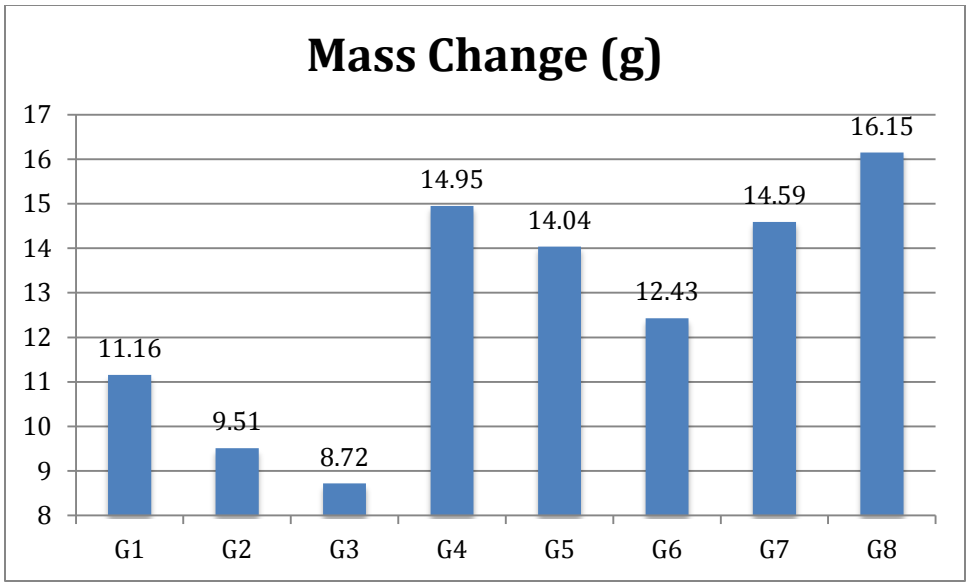

Figure 19- Mass Change of Gelatin Trials

pH Results

Below is a chart illustrating the difference in the pH values of the New York Riesling, Zoll Cellars Riesling before fining, and various trials of the Zoll Cellars Riesling after fining with Bentonite.

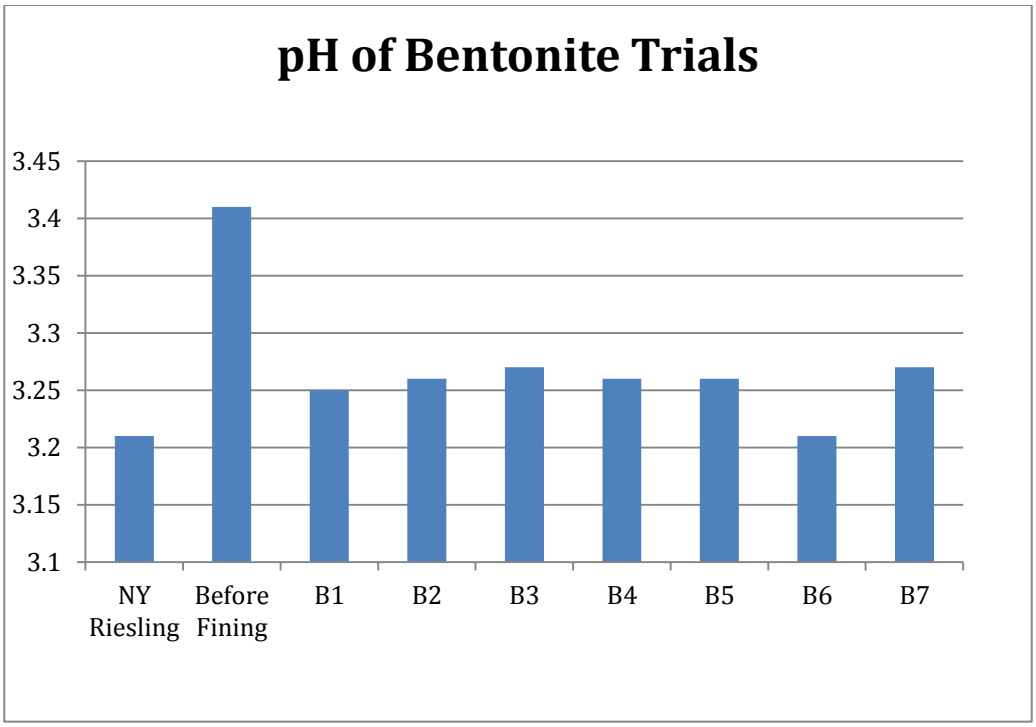

Figure 20- pH of Bentonite Trials

The New York Riesling is slightly more acidic than the Zoll Riesling. The Zoll Riesling acidity is slightly increased with the addition of Bentonite fining. The increase in acidity is fairly standard across the different Bentonite fining trials. Based on this data, the pH of the wine decreased with the addition of Bentonite, but did not vary when the amount of Bentonite was increased.

The following chart is a representation of the difference in pH between the New York Chardonnay, the Zoll Cellars Chardonnay before Chitosan and Kieselsol fining, and the various trials of fining Zoll Chardonnay with Chitosan and Kieselsol.

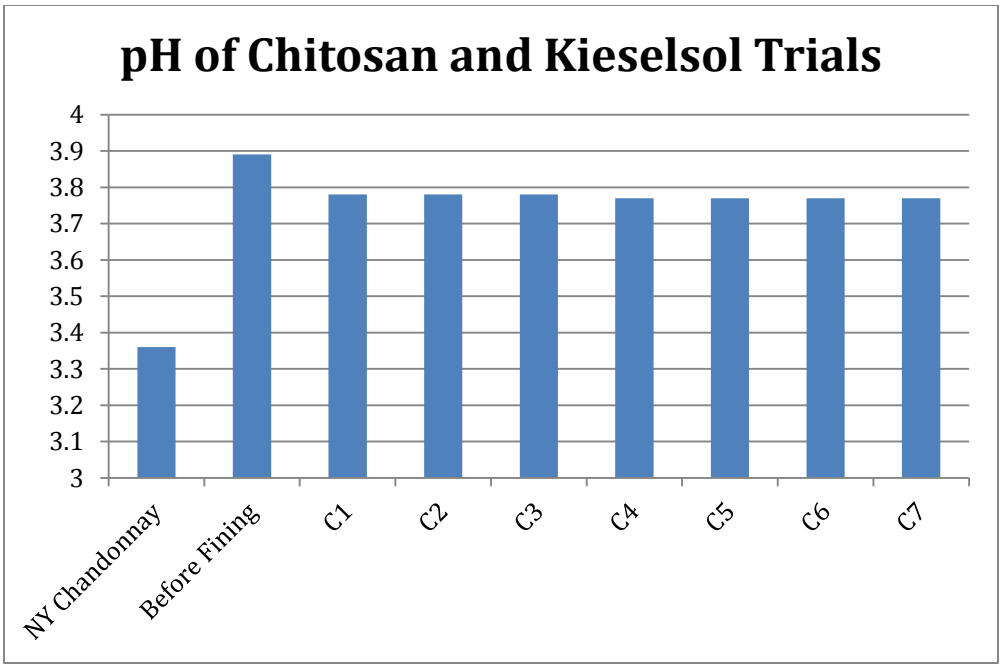

Figure 21- pH of Chitosan Trials

The New York Chardonnay is slightly more acidic than the Zoll Chardonnay. The Zoll Chardonnay became more acidic with the addition of Chitosan and Kieselsol. However, the pH remained fairly constant throughout the seven different fining trials. The acidity of the chardonnay did not change when the amount of fining agent increased.

Below is a chart displaying the pH of the New York Chardonnay, the Zoll Cellars Chardonnay, and the various trials of fining Zoll Chardonnay with Gelatin and Kieselsol.

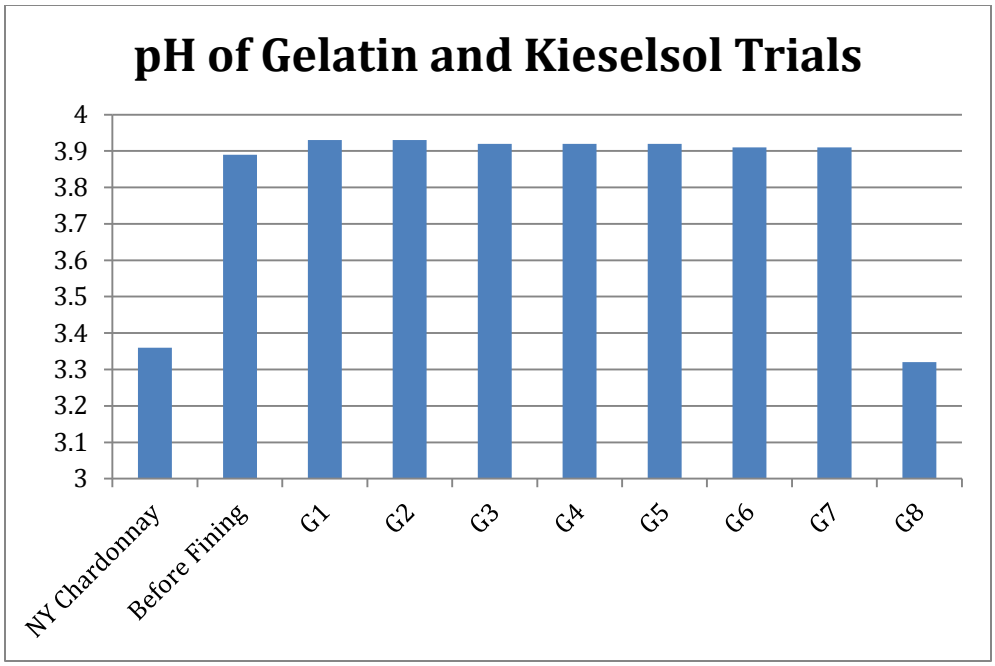

Figure 22- pH of Gelatin Trials

Once again, the New York Chardonnay is more acidic than the Zoll Chardonnay. The pH did not vary significantly with the addition of Gelatin and Kieselsol in trials 1-7. However, the pH in trial 8 decreased a significant amount. This is a result of increased wait time. Trial 8 had the largest wait time of 16 days before fining. The increased amount of time that the gelatin and Kieselsol were allowed to react with the wine caused an over stripping of the wine. This is not desired because it is likely that the gelatin removed important aromatic and flavor compounds in the wine.

Gas Chromatography Results

NY vs MA Riesling

The chemical composition of the Massachusetts Riesling, before fining agents, and the New York Riesling were compared. The can be seen below in Table __. As shown, the entire chemical profile of the Massachusetts Riesling was more extensive and displayed a larger amount of compounds. What was interesting to note was the large number of esters in the New York Riesling. This was a sweet Riesling, while the Massachusetts wine was a dry Riesling so this is expected. However, there was a large amount of acids in the New York Riesling, which typically make a wine drier. Although the large amount of esters must compensate for this and make the wine sweeter. What was interesting to note was that there were no acids present in the Massachusetts dry Riesling, like in the New York Riesling. There are 13 common chemicals present in both the Massachusetts and New York Rieslings. Phenylethyl alcohol and eicosane are two chemicals that occur very frequently in wine.

Massachusetts	New York	Shared Chemicals
1-Decene, 2,4-dimethyl-	1-Butanol, 3-methyl-, acetate	2,3-Butanediol, [R-(R*,R*)]-
1-Dodecanol, 2-hexyl-	2-Isopropyl-5-methyl-1-heptanol	2,4-Dimethyl-1-heptene
1-Dodecanol, 3,7,11-trimethyl-	2-methyltetracosane	Benzene, 1,3-bis(1,1-dimethylethyl)-
1-Propanol, 3-ethoxy-	2-Pyrrolidinecarboxylic acid-5-oxo-, ethyl ester	Benzeneethanol, 4-hydroxy-
2-Bromo dodecane	2,3-Butanediol	Benzofuran, 2,3-dihydro-
2-Isopropyl-5-methyl-1-heptanol	5-Hydroxymethyldihydrofuran-2-one	Decane, 3,7-dimethyl-
3,7-Octadiene-2,6-diol, 2,6-dimethyl-	Benzaldehyde, 2,4-dimethyl-	Dodecane
5,5-Diethylheptadecane	Butanedioic acid, diethyl ester	Dodecane, 4,6-dimethyl-
Decane, 3,6-dimethyl-	Butanedioic acid, hydroxy-, diethyl ester, (.+/-.)-	Eicosane
Decane, 4-methyl-	Butanoic acid, 4-hydroxy-	Heptadecane
Dodecane, 2-methyl-6-propyl-	Decane, 2,3,4-trimethyl-	Pentadecane
Dodecane, 2,6,10-trimethyl-	Decane, 5-ethyl-5-methyl-	Phenylethyl Alcohol
Dodecane, 2,6,11-trimethyl-	Decanoic acid, ethyl ester	Tetradecane, 5-methyl-
Dodecane, 4-methyl-	Ethyl hydrogen succinate	
Heneicosane	Formic acid, hexyl ester	
Heptadecane, 2,6,10,15-tetramethyl-		

Heptane, 2,4-dimethyl- Heptane, 5-ethyl-2-methyl- Hexadecanal Hexadecane Hexadecane, 1-iodo- Hexadecane, 2,6,11,15-tetramethyl- Methyl 4-O-methyl-d-arabinopyranoside Nonadecanenitrile Nonane, 2,5-dimethyl- Nonane, 3-methyl-5-propyl- Octane, 4-methyl- Pentadecane, 2,6,10-trimethyl- Pentafluoropropionic acid, octadecyl ester Pentane, 3-ethyl- PYRIMETHANIL Tetradecanal Tetradecanenitrile Tridecane Undecane Undecane, 2-methyl- Undecane, 2,5-dimethyl- Undecane, 2,9-dimethyl- Undecane, 3,8-dimethyl- Undecane, 4,4-dimethyl-	Hexanoic acid, ethyl ester N-(3-Methylbutyl)acetamide Nonadecane, 9-methyl- Octanoic acid Octanoic acid, ethyl ester Propanoic acid, 2-hydroxy-, ethyl ester Propanoic acid, 2-hydroxy-, ethyl ester, (S)- Tetradecane	

Table 4-Massachusetts vs New York Riesling

NY vs MA Chardonnay

The chemical composition of the Massachusetts Chardonnay, before fining agents, and the New York Chardonnay were compared. The can be seen below in Table 5. As shown, the entire chemical profile of the Massachusetts Riesling was more extensive and displayed a larger amount of compounds. An important comparison between the two wines was the large number of esters and acids in the New York Chardonnay, which were not present in the Massachusetts Chardonnay. However, there were 22 shared chemicals between the two chardonnay variations, which was much larger than the 13 shared chemicals between the Rieslings.

Massachusetts	New York	Shared Chemicals
1-Decene, 2,4-dimethyl- 1-Dodecanol, 2-hexyl- 1-Dodecanol, 3,7,11-trimethyl- 1-Propanol, 3-ethoxy- 2-Bromo dodecane 3,7-Octadiene-2,6-diol, 2,6-dimethyl- 5,5-Diethylheptadecane Benzofuran, 2,3-dihydro- Decane, 4-methyl- Dodecane, 2-methyl-6-propyl- Dodecane, 2,6,10-trimethyl- Dodecane, 2,6,11-trimethyl- Heptane, 5-ethyl-2-methyl- Hexadecane, 1-iodo- Hexadecane, 2,6,11,15-tetramethyl- Methyl 4-O-methyl-d-arabinopyranoside Nonadecanenitrile Nonane, 2,5-dimethyl- Nonane, 3-methyl-5-propyl- Octane, 4-methyl- Pentadecane, 2,6,10-trimethyl- Pentafluoropropionic acid, octadecyl ester Pentane, 3-ethyl- PYRIMETHANIL Tetradecanal Tetradecanenitrile Tridecane Undecane Undecane, 2-methyl- Undecane, 2,9-dimethyl- Undecane, 3,8-dimethyl- Undecane, 4,4-dimethyl-	1-Butanol, 3-methyl-, acetate 1-Propanol, 3-ethoxy- 10-Methylnonadecane 2-Pyrrolidinecarboxylic acid-5-oxo-, ethyl ester 2,3-Butanediol 3-Ethyl-3-methylheptane 4-O-Methylmannose 5-Hydroxymethyldihydrofuran-2-one Butanedioic acid, hydroxy-, diethyl ester, (.+/-.)- Decane, 5-ethyl-5-methyl- Decanoic acid, ethyl ester Decanoic acid, silver(1+) salt Disulfide, di-tert-dodecyl Dodecane, 2,7,10-trimethyl- Ethyl hydrogen succinate Formic acid, hexyl ester Hexanoic acid, ethyl ester Nonane, 5-methyl-5-propyl- Octanoic acid Octanoic acid, ethyl ester Oxalic acid, 2-ethylhexyl hexyl ester Propanoic acid, 2-hydroxy-, ethyl ester	2-Isopropyl-5-methyl-1-heptanol 2,3-Butanediol, [R-(R*,R*)]- 2,4-Dimethyl-1-heptene Benzene, 1,3-bis(1,1-dimethylethyl)- Benzeneethanol, 4-hydroxy- Decane, 3,6-dimethyl- Decane, 3,7-dimethyl- Dodecane Dodecane, 4-methyl- Dodecane, 4,6-dimethyl- Eicosane Heneicosane Heptadecane Heptadecane, 2,6,10,15-tetramethyl- Heptane, 2,4-dimethyl- Hexadecanal Hexadecane Pentadecane Phenylethyl Alcohol Tetradecane Tetradecane, 5-methyl- Undecane, 2,5-dimethyl-

Table 5- Massachusetts vs New York Chardonay

Fining Agent Trial Chemical Profile Comparison Trends

Bentonite

Throughout the seven Bentonite trials, the entire chemical profile was given. The top twenty chemicals in the Massachusetts Riesling were studied. The area percentages were then looked at to see generic trends throughout the trials. The compounds in each of

the trials were described as increased, decreased, eliminated, or staying the same based on area percentages. Seeing as the area percentages were studied, technically if one compound's percentage is decreased, the remaining compounds' percentages will increase. Due to this, if a compound's percentage remained the same, technically the actual amount of that compound in the samples differed slightly. There was some error in the GC and extraction method so this small change was considered insignificant. The chemical profile across the seven trials can be seen in Appendix D. From this, we were able to conclude trends for benzeneethanol, 4-hydroxy-, decane, 3,6-dimethyl-, decane, 3,7-dimethyl-, dodecane, dodecane, 4,6-dimethyl, eisocane, hexadecanal, phenylethyl alcohol, and tetradecane.

Benzeneethanol, 4-hydroxy- increased in percentage in all seven Bentonite trials. This is because it was not removed at all from the wine because of the Bentonite. Not removing this chemical from the wine is beneficial because it is an antioxidant, which is regarded as the healthy portion of wine. Antioxidants are becoming increasingly popular and people want antioxidants in their diets, so keeping this in the wine is good. What is interesting though, is that benzeneethanol, 4-hydroxy- is typically found in red wines and not white wines.

Decane, 3,6-dimethyl- decreased, or was completely removed in all seven trials of the Bentonite. The Bentonite worked to remove this chemical. On the other hand, decane, 3,7-dimethyl- drastically increased in percentage after the Bentonite trials. This is likely due to the chemical structure shown below. The methyl groups are in different locations which effects bonding.

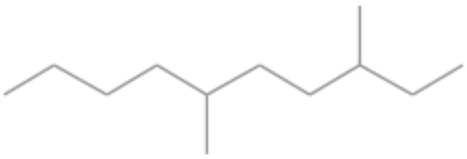

Figure 23- Decane, 3,6-dimethyl- (Decane, 3,6-dimethyl).

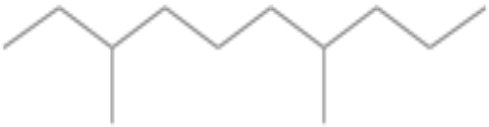

Figure 24- Decane, 3,7-dimethyl- (Decane, 3,7-dimethyl).

Dodecane increased in percentage throughout all seven trials. Once again, this was not a chemical that was removed. Dodecane, 4,6-dimethyl was largely removed across the Bentonite trials. Once again, despite being similar, this is likely due to the chemical structure shown below. Dodecane, 4,6-dimethyl has two methyl groups which makes the chemical very different.

Figure 25- Dodecane (Dodecane).

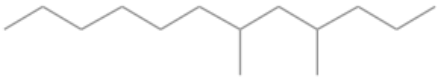

Figure 26- Dodecane, 4,6-dimethyl- (Dodecane, 4,6-dimethyl).

Eicosane drastically decreased in percentage throughout the seven trials. Eicosane provides a sweeter, floral flavor to a wine, and it is also commonly found in rose water. Since this is a dry reisling, removing sweeter components is beneficial.

Hexadecanal decreased after adding Bentonite as a fining agent. It was only removed in small quantities though, and is important to note but did not make a large difference.

Phenylethyl alcohol had a large increase in percentage across the trials. It started with a large area percentage, but when other things were removed, it increased greatly.

This is due to the fact that other compounds in the wine were removed in larger portions, while the phenylethyl alcohol was not removed at all. This is beneficial because phenylethyl alcohol is an aromatic alcohol and has a floral odor.

Lastly, tetradecane largely decreased throughout the trials.

Chitosan and Kieselsol

Similar to the Bentonite trials, the entire chemical profile for Chitosan and Kieselsol trials was given. The top twenty chemicals in the Massachusetts Chardonnay were looked at for the seven trials. Once again, the area percentages were then studied to see generic trends throughout the trials. The chemical profile across the trials can be seen in Appendix E. From this analysis, trends concluded for 2-isopropyl-5-methyl-1-heptanol, decane, 3,7-dimethyl-, decane, 4-methyl-, eicosane, heptadecane, 2,6,10,15-tetramethyl-, heptane, 5-ethyl-2-methyl-, hexadecanal, phenylethyl alcohol, and tetradecane.

2-isopropyl-5-methyl-1-heptanol decreased in area percentage in all seven trials. It was removed from the wine with the combination of Chitosan and Kieselsol.

Decane, 3,7-dimethyl- was also removed from the wine. What is important to note about this is that it differs from the Bentonite, which increased throughout the trials. This makes sense because Chitosan is a positive charge, while Bentonite is negatively charged. Decane,4-methyl was also removed from the wine, which is expected since they have similar structures.

Eicosane was also removed, but in drastically different amounts in each of the trials. In one, 64% of the eicosane was removed but in another trial, only 6% was removed. This could be explained by error.

Heptadecane, 2,6,10,15-tetramethyl-, was removed from the wine. In two trials, it was completely removed. Heptane, 5-ethyl-2-methyl- was also removed in large quantities, and in four trials was completely removed. Finally, hexadecanal was also largely removed and was eliminated in three trials.

Phenylethyl alcohol had a large increase in percentage across the trials. This is favorable because phenylethyl alcohol is an aromatic alcohol and has a floral odor, which is good for wines.

Finally, tetradecane was removed in all seven trials. What was interesting about this was that in each trial the tetradecane was eliminated by at least 52%, and ranged up to 80%.

Gelatin and Kieselsol

Like the Bentonite and Chitosan trials, the entire chemical profile for gelatin and Kieselsol trials was given. The top twenty chemicals in the Massachusetts Chardonnay were studied for the eight trials, which were the same 20 chemicals compared for the Chitosan and Kieselsol trials. Once again, the area percentages were then studied to see generic trends throughout the trials. The entire chemical profile across the trials can be seen in Appendix F. From this analysis, trends were concluded for dodecane, 4,6-dimethyl-, heptane, 5-ethyl-2-methyl, pentadecane, phenylethyl alcohol, and tetradecane.

Dodecane, 4,6-dimethyl- was removed throughout all eight trials. A significant amount of 43% to 86% of this compound was removed from the trials. This is similar to the Bentonite trials, since this chemical was largely removed in those trials as well. This is interesting because gelatin is a positively charged fining agent, while Bentonite is a

negatively charged fining agent. This could be explained because Kieselsol was added immediately to negate the effects of gelatin, and Kieselsol has a negative charge.

Heptane, 5-ethyl-2-methyl- was also removed from the wine. This was expected because it was also removed in the Chitosan and Kieselsol trials, which were a positively and negatively charged fining agent combination, like the gelatin and Kieselsol.

Pentadecane slightly decreased in area percentage in the eight trials, except for trial G8, in which it was completely eliminated.

Phenylethyl alcohol had a large increase in percentage across the trials. This was especially true in trial G8, when it increased from 12.32% phenylethyl alcohol to 49.05% after. Trial G8 was noticeably stripped, which was mentioned in the clarity section, so all the other chemicals were removed in such large quantities that the phenylethyl alcohol was half of the chemical profile. This was expected since many of the chemicals were completely eliminated in trial G8.

Finally, tetradecane was removed in all eight trials. Once again, this was anticipated because it was also removed in the Chitosan and Kieselsol trials, which were a positively and negatively charged fining agent combination, like the gelatin and Kieselsol.

Conclusions

Bentonite

After conducting the Bentonite trials, certain conclusions were able to be drawn. The more Bentonite used made for a clearer wine. Also, it made the precipitate more compact and easier to siphon. In addition, when making the Bentonite slurry, the water has to be at an adequate temperature or the Bentonite will not completely dissolve in the water and will cause a hazy wine. Finally, after running the gas chromatography analysis, it was concluded that decane, 3,6-dimethyl, dodecane, 4,6-dimethyl, eicosane, hexadecanal, and tetradecane were removed from the wine.

Chitosan and Kieselsol

The completion of the Chitosan and Kieselsol fining trials led to certain conclusions. Once again, similar to the Bentonite trials, the more Chitosan used made for a clearer wine. It also caused the precipitate to be less compact, and easier to siphon. The trends revealed from the gas chromatography analysis revealed that 2-isopropyl-5-methyl-1-heptanol, decane, 3,7-dimethyl, decane, 4-methyl-, eicosane, heptadecane, 2,6,10,15-tetramethyl, heptane, 5-ethyl-2-methyl, hexadecanal, and tetradecane were all removed.

Gelatin and Keiselsol

Lastly, conclusions were drawn based on the data collected from the gelatin and Kieselsol fining trials. A smaller gelatin: Kieselsol ratio leads to a clearer wine, and a larger

ratio makes for a hazy wine. Also, letting the fining agents remain in the wine for extended periods of time strips the wine of its color, and other important flavor compounds. Finally, the gas chromatography analysis revealed that dodecane, 4,6-dimethyl, heptane, 5-ethyl-2-methyl, pentadecane, and tetradecane were removed in all eight trials.

NY vs MA Riesling

The Salmon Run Riesling from New York and Zoll Cellar's Massachusetts Riesling were compared to one another. It is important to note, the New York Riesling is a sweet Riesling, while the Massachusetts Riesling is a dry Riesling. When comparing the GC results, the two Rieslings had thirteen chemical compounds in common, while the Massachusetts list was much larger. Also, the New York Riesling had a larger number of esters, which are typically sweeter compounds. There were also some acids, which explain why the New York Riesling had a much lower pH than the Massachusetts Riesling. However, after the addition of bentonite, the two were much more similar in pH levels.

NY vs MA Chardonnay

Similar to the Riesling varieties, the Salmon Run Chardonnay from New York and Zoll Cellar's Massachusetts Chardonnay were also compared to one another. When comparing the GC results, the two Chardonnays had 22 shared chemical compound in common. Once again, the Massachusetts Chardonnay had a much larger list of chemicals. Also, the New York Chardonnay had more acids, which explain why the New York Chardonnay had a lower pH than the Massachusetts variety. What was different was that

after fining agents were added, in both the Chitosan and Kieselsol and the gelatin and Kieselsol trials, neither were similar in pH levels to the New York Chardonnay.

Recommendations

After the completion of our trials, a series of recommendations were made for Zoll Cellars on how to use each of the fining agents, and which projects should be done for further research.

Bentonite

Bentonite was a successful fining agent at clearing the wine. However, when making the Bentonite slurry, it is necessary to warm the water to a minimum of 140°F so the Bentonite slurry can properly form. If not heated, the slurry can cause the wine to be hazy due to the excess Bentonite suspended in the wine.

When more Bentonite slurry is used in the wine, the wine is clearer. More research should be done to determine what the optimal amount of Bentonite for clearing wine is. This could be done in the form of a major qualifying project for the '15-'16 academic year. Metrics would include a cost comparison for the amount of Bentonite used, and discovering at what point the Bentonite amount plateaus at effectiveness of clearing the wine.

Another major qualifying project to further understand Bentonite would be looking at how Bentonite reacts with Chardonnay and other white wines. This project only looked at how Bentonite affected the dry Riesling, but Bentonite can also be effective with other white wines.

Chitosan and Kieselsol

The combination of Chitosan and Kieselsol cleared the Chardonnay successfully. However, it is necessary to wait a minimum of 24 hours after the addition of the fining gents and before racking the wine so that the precipitate and fining agents have ample time to settle. If racked too early, the precipitate will be loose and will more difficult to rack, leaving a larger amount of otherwise good wine behind.

The wine was clearer when more Chitosan and Kieselsol were added. Like with Bentonite, more research should be done to determine the optimal amount of Chitosan and Kieselsol for clearing the wines in the form of a major qualifying project for the '15-'16 academic year. A cost comparison and finding where the amount of Chitosan and Kieselsol plateaus at effectiveness should be done, similar to the Bentonite project recommendation.

Also, project studying how Chitosan and Kieselsol react with dry Riesling and other white wines should be done, similar to the Bentonite project suggestion. This project only studied the correlation between the fining agents and Chardonnay, but it would be important to study how Chitosan and Kieselsol interact with other white wines.

Gelatin

Finally, it is recommended that gelatin and Kieselsol should not be used as a fining agent combination for white wines. Gelatin is very harsh, and can easily over strip white wines, which was seen in trial G8. If more extensive research on gelatin is desired, it is recommended that gelatin is studied on red wines instead of white wines.

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Appendix

Appendix A-Bentonite Fining Visual Results

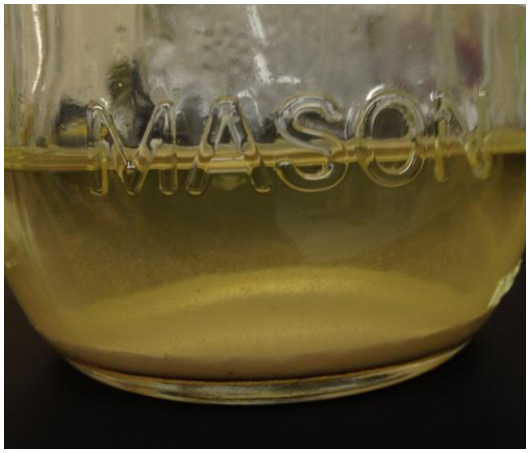

Figure 27- Trial B1 Before

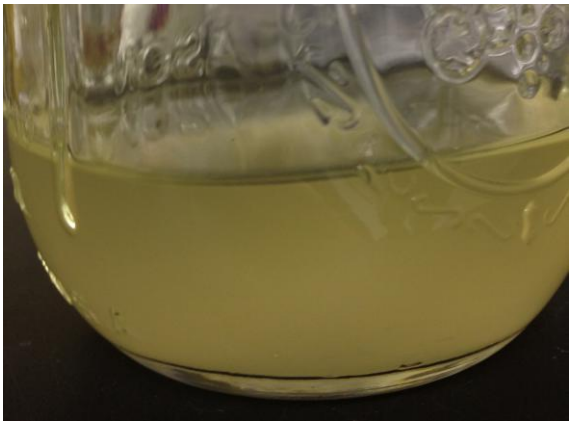

Figure 28- Trial B1 After

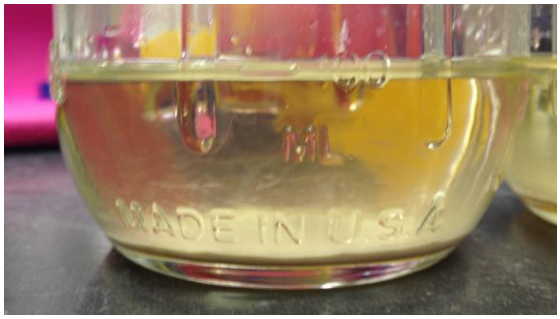

Figure 29- Trial B2 Before

Figure 30- Trial B2 After

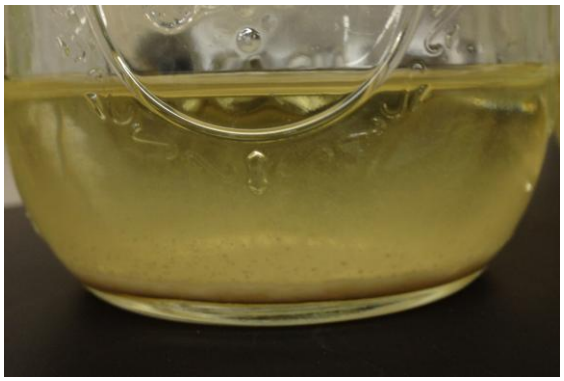

Figure 31- Trial B3 Before

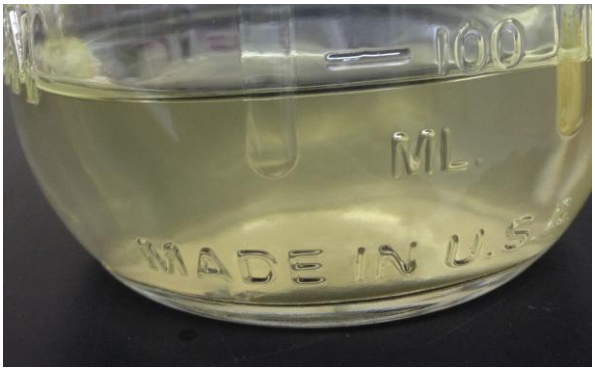

Figure 32- Trial B3 After

Figure 33- Trial B4 Before

Figure 34- Trial B4 After

Figure 35- Trial B5 Before

Figure 36- Trial B5 After

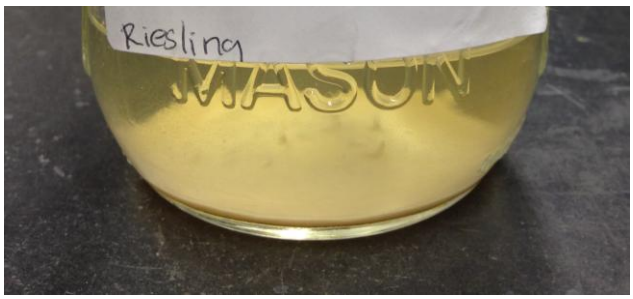

Figure 37- Trial B6 Before

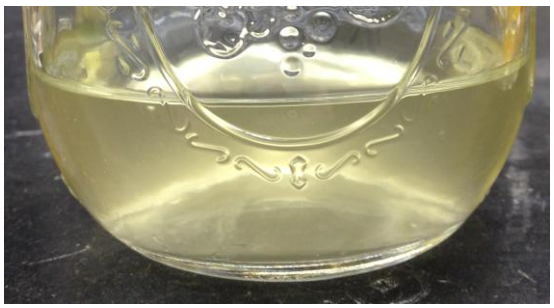

Figure 38- Trial B6 After

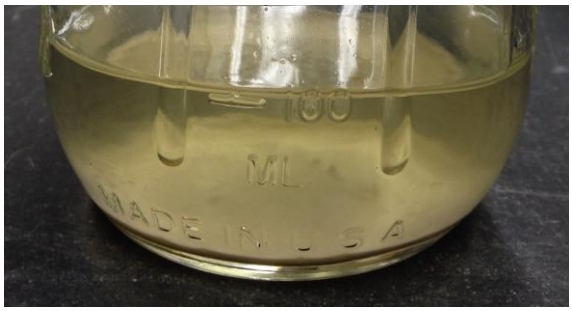

Figure 39- Trial B7 Before

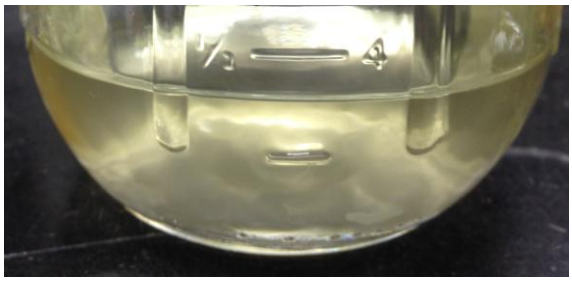

Figure 40- Trial B7 After

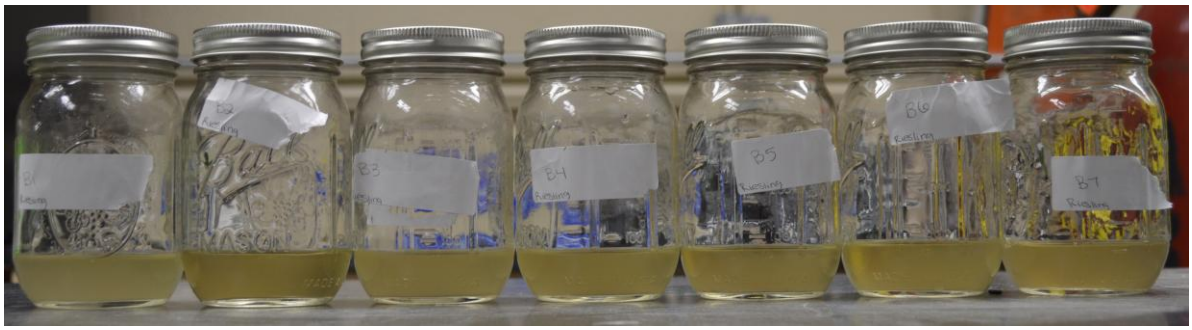

Figure 41- Trials B1(left)-B7(right)

Appendix B-Gelatin and Kieselsol Fining Visual Results

Figure 42- Trial C1 Before

Figure 43- Trial C1 After

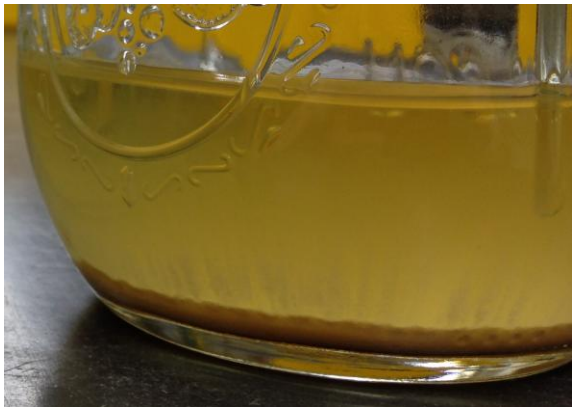

Figure 44- Trial C2 Before

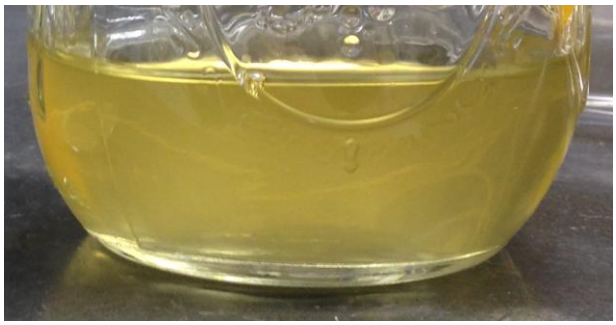

Figure 45- Trial C2 After

Figure 46- Trial C3 Before

Figure 47- Trial C3 After

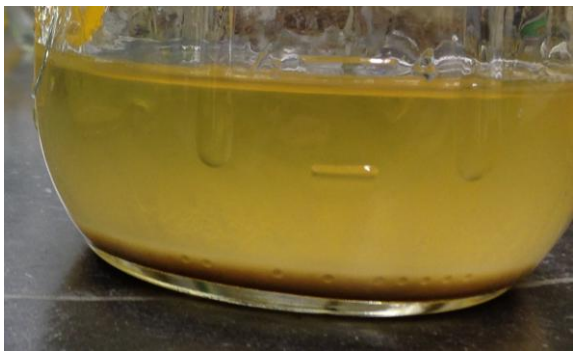

Figure 48- Trial C4 Before

Figure 49- Trial C4 After

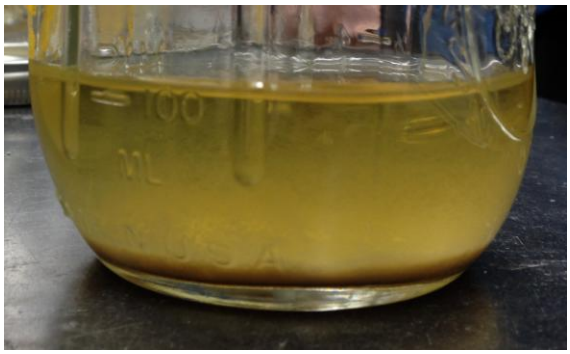

Figure 50- Trial C5 Before

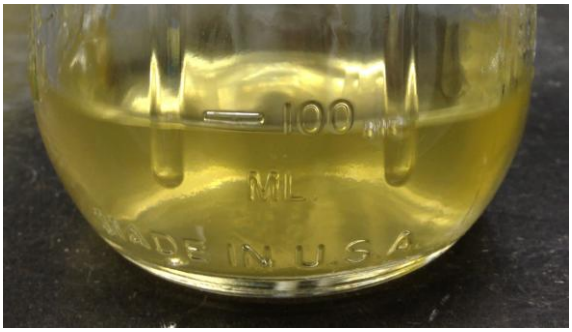

Figure 51- Trial C5 After

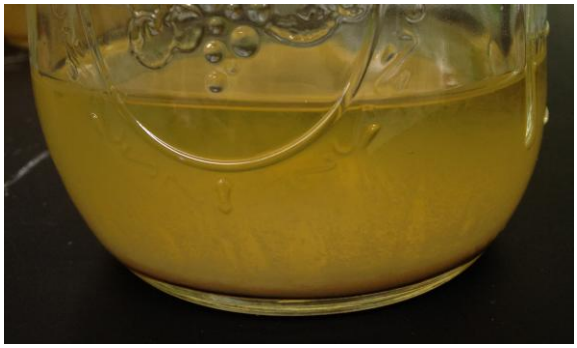

Figure 52- Trial C6 Before

Figure 53- Trial C6 After

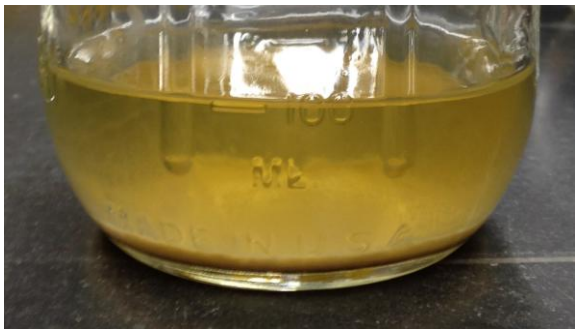

Figure 54- Trial C7 Before

Figure 55- Trial C7 After

Figure 56- Trials C1(left)-C7(right)

Appendix C- Gelatin and Kiesolsol Fining Visual Results

Figure 57- Trial G1 Before

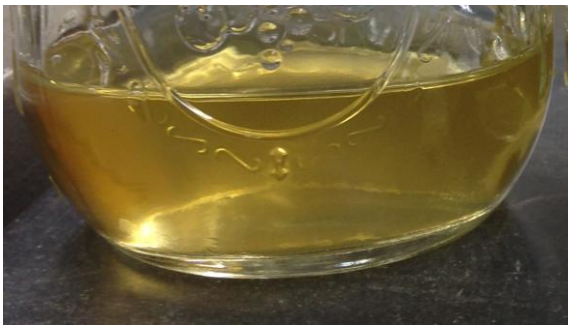

Figure 58- Trial G1 After

Figure 59- Trial G2 Before

Figure 60- Trial G2 After

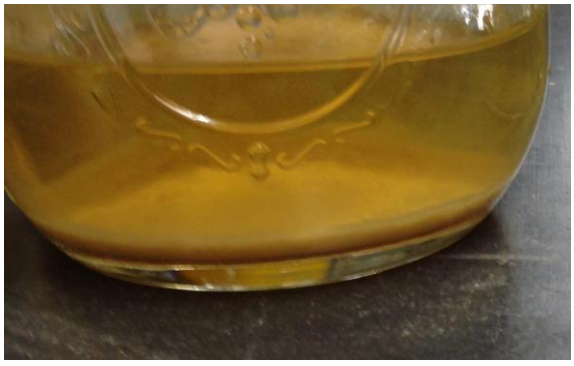

Figure 61- Trial G3 Before

Figure 62- Trial G3 After

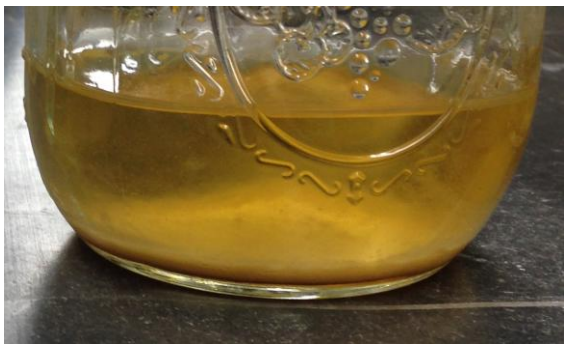

Figure 63- Trial G4 Before

Figure 64- Trial G4 After

Figure 65- Trial G5 Before

Figure 66- Trial G5 After

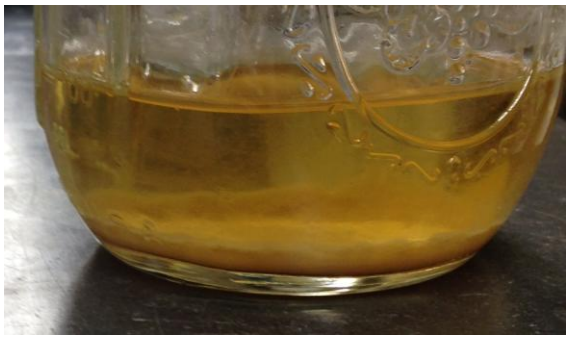

Figure 67- Trial G6 Before

Figure 68- Trial G6 After

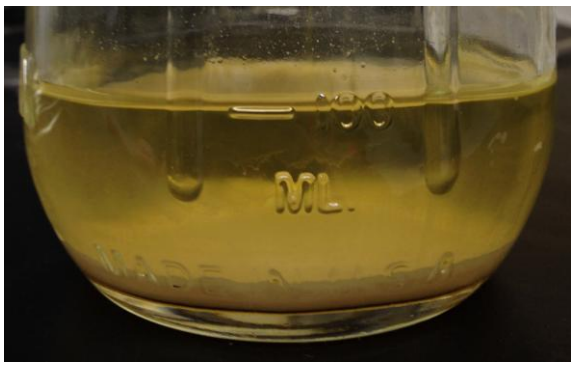

Figure 69- Trial G8 Before

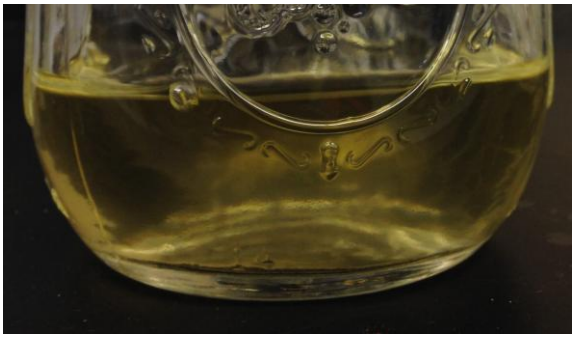

Figure 70- Trial G8 After

Figure 71- Trials G1(left)-G8(right)

Appendix D- Bentonite Fining GC Trial Results

Chemical	Before	B1	B2	B3	B4	B5	B6	B7
2-Isopropyl-5-methyl-1-heptanol	2.53	3.52	2.42	3.05	3.07	1.88	2.9	2.42
Benzene, 1,3-bis(1,1-dimethylethyl)-	1.71	1.65	1.49	1.66	1.12	2.6	1.72	1.44
Benzeneethanol, 4-hydroxy-	1.05	1.89	1.86	1.89	1.49	1.84	1.77	2.14
Decane, 3,6-dimethyl-	4.71	0.83	2.03	0	2.42	0.81	2.66	0.69
Decane, 3,7-dimethyl-	1.77	5.48	4.32	4.97	5.09	5.25	5.36	4.29
Decane, 4-methyl-	1.53	1.31	0.86	0	1.29	1.12	1.36	0
Dodecane	1.9	2.54	2.5	2.83	2.44	2.6	2.59	2.55
Dodecane, 4,6-dimethyl-	5.6	2.23	3	2.11	3.3	3.4	1.76	4.04
Eicosane	13.55	7.63	8.48	9.32	10.62	9.65	10.53	11.63
Heneicosane	2.48	2.27	1.9	0.62	2.27	0.54	0.98	0.52
Heptadecane	7.45	8.28	7.1	6.67	6.92	5.85	14.31	5.97
Heptadecane, 2,6,10,15-tetramethyl-	1.79	0	1.59	1.66	1.64	0	1.78	0
Heptane, 5-ethyl-2-methyl-	1.43	0	0	1.21	1.16	3.14	1.31	0
Hexadecanal	1.08	0.8	0.75	0.74	1.03	0.48	0.84	0.76
Methyl 4-O-methyl-d-arabinopyranoside	1.13	0	1.58	1.71	1.12	0	1.44	2.61
Pentadecane	5.82	5.86	5.6	4.24	8.25	5.82	0	3.16
Phenylethyl Alcohol	12.32	18.56	25.46	19.38	13.16	26.51	17.73	31.65
Tetradecane	8.07	3.01	2.87	5.41	5.46	4.87	4.09	2.89
Tetradecane, 5-methyl-	1.6	1.5	1.39	1.46	1.8	1.25	1.54	1.29
Undecane, 2,5-dimethyl-	1.08	0.93	0.72	3.55	1.09	1.12	1.42	1

Numbers in Blue significantly increased from the original Riesling. Numbers in Red significantly decreased from the original Riesling. Numbers in Yellow were completely eliminated from the trial, and white numbers are approximately the same/nothing was able to be concluded.

Appendix E- Chitosan and Kieselsol Fining GC Trial Results

Chemical	Before	C1	C2	C3	C4	C5	C6	C7
2-Isopropyl-5-methyl-1-heptanol	2.53	1.81	1.75	1.6	2.02	1.68	1.8	1.73
Benzene, 1,3-bis(1,1-dimethylethyl)-	1.71	1.31	0.99	1.11	1.28	1.84	1.59	1.61
Benzeneethanol, 4-hydroxy-	1.05	0.91	0.98	1.3	0.66	0.96	1.3	0.81
Decane, 3,6-dimethyl-	4.71	0	0	2.74	1.73	4.29	1.49	4.96
Decane, 3,7-dimethyl-	1.77	1.17	0.92	0.86	1.15	1.11	0.25	1.12
Decane, 4-methyl-	1.53	0.91	0.69	0.8	0.98	1.01	0.83	1.08
Dodecane	1.9	1.42	1.3	1.22	1.25	1.75	1.54	1.83
Dodecane, 4,6-dimethyl-	5.6	5.87	4.04	2.76	2.4	2.09	1.5	1.72
Eicosane	13.55	11.27	12.69	4.89	10.5	8.71	6.08	10.34
Heneicosane	2.48	0.7	0.92	0	2.89	1.27	0.51	2.08
Heptadecane	7.48	5.6	5.44	7.55	7.71	7.26	4.29	8.56
Heptadecane, 2,6,10,15-tetramethyl-	1.79	0	1.27	0	0.65	0.19	0.47	1.15
Heptane, 5-ethyl-2-methyl-	1.43	0	0	0	0.93	1.04	0	0.92
Hexadecanal	1.08	0	0.5	0	0.64	0.4	0	0.74
Methyl 4-O-methyl-d-arabinopyranoside	1.13	1.26	1.34	1.77	1.08	1.17	1.67	0
Pentadecane	5.82	4.81	6.72	1.36	0.53	4.25	3.63	1.12
Phenylethyl Alcohol	12.32	16.72	18.82	24.67	15.12	16.44	21.81	13.24
Tetradecane	8.07	3.68	2.56	1.61	3.47	3.16	2.14	3.85
Tetradecane, 5-methyl-	1.6	1.03	1.02	0.91	1.66	1.44	0.87	2.06
Undecane, 2,5-dimethyl-	1.08	0.75	0.56	0.61	0.77	0.72	0.53	0.96

Numbers in Blue significantly increased from the original Riesling. Numbers in Red significantly decreased from the original Riesling. Numbers in Yellow were completely eliminated from the trial, and white numbers are approximately the same/nothing was able to be concluded.

Appendix F- Gelatin and Kieselsol Fining GC Trial Results

Chemical	Before	G1	G2	G3	G4	G5	G6	G7	G8
2-Isopropyl-5-methyl-1-heptanol	2.53	1.19	1.22	1.9	2.04	1.32	1.95	1.31	1.23
Benzene, 1,3-bis(1,1-dimethylethyl)-	1.71	0.86	1.07	1.21	2.02	1.93	2.09	2	0.56
Benzeneethanol, 4-hydroxy-	1.05	1.24	1.66	1.07	1.29	1.34	1.25	3.06	2.88
Decane, 3,6-dimethyl-	4.71	0.95	1.32	1.45	1.81	4.33	5.33	0	2.91
Decane, 3,7-dimethyl-	1.77	2.15	2.88	3.16	1.13	1.26	1.29	2.66	0.46
Decane, 4-methyl-	1.53	0.51	0.72	0.75	1.11	1.08	1.18	0.57	0
Dodecane	1.9	0.78	0.9	1.13	1.86	1.73	1.94	1.13	0.89
Dodecane, 4,6-dimethyl-	5.6	1.17	3.25	2.67	2.7	3.2	1.69	1.11	0.82
Eicosane	13.55	13.84	11.25	13.93	7.88	8.83	11.53	1.72	6.48
Heneicosane	2.48	0.63	0.49	1.11	1.72	2.16	1.89	0	0
Heptadecane	7.48	3.78	4.63	5.59	4.9	6.62	9.23	1.67	2.99
Heptadecane, 2,6,10,15-tetramethyl-	1.79	0.2	0	0.22	1.08	0.72	0.76	1.55	0.82
Heptane, 5-ethyl-2-methyl-	1.43	0	0.73	0	0	0	1.02	0	0.51
Hexadecanal	1.08	1.01	0.69	0.33	0.51	0.79	0.69	0	0.32
Methyl 4-O-methyl-d-arabinopyranoside	1.13	1.13	0.73	1.01	0	0	1.05	2.3	0
Pentadecane	5.82	1.16	1.62	4.35	5.31	2.91	0.46	2.68	0
Phenylethyl Alcohol	12.32	24.49	32.87	19.43	23.99	21.28	19.35	42	49.05
Tetradecane	8.07	3.26	1.94	4.87	3.68	2.27	3.7	1.73	3.38
Tetradecane, 5-methyl-	1.6	0.65	0.71	1.68	1.06	1.11	1.62	0.76	0.63
Undecane, 2,5-dimethyl-	1.08	0.43	0.5	1.11	0.78	0.77	0.82	0.47	0.56

Numbers in Blue significantly increased from the original Riesling. Numbers in Red significantly decreased from the original Riesling. Numbers in Yellow were completely eliminated from the trial, and white numbers are approximately the same/nothing was able to be concluded.