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Visual, Spectrophotometric, and Colorimetric Measurement of Red Wine and Wine Blends

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of
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Honors Enology Research

An Undergraduate Honor's Thesis

By

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ABSTRACT

Partially due to prevalence and popularity around the world, much research has been done in the field of enology and wine analysis. The visual aspect of wine is one of the key features of wine. This research focused on how blending and storage affected the color and composition of wine. Visual, sensory, color, and composition data were collected. Three primary red wine varietals (Cabernet Sauvignon, Merlot, and Zinfandel) and seven blends were analyzed for color, acidity, polymeric color, and optical density. The ten wine treatments were composed based on a mixture design model. The color and composition results were compared to results from a visual sensory panel ($n \approx 70$) determining color by ranking. Data was collected initially, at 180 days, and 360 days during storage at 15° C. Results came out to be very similar to expected hypothesis. Before testing, it was formulated that no major deviations from standard tendencies would occur due to blending or storage. Cabernet had the darkest color, Zinfandel had the lightest, and Merlot was in the middle but closer to Cabernet than Zinfandel by most metrics.

Keywords: visual, sensory, color, blending, storage, red wine, spectrophotometric.

Approval Signatures

Dr. Jean-François Meullenet ______________________________

Dr. Renee Threlfall ______________________________

INTRODUCTION

Wine makers have long blended wines to achieve more desirable wines. Blending can adjust any target aspect to meet and exceed expectations of consumers, retailers, and regulatory bodies. Most blending is done on a trial-and-error basis, sacrificing a small amount of juice before production starts. While many physical characteristics of the final product are manageable to determine, other important factors require a higher level of analysis. Visual color plays a key role in consumer sensory evaluation of wine both before and after purchase. It has even been shown to affect flavor perceived by the customer. Wine consumers have expectations for the color and use it to make initial conclusions on the overall style and quality (Parpinello and others 2009). Constituents in red wine, such as anthocyanin level, even help determine the level of copigmentation, antioxidant properties, and slight change in color over time (Boulton, 2009). One interesting note is that consumer liking cannot be reliably predicted by experts in the wine industry (Lesschaeve, 2003). This is part of the justification to why correlated, multivariate wine analysis is needed. As wines become more widespread in this global marketplace, the more producers will need to understand about what consumers perceive in wine and how to achieve desired results in spite of highly variable growing conditions.

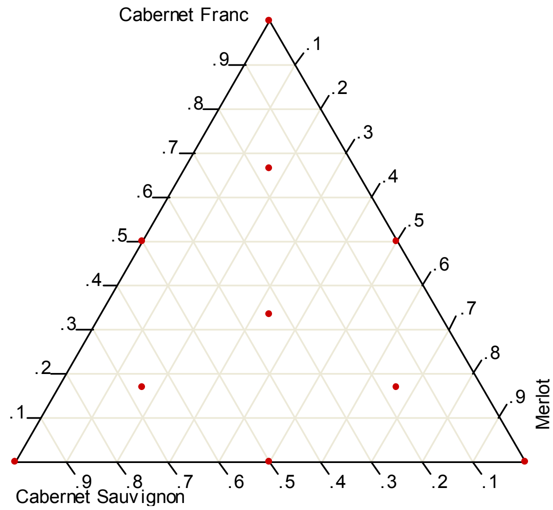


Figure 1 – Experimental Mixture Design

Laboratory testing can determine how varietal, blend, and storage time affect key color indicators. The mixture treatments were created based on Figure 1 (Dooly and others, 2011). Three single, three binary, and four tertiary (wine) blends were tested. The objective of this research is to conduct an analysis to increase insight on the color of wine and how red wine blends stored for one year affect the color from a quantitative and qualitative perspective. In addition, visual sensory data will be compared to composition and color data. Sensory data was collected from a panel in the Sensory Service Center of approximately 70 people at each testing period (0, 180, 360 days).

MATERIALS AND METHODS

Acquisition of materials

All wines in this experiment came from a commercial winery. On October 21, 2009, three red wine varietals (Cabernet Sauvignon, Merlot, and Zinfandel) were obtained in 15-gallon water tanks lined with polyethylene plastic bags. The wines were cold when pumped into the storage containers. The bags were first sparged with nitrogen gas and then filled with each wine. The bags were sealed and transported back to the University of Arkansas Food Science building. There, the wines were kept under cold storage (2° C) overnight.

Wine and wine blending treatments for storage

The wine treatments were created and analyzed at the University of Arkansas Enology Research Laboratory in the Department of Food Science. The blending was completed on October 22, 2009. After deciding on the mixture compositions for each treatment blend, it was decided that 3 liters would be needed for each one, if 60% excess is also accounted for in case any mistakes would be made in processing. Ten 3.75-liter glass jugs were steam-cleaned and sterilized before use. The mixtures were carefully made with volumetric flasks and funnels. The resulting mixtures are shown below.

Table 1 – Experimental Volumes and Compositions for Wine and Wine Blends of Cabernet Sauvignon (Cab), Merlot (Mer), and Zinfandel

Treatments	Cabernet	Merlot	Zinfandel	Composition
1	0.5L	2.0L	0.5L	17%Cab / 67%Mer / 17%Zin
2	3.0L	-	-	100% Cabernet
3	1.5L	-	1.5L	50%Cabernet / 50%Zinfandel
4	2.0L	0.5L	0.5L	67%Cab / 17%Mer / 17%Zin
5	1.0L	1.0L	1.0L	33%Cab / 33%Mer / 33%Zin
6	-	1.5L	1.5L	50%Merlot / 50%Zinfandel
7	-	3.0L	-	100% Merlot
8	0.5L	0.5L	2.0L	17%Cab / 17%Mer / 67%Zin
9	1.5L	1.5L	-	50%Cabernet / 50%Merlot
10	-	-	3.0L	100% Zinfandel

From each three liter treatment, the wine was bottled into fifteen 125 ml glass bottles with caps per treatment. Before tightly screwing the caps on, each bottle was sparged with nitrogen gas. Wine was stored with minimal light and at a temperature of 15°C. An adequate number of backup samples were also made and put into storage. Tests were conducted that week for each parameter, in addition to 6 months (180 days) and 12 months (360 days) later.

Wine sample preparation

The set of samples was placed at room temperature overnight before any sample was analyzed. After inverting the bottles 10 times to ensure proper mixing, the samples were placed into 45 ml centrifuge tubes and sonicated for 5 minutes each. The samples were then centrifuged for 10 minutes at 10,000 rotations per minute. The centrifuged samples were poured into 50 ml beakers. Nitrogen gas was added to the headspace of each bottle to flush out oxygen.

Total polymeric analysis

To run tests on the total amount of polymeric content in each treatment, sample dilutions had to be prepared. Nine milliliters (mL) of deionized water were added to test tubes along with a 1 ml volume of sample. The test tubes were vortexed and the samples were transferred to clean centrifuge tubes. Next, 5 grams (g) of potassium metabisulfite (KMBS) was dissolved into 25 ml of water. The solution was sonicated and poured into a 50 ml beaker. To obtain valid comparison, each treatment contained a KMBS sample as well as a control water sample. These were prepared by filling test tubes up with 2.8 ml of diluted sample and adding 0.2 ml of either KMBS or deionized water. The samples were allowed to rest for 15 minutes. The spectrometer was run with a blank deionized water sample. The absorbance of each sample was measured at 420, 510, and 700 nanometers (nm). Calculations were done to determine the percentage of polymeric color. The equations below show the calculations involved (Hager and others 2008). The color density was calculated from the polymeric test with water added, while polymeric color used results from samples with sodium metabisulfite added.

$$color\ density = \ [(A_{420nm} - A_{700nm}) + (A_{510nm} - A_{700nm})] * dilution\ factor$$

$$poly.color = \ \left[\left(A_{KMBS,420nm} - A_{KMBS,700nm}\right) + \left(A_{KMBS,510nm} - A_{KMBS,700nm}\right)\right] * dil.factor$$

$$\%\ polymeric\ color = \left(\frac{polymeric\ color}{color\ density}\right) * 100$$

Spectrophotometry optical color density

The optical density of each sample was measured using a Unicam Helios Beta UV-VIS spectrophotometer (Unicam, Cambridge, United Kingdom). The spectrophotometer was standardized using a 1 mm cuvette filled with deionized water. Unadjusted sample absorbance was measured using a 1 mm cuvette at wavelengths of 280, 365, 420, 520, 570, and 630 nm. The calculation for unadjusted color density was 420+520 nm. A dilution factor of 10 was used.

Acidified optical color density

To measure acidified optical density, 200 µL of juice were brought to a volume of 10 ml with 1 M hydrochloric acid (HCl) in a volumetric flask. The flask was covered with flexible film and inverted 10 times for mixing. The sample was allowed to rest for three hours before testing. The absorbance was measured at 280 nm and 520 nm. The acidified reading at 520 nm indicates the (acidified) red color. This analysis was also done measured using a Unicam Helios Beta UV-VIS spectrophotometer.

pH

Only uncentrifuged wine was used to determine pH. These samples were allowed to sit at room temperature for one hour before testing. The pH meter used was a Beckman Coulter, model 250 (Fullerton, CA). The meter was first configured and standardized using provided solutions for a three-point acidic calibration. Below is chart of initial pH for each varietal.

Table 2 – Initial pH of 3 Red Wine Varietals

Wine Varietal	pH
Cabernet Sauvignon	3.54
Merlot	3.36
Zinfandel	3.49

Titratable acidity

To measure titratable acidity, a 5 ml aliquot of wine was pipetted into 126 ml of deionized water. The sample was titrated to pH 8.2 with 0.1 N sodium hydroxide (NaOH). The main acid of interest in this test is tartaric acid and is measured in grams per liter (g/L). The pH is not allowed to exceed the endpoint of 8.2 in this test and is continuously monitored by a pH meter. The mL's of NaOH added are also carefully managed.

Alcohol content

Alcohol content, in this case primarily ethanol (EtOH), was measured using ebuilliometer (Dujardin-Salleron, Model 360, Paris, France) method. This is a device that measures the boiling point of liquids. Along with the barometric pressure, the percentage of ethanol can be determined.

Chroma Meter color analysis

To quantitatively measure the color of blended wine, a ColorFlex (HunterLAB, Reston, VA) was used. The equipment was operated using a program called Universal Software. The machine was calibrated with a standard, and all surfaces were cleaned with chemical wipes. The standard for this set has clear glass cup, a completely opaque cover, and a flexible black ring. The 10-mm black ring was placed into the bottom of the sample cup for the disk to later sit on. The cup was filled with the sample wine and a clean white ceramic disk was floated on top of the liquid. The sample was measured and calculated after the sample was measured again at 180 degrees rotation. The computer uses both configurations to calculate a final value. The process was completed for each sample, and the results were recorded. All pieces of equipment were thoroughly cleaned between each sample to get optimal readings.

Sensory analysis

Sensory analysis was done at the University of Arkansas Sensory and Service Center in the Department of Food Science. Just prior to sensory analysis, each wine treatment was poured into two 45 ml centrifuge tubes and sonicated for 5 minutes. The samples were then centrifuged and transferred to a corresponding 150 mL beaker. Ten ml of each sample were added to test tubes with screw tops. Before screwing the top on tightly, the air head space was sparged with nitrogen gas. The test tubes were place near flat on foam inspection trays. One test tube of each treatment, totaling 10 test tubes, was placed on these trays for analysis. Three random numbers were placed on each tube. Panelists were asked to rank the samples on the basis of lightness, redness, and brownness. Approximately 70 people participated in each round of sensory panels. Figure 2 shows this visually.

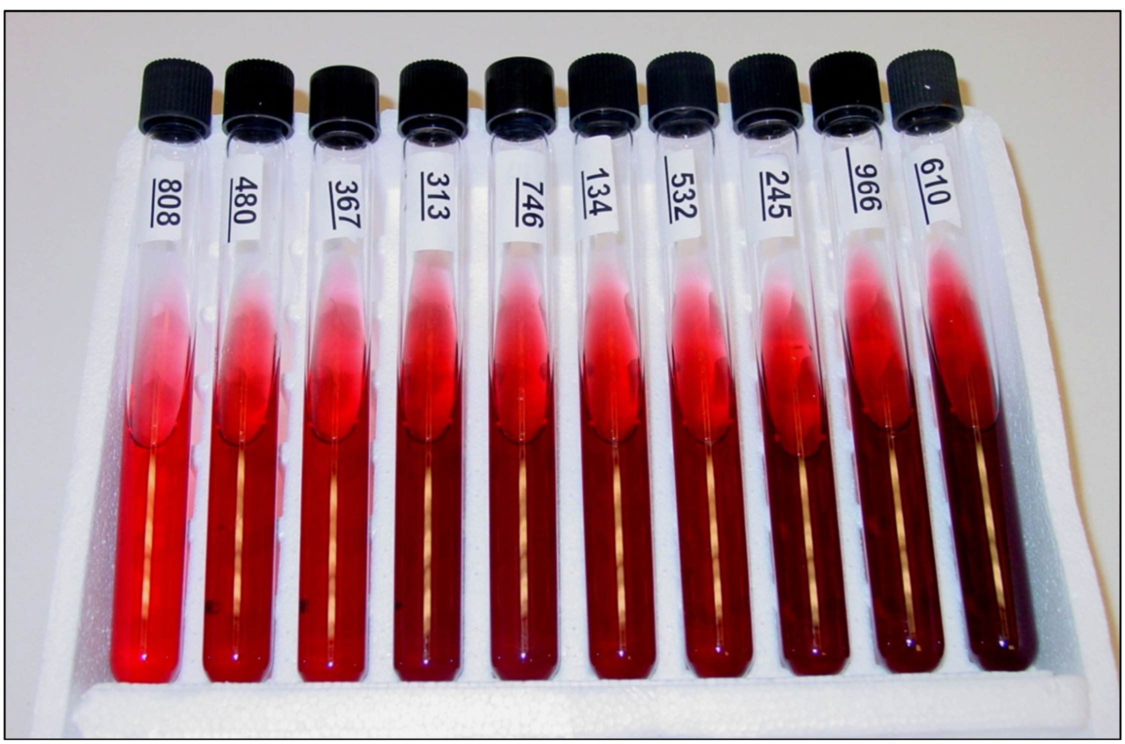


Figure 2 – Sensory analysis experimental setup to rank color visually by a panel (n≈70)

RESULTS AND DISCUSSION

Total polymeric analysis

Table 3 – Total Polymeric Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	52.95 a	53.82 a	51.75 a
100% Merlot	39.60 f,g	38.38 e,f	36.70 f,g
100% Zinfandel	34.93 h	35.05 g	33.88 g
17%Cab/17%Mer/67%Zin	39.83 f,g	37.65 e,f,g	37.90 e,f,g
17%Cab/67%Mer/17%Zin	40.82 e,f	40.42 d,e	39.95 d,e,f
67%Cab/17%Mer/17%Zin	48.53 b	46.87 b	45.97 b
50%Cabernet/50%Merlot	46.33 b,c	45.00 b,c	45.38 b,c
50%Cabernet/50%Zinfandel	43.98 c,d	43.40 c	42.85 b,c,d
50%Merlot/50%Zinfandel	37.43 g,h	37.05 f,g	37.52 e,f,g
33%Cab/33%Mer/33%Zin	42.57 d,e	42.70 c,d	41.22 c,d,e

*Letters represent mean separations as found by Tukey's HSD

The data shows that significant differences do exists among the 10 treatments, at least in reference to total polymeric color. The means of each sample time were found, recorded and graphed in Figure 3. Although there was not much change over time, varietal did help determine total polymeric color, as shown in the mean separation "tiers". Clearly, Cabernet Sauvignon contributes the most to increasing the total polymeric count.

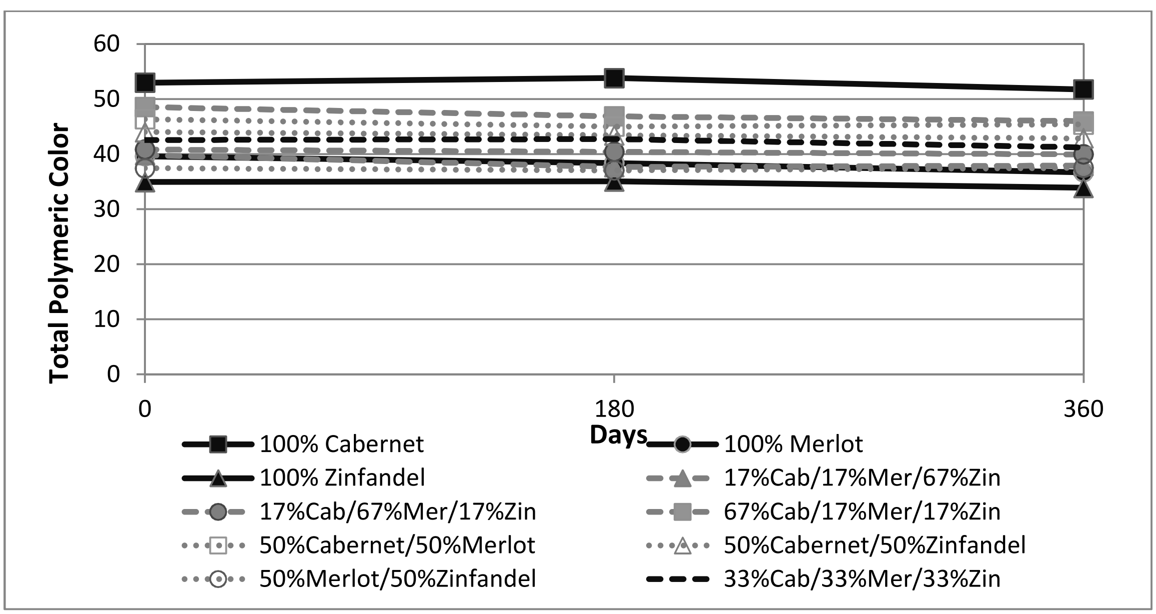


Figure 3 – Total Polymeric Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Table 4 – Percent Polymeric Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	61.19 a	61.45 a	63.53 a
100% Merlot	60.15 a,b	52.19 a,b	58.95 b,c
100% Zinfandel	25.91 b	42.03 b	46.61 e
17%Cab/17%Mer/67%Zin	42.32 a,b	59.54 a	55.04 d
17%Cab/67%Mer/17%Zin	55.79 a,b	54.23 a	57.94 c
67%Cab/17%Mer/17%Zin	65.07 a	59.31 a	61.33 a,b
50%Cabernet/50%Merlot	74.11 a	56.59 a	61.33 a,b
50%Cabernet/50%Zinfandel	55.68 a,b	58.53 a	58.99 b,c
50%Merlot/50%Zinfandel	43.37 a,b	51.49 a,b	54.11 d
33%Cab/33%Mer/33%Zin	51.95 a,b	57.75 a	57.56 c

*Letters represent mean separations as found by Tukey's HSD

The percent polymeric color was found as shown in the previous, corresponding "Materials and Methods" section. There was not nearly as much difference, or mean separation during this test of the samples. Most (7 out of 10) of the samples cannot be differentiated based on % polymeric color, after initial analysis. One interesting trend is the change over time of this parameter. The % polymeric color seemed to converge over time, to a value between 55 and 60%.

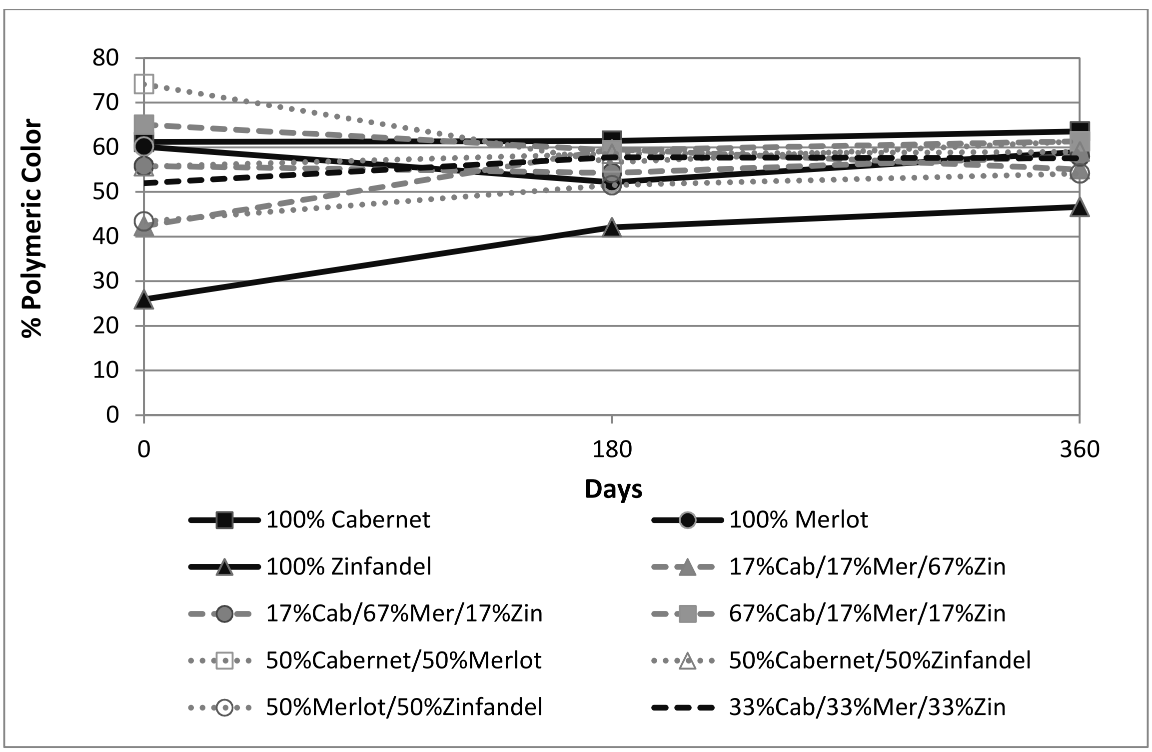


Figure 4 – Percent Polymeric Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Spectrophotometry optical color density

Table 5 – Absorbance at 420 nm of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	3.797 a	4.043 a	4.127 a
100% Merlot	2.720 c	3.107 d	3.317 c
100% Zinfandel	1.477 f	1.290 h	1.343 f
17%Cab/17%Mer/67%Zin	1.773 e,f	1.907 g	2.077 e
17%Cab/67%Mer/17%Zin	2.440 c,d	2.800 e	2.943 d
67%Cab/17%Mer/17%Zin	3.203 b	3.427 c	3.637 b
50%Cabernet/50%Merlot	3.447 a,b	3.643 b	3.723 b
50%Cabernet/50%Zinfandel	2.663 c	2.580 f	2.853 d
50%Merlot/50%Zinfandel	2.133 d,e	1.987 g	2.110 e
33%Cab/33%Mer/33%Zin	2.787 c	2.637 f	2.813 d

*Letters represent mean separations as found by Tukey's HSD

The mixtures in this data set differ significantly in this absorbance wavelength, for the most part. This range (420 nm) measures the amount of browning color in the wine. No blend has more than one "tier", as indicated by the letter under mean separation in Table 5. Cabernet exhibited the highest level of brown coloring, while Zinfandel had a relatively low amount. The value for (pure) Merlot was very close to the center point of Cabernet and Zinfandel. Cabernet Sauvignon and Merlot (and blends with high proportions of each) actually seemed to even increase in browning over time, based on the analytical data.

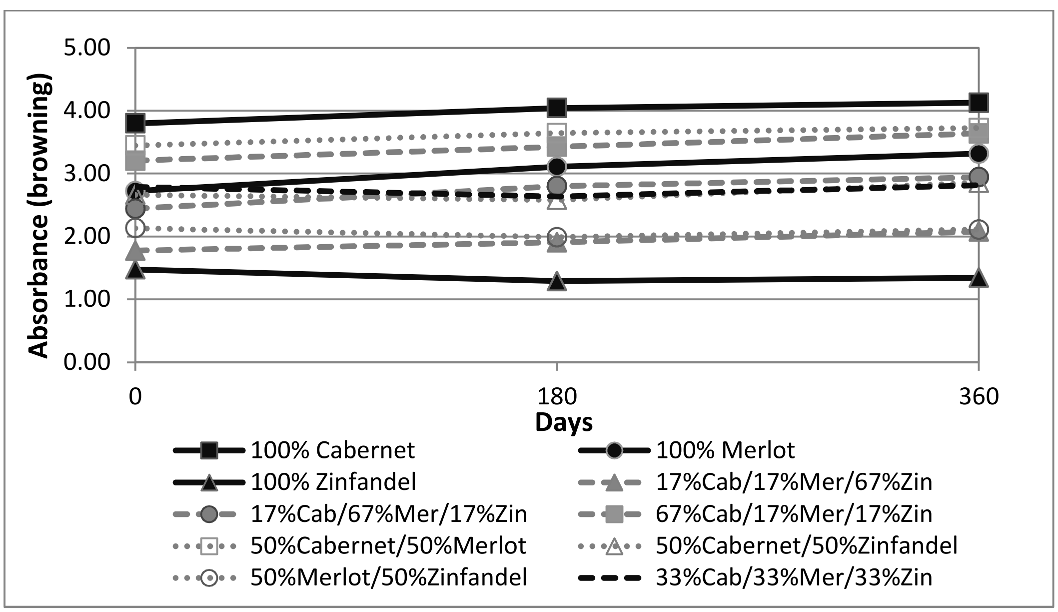


Figure 5 – Absorbance at 420 nm of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored for one year at 15°C

Table 6– Absorbance at 520 nm of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	5.690 a	6.370 a	6.420 a
100% Merlot	3.750 c	4.873 d	5.033 c
100% Zinfandel	1.837 e	1.757 h	1.747 f
17%Cab/17%Mer/67%Zin	2.563 d	2.813 g	2.880 e
17%Cab/67%Mer/17%Zin	3.553 c	4.397 e	4.437 d
67%Cab/17%Mer/17%Zin	4.670 b	5.343 c	5.563 b
50%Cabernet/50%Merlot	4.840 b	5.827 b	5.807 b
50%Cabernet/50%Zinfandel	3.823 c	3.920 f	4.153 d
50%Merlot/50%Zinfandel	2.813 b	2.863 g	2.897 e
33%Cab/33%Mer/33%Zin	3.853 c	3.950 f	4.123 d

*Letters represent mean separations as found by Tukey's HSD

The treatments for this test at absorbance for 520 nm also include significant differences. This range (520 nm) measures the amount of red color in the wine. The only blend that bridges multiple mean "tiers" is the 17% Cabernet / 67% Merlot / 17% Zinfandel blend. Cabernet exhibited the highest level of red color and Zinfandel had a relatively low amount. The value of Merlot wine was again close to the center point of Cabernet and Zinfandel. Cabernet Sauvignon, Merlot, and blends primarily of these two seemed to even increase in red color over time, as much as a 20% increase.

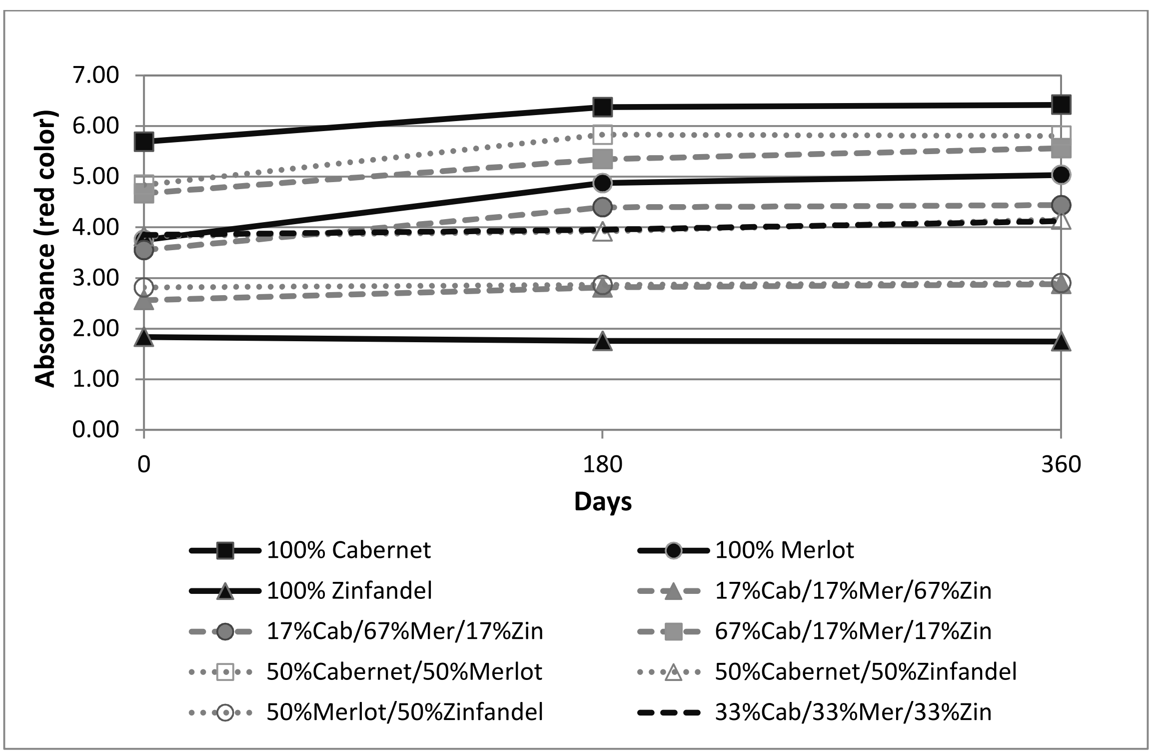


Figure 6 – Absorbance at 520 nm of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Table 7 – Optical Density of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	9.487 a	10.41 a	10.55 a
100% Merlot	6.470 c	7.980 d	8.350 c
100% Zinfandel	3.313 e	3.047 h	3.090 f
17%Cab/17%Mer/67%Zin	4.337 d	4.720 g	4.957 e
17%Cab/67%Mer/17%Zin	5.993 c	7.197 e	7.380 d
67%Cab/17%Mer/17%Zin	7.873 b	8.770 c	9.200 b
50%Cabernet/50%Merlot	8.287 b	9.470 b	9.530 b
50%Cabernet/50%Zinfandel	6.487 c	6.500 f	7.007 d
50%Merlot/50%Zinfandel	4.947 d	4.850 g	5.007 e
33%Cab/33%Mer/33%Zin	6.640 c	6.587 f	6.937 d

*Letters represent mean separations as found by Tukey's HSD

The optical density of the wine samples trends similar to the absorbance for 420 nm and 520 nm. This is to be expected, as the optical density is essential the summation of the previous two values. Not surprisingly, the Cabernet tested to have the highest optical density. Zinfandel was observed to have the lowest optical density with the blends and Merlot being in the middle of the range.

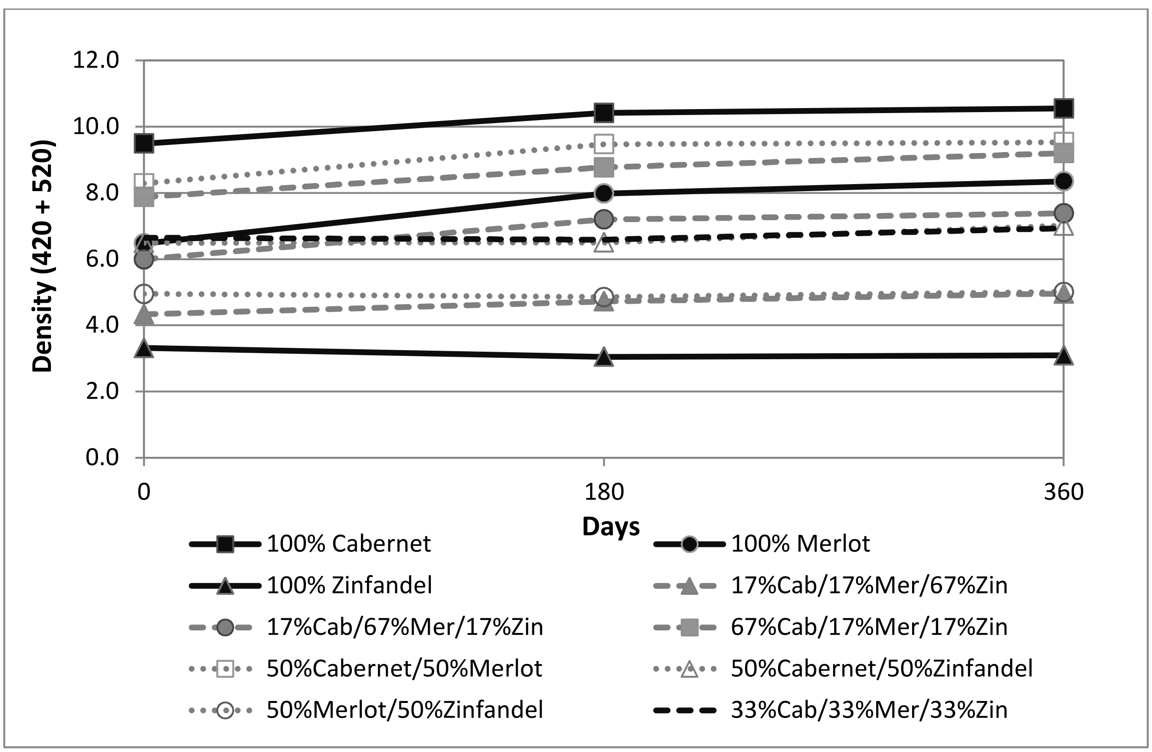


Figure 7 – Optical Color Density of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Acidified optical color density (red-colored anthocyanins)

Table 8 – Acidified Red Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	17.37 a	14.90 a	12.88 a
100% Merlot	13.77 c	10.35 d	8.800 c,d
100% Zinfandel	9.350 e	6.850 f	5.500 e
17%Cab/17%Mer/67%Zin	11.48 d	8.750 e	7.633 d
17%Cab/67%Mer/17%Zin	13.53 c	10.85 c,d	9.300 c
67%Cab/17%Mer/17%Zin	15.57 b	12.63 b	10.90 b
50%Cabernet/50%Merlot	15.43 b	12.02 b	11.00 b
50%Cabernet/50%Zinfandel	13.20 c	10.77 c,d	9.350 c
50%Merlot/50%Zinfandel	11.60 d	9.100 e	8.433 c,d
33%Cab/33%Mer/33%Zin	13.32 c	11.17 c	9.467 c

*Letters represent mean separations as found by Tukey's HSD

The red color from the acidified portion displayed a negative linear trend, which is as expected. All of the treatments decreased as time progressed in regards to the acidified red color, as detected by the spectrophotometer. This represents total anthocyanins, which polymerize and drop out of solution with time. As with the previous absorbance testing, the Cabernet was again higher than the other two varietals. The difference was less pronounced this time, as only the pure Cabernet was significantly higher than most other samples.

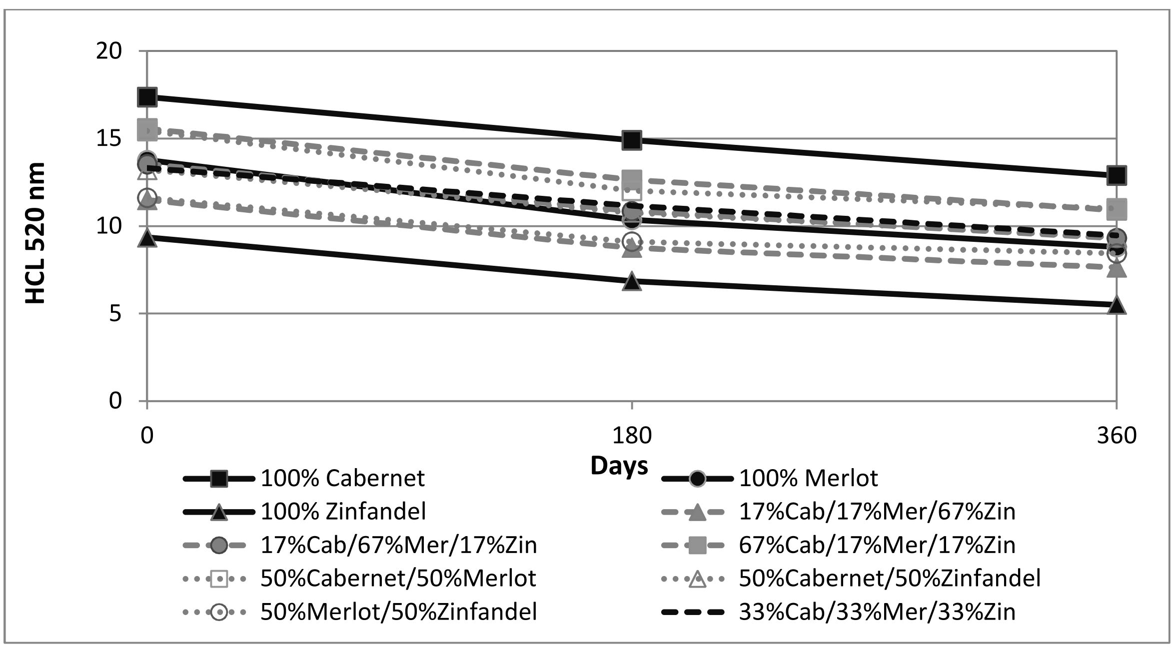


Figure 8 –Acidified Red Color of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored and blends for one year at 15°C

pH

The pH of each sample tested about as expected. The Cabernet Sauvignon had the highest pH, which means it was the least acidic. The Zinfandel was the most acidic and the Merlot had an intermediate pH value. An interesting trend occurred with the 17%Cab/67%Mer/17%Zin. It appears as if the pH of this sample increased, then decreased. This is most likely a result of a bad data point during the first data set. Similar blends did not display similar behavior. Still, pH changes must be considered when blending wine.

Titratable acidity

Titratable acidity tests for acids not always easily seen by a standard pH meter. The pH results strongly correlated with this titratable acidity (TA) ranks. The blends without Zinfandel were much less acidic from the rest in terms of tartaric acid. Even a small amount (17%) of Zinfandel results in a significantly more amount of titratable acidity in the sample.

Alcohol Content

Reliable data for ethanol via ebuilliometer is only available for the 180 day (6 month) data set, due to laboratory difficulties. Both the Cabernet and Merlot varietals had an alcohol percentage about 13%, while Zinfandel was much closer to 12%. To be considered table wine, the wine has to have at least 12% (by volume) alcohol content. The composition of the wine blend yielded results of ethanol percentage in a direct, predictable fashion.

Chroma Meter color analysis

Table 9 – Lightness (L*) as measured by the HunterLAB Colorflex of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine Blend	0 days	180 days	360 days
100% Cabernet	1.240 e	1.077 e	0.917 e
100% Merlot	2.807 c,d	1.857 d	1.393 d,e
100% Zinfandel	13.00 a	11.43 a	10.47 a
17%Cab/17%Mer/67%Zin	5.693 b	4.803 b	4.067 b
17%Cab/67%Mer/17%Zin	2.920 c,d	2.413 c	1.947 c,d
67%Cab/17%Mer/17%Zin	2.297 d	1.533 d,e	1.193 e
50%Cabernet/50%Merlot	2.133 d	1.423 d,e	1.233 e
50%Cabernet/50%Zinfandel	3.520 c	2.723 c	2.057 c
50%Merlot/50%Zinfandel	5.377 b	4.717 b	4.010 b
33%Cab/33%Mer/33%Zin	3.143 c	2.640 c	2.043 c

*Letters represent mean separations as found by Tukey's HSD

Samples with an "L* " value closer to zero are dark, while those with a value closer to 100 are relatively lighter. Therefore, the samples with a high percentage of Zinfandel were significantly lighter (and allowed more light to pass through) than other blends. However, all of the blends showed decreasing lightness over time.

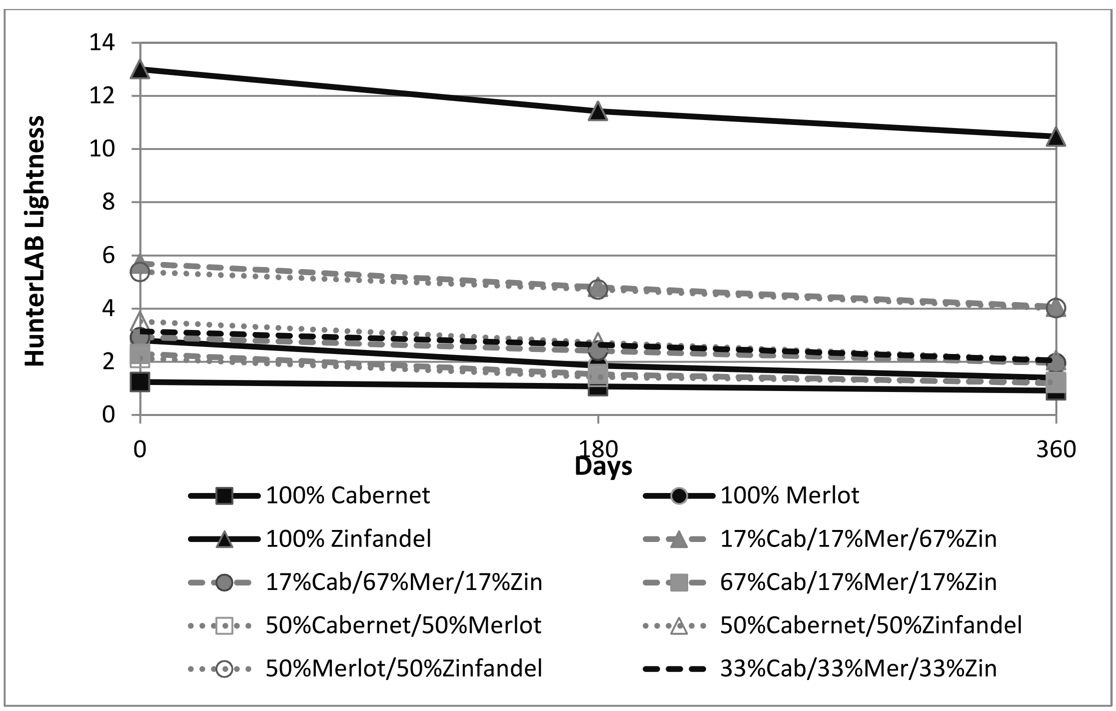
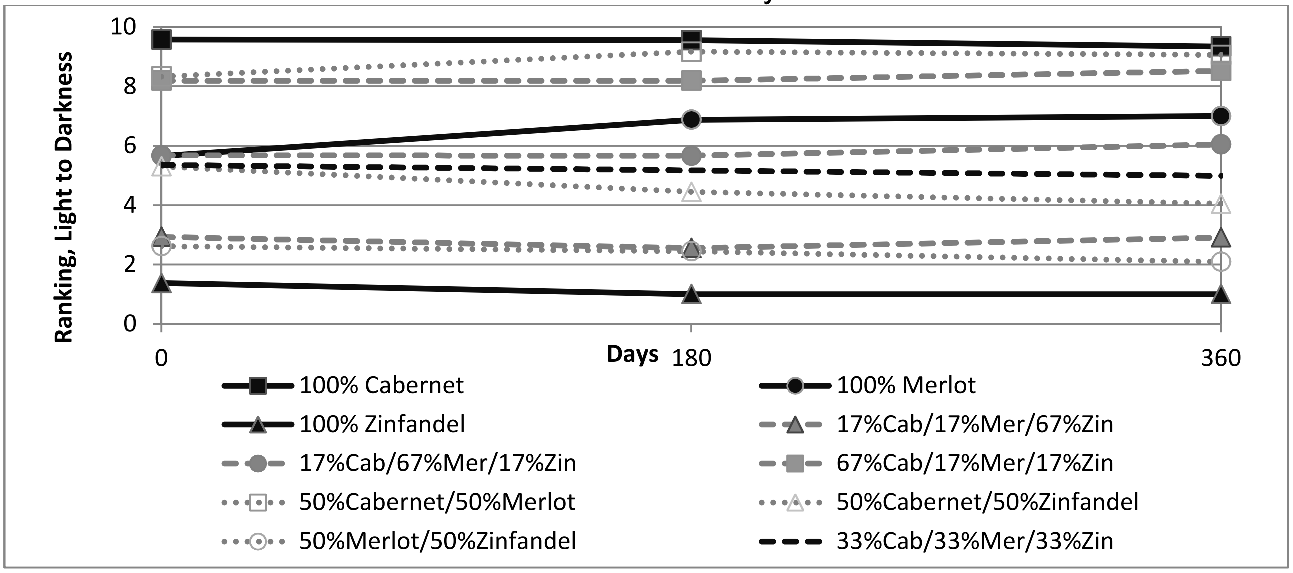


Figure 9 – Lightness (L*) of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored and blends for one year at 15°C

Sensory analysis

Figure 10 – Lightness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored and blends for one year at 15°C



Since none of the lines really cross, it can be assumed that the order ranking did not change over time in regards to lightness as perceived by people. Rating the samples (instead of ranking) might produce more quantitatively significant results, but that would have taken knowingly more resources, such as training for panelists. The null hypothesis for each sensory test is that there is no difference between specific colors as tested by analytical equipment and perceived by humans. The statistics calculated for each test still need to be analyzed. For this particular test the sensory results were compared to average ranking of lightness by the Chroma Meter.

Table 10 – Friedman's Test based on Lightness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine	6 months	Separation
100% Zinfandel	65	a
50%Merlot/50%Zinfandel	159	b
17%Cab/17%Mer/67%Zin	166	b
50%Cabernet/50%Zinfandel	289	c
33%Cab/33%Mer/33%Zin	336	cd
17%Cab/67%Mer/17%Zin	368	d
100% Merlot	447	e
67%Cab/17%Mer/17%Zin	528	f
50%Cabernet/50%Merlot	596	fg
100% Cabernet	621	g
Friedman's statistic	*554 > 16.9*	
LSD rank	70.2	

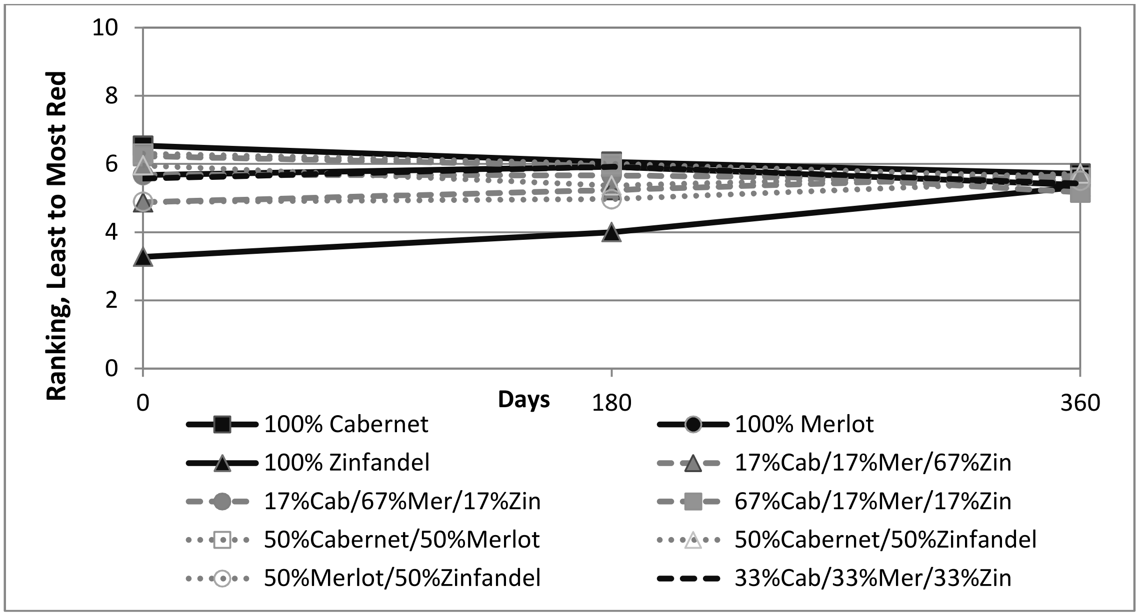


Figure 11 - Redness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

More so than any other test in this experiment, each wine mixture seems to converge to an average ranking of 5.5 out of 10. This could be due to panelists mixing up which direction is least and most red. However, this scenario might not be credible since only a couple panelists actually did that. Even another option would be the panelist not knowing what truly red color in a wine looks like. The null hypothesis for each sensory test is that there is no difference between specific colors as tested by analytical equipment and perceived by humans. The statistics calculated for each test still need to be analyzed. For this particular test the sensory results were compared to average ranking of absorbance at 520 nm for red color.

Table 11 - Friedman's Test based on Redness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

Wine	6 months	
100% Zinfandel	260	a
50%Merlot/50%Zinfandel	323	ab
17%Cab/17%Mer/67%Zin	340	bc
50%Cabernet/50%Zinfandel	349	bc
17%Cab/67%Mer/17%Zin	368	bc
67%Cab/17%Mer/17%Zin	381	bc
100% Merlot	385	bc
33%Cab/33%Mer/33%Zin	385	bc
50%Cabernet/50%Merlot	390	bc
100% Cabernet	394	c
Friedman's statistic	26.24 > 16.9	
LSD rank	70.2	

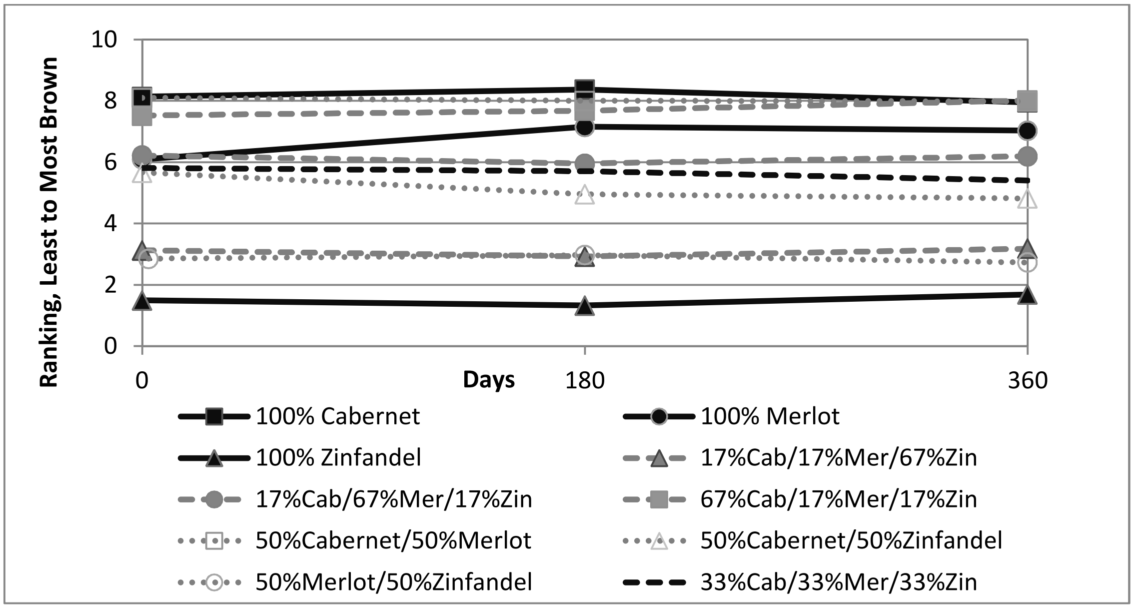


Figure 12 - Brownness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine and blends stored for one year at 15°C

For the most part, the brownness levels stayed the same over time. The null hypothesis was that browning would increase as the wine ages since that is what normally happens. This part of the total experiment should be reproduced over a much longer time period to observe when, if any real brown tint appears in the samples. The null hypothesis for each sensory test is that there is no difference between specific colors as tested by analytical equipment and perceived by humans. The statistics calculated for each test still need to be analyzed. For this particular test the sensory results were compared to average ranking of absorbance at 420 nm for brown color.

Table 12 - Friedman's Test based on Browness Ranking of Cabernet (Cab), Merlot (Mer), and Zinfandel (Zin) wine stored for one year at 15° C

Wine	6 months	
100% Zinfandel	86	a
17%Cab/17%Mer/67%Zin	190	b
50%Merlot/50%Zinfandel	193	b
50%Cabernet/50%Zinfandel	322	c
33%Cab/33%Mer/33%Zin	371	cd
17%Cab/67%Mer/17%Zin	387	cd
100% Merlot	465	e
67%Cab/17%Mer/17%Zin	497	ef
50%Cabernet/50%Merlot	520	ef
100% Cabernet	544	f
Friedman's statistic	554 > 16.9	
LSD rank	70.2	

Conclusion

More work could be done to correlate these variables with more than just varietal and blend. Some researchers are doing studies that are looking at color as determined by winemaking techniques over time (Gomez-Plaza and others 2000). Another improvement would be to screen panelists to get consumers who buy wine often, can distinguish color well, and can understand all of the questions required in the survey. Also, the Zinfandel used in these series of tests might have not been a good representation, since the color was so much lighter, and it was relatively acidic. Result from another study parallel this one (Dooley and others, 2011) were also tested for important aspects such as taste. Research that can combine data for sight, smell, and taste in detail for wine blends would be invaluable to the industry.

Based on data found, Zinfandel was generally lighter, more acidic, and less alcoholic. Cabernet Sauvignon was the darkest, contained the most alcohol, redness, brownness, and was the least acidic. Merlot ranked somewhere in the middle of each test, favoring the Cabernet Sauvignon in terms of analytical value proximity.

Based on the sensory redness test results, the level of red color in these wines seems to converge, or meet, at a common value the more time increases. This could point to another analytical test needed for wine color, since sensory can possibly detect color change that current analytical equipment is unable to detect.

Also, the acidified red color for every single sample definitely decreased noticeably over time. This is a measure of the total anthocyanins, and is expected. Over time, anthocyanins link and polymerize, decreasing the total amount of these compounds. This is also interesting since the all samples decreased at (essentially) the same rate. This could mean that no matter which varietal of these 3 is used, the acidified red color can be expected to decrease at the same rate even though the starting amount will be different.

Thus, there were no significant adverse effects from blending and storing these three red wine varietals. Winemakers should be encouraged to continue blending as without worry from a visual perspective when using these three red wines.

This whole experience and research process has been a great arena for learning by discovery in addition to working on subject matter that invokes passion in the researcher. Immense thanks go out to Dr. Renee Threlfall, Dr. Jean-François Meullenet, Dr. Gary Main, Tonya Tokar, and Lauren Dooley. This was a true team effort and could not have been completed without contributions from all parties.

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