Descriptive Analysis and Consumer Study of Viognier Wines from Virginia, France and California

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Abstract:

A trained panel (n=12) identified the key characteristics of Viognier wines from Virginia, France, and California. Fourteen aroma attributes were identified and assessed: *Artificial fruit, chemical, citrus, earthy/dusty/musty, floral, green apple, hay, honey, hot (ethanol), melon/cucumber, stone fruit, sulfidic, tropical fruit, woody, yeasty*, and *overall product intensity*. Six taste and mouth feel attributes were measured: *astringent, bitter, hot (ethanol), sour*, *sweet,* and *viscosity*. Principal component analysis and analysis of variance were used to describe and differentiate among wines and countries. *Overall product intensity, artificial fruit, honey, hot, stone fruit, sulfidic, tropical fruit, viscosity, sweet, sour, astringent* and *hot mouthfeel* were all found be significant across wines. When analyzing product versus region, wines from California were found to be significantly greater in *overall intensity*, *stone fruit*, *artificial fruit* and *tropical fruit* than wines from Virginia and France. French Viogniers were found to be significantly greater in *woody* than Virginian or Californian Viogniers. Consumer studies in Virginia (n=193) and California (n=109) found a preference for wines high in fruit intensities and higher residual sugar and acidity.

Introduction:

The European wine grape variety Viognier was on the brink of extinction some forty years ago. The variety had dwindled to only 20 acres in its home, the Northern Rhone Valley, during the late 1960's. It was rediscovered in the 'New World' with plantings in Virginia and California in the early 1980's. Today, Viognier acreage has grown substantially and it is planted around the world totaling approximately 22,200 acres in 2009 (Schwab and Knott, 2011). In 2008, there were 154 acres of Viognier planted in the Commonwealth of Virginia, which has grown to 289 planted acres in 2012, overthe span of four years (Virginia 2008 and 2012 Commercial Grape Report).

New world wine regions, those outside of Western Europe, are often identified by consumers and wine experts alike for particular wine varieties which have gained recognition because of a consistent and unique quality across that region. Regional wines such as New Zealand Sauvignon blanc, Napa Valley Cabernet Sauvignon, or Argentinian Malbec can be considered brands and are prime examples of such identification. As Virginian wines are emerging onto a broader market, it becomes necessary for our industry to explore what makes our wines unique. Virginia is already known for its version of Viognier. Wine critic Oz Clarke is quoted in his Pocket Wine Guide 2011 as saying "My most thrilling discovery in the USA this year has been the wine from vineyards spread around Washington, DC, in particular those of Virginia, whose sumptuous, scented Viogniers are world-class." While Chardonnay is still the number one white variety grown in Virginia, the Viognier grape variety was named Virginia's official signature grape variety in 2011. The recognition of Virginia Viognier and the variety's unique aromatic characteristics are the reasons why this first sensory study of the typicity of Virginian wines is focusing on Viognier as a first step into sensory profiling.

There have been many studies published in which Descriptive Analysis is used as a tool to help create AVA's (McCloskey, Sylvan and Arrhenius, 1995; Guinard and Cliff, 1987), discriminate varietal wines across growing regions (Noble and Shannon, 1987; Lund et al., 2009) and to create sensory profiles for varietal wines such as Albariño (Vilanova and Vilarino, 2006), Touriga Nacional (Falque et al., 2004), Riesling (Douglas et al., 2001), Chardonnay (Schlosser et al., 2005), Sauvignon blanc (Lund et al., 2009), Tannat (Varela and Gámbaro, 2006), and Pinot noir (Cliff and Dever, 1996). However, there have been limited published sensory studies to characterize Virginian wines. This study combines descriptive analysis with bi-coastal United States consumer studies to determine if the Viognier from the three regions are discernibly different and if there exists a regional preference for Viognier wines. The results of this research can be used to help define Virginia as a unique wine destination, to help in marketing our wines, and to enhance further research on terroir, vineyard treatments, the impact of vine age, soil composition, winemaking style and by giving insight into the Virginia wine consumer.

Materials and Methods:

Wines:

Eighteen Viognier wines were selected from three notable Viognier producing regions: France, California and Virginia. An equal number of wines were chosen from each region for the assessment of distinctive flavor profiles and consumer preference. The wines from Virginia were sourced from the Monticello AVA, Northern Virginia AVA, and the Shenandoah AVA. Wines from California were selected from Napa Valley, Sonoma, Central Coast and Mendocino. The Viogniers from France included wines from Condrieu and the Rhone Valley,. The wines were selected based on the criteria that they were all 75% or more Viognier based on Tax and Trade Bureau standards for varietal labeling. The wines were selected to represent a cross section of retail price points for each region. Retail prices ranged from $12 to $65 per a bottle. The most expensive wine was from Condrieu and was included to represent the specific area where Viognier originated. The Virginia wines were all priced closely together, with an average price per bottle of $22.

Standard chemical analysis was conducted on all 18 wines including ethanol, residual sugar, pH, titratable acidity, volatile acidity and malic acid. Chemical analysis results are shown in Table 5. Malic acid was included because there are regional differences in the winemaking styles of Viognier wines. In France it is common to allow Viognier wines to complete malolactic fermentation, whereas in Virginia and California, many winemakers prefer to prevent this secondary fermentation in their winemaking. All wines are commercially available.

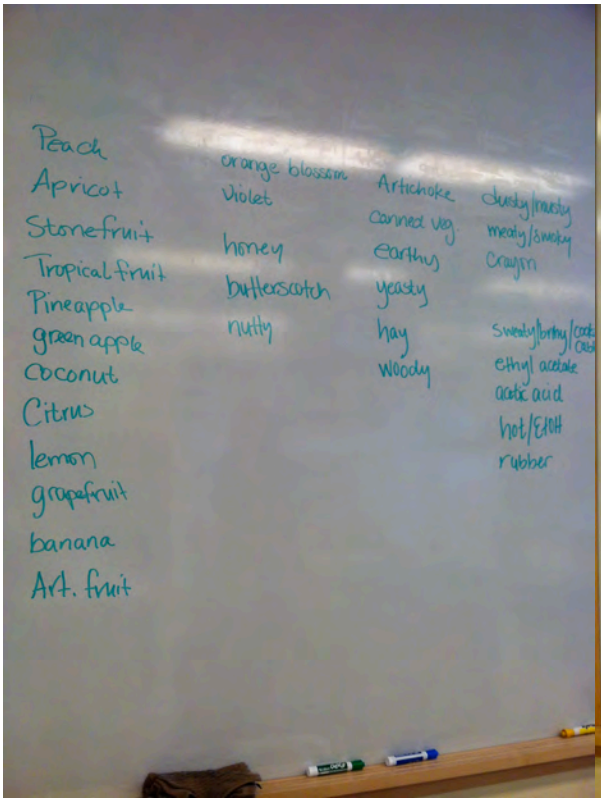
Table 1: Wine codes and vintages for 18 wines from California, France, and Virginia.

Virginia	French	California
VA1-2010	FR1-2010	CA1-2011
VA2- 2011	FR2-2011	CA2-2012
VA3-2011	FR3-2011	CA3-2010
VA4-2012	FR4-2010	CA4-2012
VA5-2011	FR5-2010	CA5-2011
VA6-2011	FR6-2011	CA6-2012

Descriptive Analysis:

For the descriptive analysis, 12 panelists were selected based on interest and availability. The panel was comprised of four men and eight women, ages ranging from 22 to 50 years old. Two-thirds of the panelists had previously participated in other descriptive analysis studies. The panelists were trained over nine consecutive training sessions in a two-week period. During the training sessions, the panelists tasted through all the wines blindly and were given duplicate samples to test for reproducibility. The panelists were presented with between four and six wines to assess at a time. Upon developing a lexicon and agreeing on the reference standards, the panelists memorized the reference standards. During this period, the panelists were tested on the attributes blindly to check their progress. Prior to the formal evaluation, the panelists participated in a booth test run to become familiar with the process .Reference standards were presented using black wine glasses to help prevent visual identification over aroma identification. Recipes for the aroma standards can be found in Table 2. The 18 wines were served in sets of six wines in a randomized order per evaluation session and assessed in triplicate over the course of three weeks using a randomized block design. Prior to each formal evaluation session, the trained panelists were directed to focus and refresh their memories by smelling the aroma standards.

During a formal evaluation session, the wines were assessed monadically under red lighting and the panelists were asked to score the intensity of the wines for each of the attributes using an unstructured line scale (10cm). The wines were served in 25 mL portions, at room temperature, using standard ISO glassware with plastic petri dish lids. Panelists evaluated six wines per session with thirty-second pauses between samples and a two-minute break after the third sample to reduce sensory fatigue. Water and unsalted crackers were provided to help refresh the panelist's palate between wines. FIZZ software (ver.2.31G; Biosystèmes, Couternon, France) was used for data acquisition and to produce the randomized serving order for the wine samples.


Peach
Apricot
Stonefruit
Tropical fruit
Pineapple
green apple
Coconut
Citrus
lemon
grapefruit
banana
Art. fruit
orange blossom
violet
honey
butterscotch
nutty
Artichoke
canned veg.
earthy
yeasty
hay
woody
dusty/musty
meaty/smoky
Crayon
ethyl acetate
acetic acid
hot/EtOH
rubber
dusty/musty
Stonefruit
Tropical fruit
green apple
Citrus
banana
Art. fruit
honey
butterscotch
nutty
smoky
oak
floral
melon/cucumber
Canned veg.
earthy
yeasty
hay
woody
ethyl acetate
acetic acid
hot/EtOH
rubber
waxy

The top two photos show the attributes that were detected in the wines and how they were eliminated or combined to the most important attributes. The bottom two photos are two of the judges memorizing the aroma reference standards.

The red photo shows a panelist in the midst of assessing the wine in the practice booth training session.

Table 2: Recipes for sensory reference standards used for defining aroma and taste attributes.

Aroma	**Recipe**
Artificial fruit (with fake banana)	1 watermelon jolly rancher dissolved in 40mL wine with 5 drops of banana extract. Then dilute 20mL of solution into 20 mL wine and add 3 drops banana extract.
Chemical	4 mL distilled white vinegar (Best Yet Brand) + 30 drops ethyl acetate in 25 mL base wine
Citrus	2g orange zest, 2g grapefruit zest, 2g lemon zest in 20mL distilled H2O
Earthy/dusty/musty	1 tsp wood shavings (hamster bedding) in 10 mL distilled water+ 2tsp earth from the vineyard at UC Davis
Floral	4 drops orange blossom water (Sadaf brand) in 100mL base wine
Green Apple	20g green apple, chopped in 25mL water (made fresh daily)
Hay	1/4 tsp dried oak straw green tops and 1/4 tsp dried alfalfa (from Davis Co-op), without wine
Honey	1 tsp SueBee honey in 25mL of base wine
Hot/Ethanol	Vodka (Newport brand) 25mL
Melon/Cucumber	1-2cm squared cube of honeydew melon and 1.5mm slice of cucumber (made fresh daily), with no wine
Stone Fruit	20mL apricot syrup (Del Monte),5mL peach nectar (Kerns)
Sulfidic (Cooked Cabbage)	1 mL fish sauce (Rufina Patis Brand), 0.5 mL sauerkraut juice (Biotta Naturals Brand), 60mL base wine
Tropical Fruit	2mL passion fruit nectar, 5mL pineapple juice (Doles), 15mL each of Guava and Mango nectars (Kerns)
Woody (with Smokey)	1g Evoak French oak small chips, HT, toasted further using a blow torch until evenly browned in 25 mL distilled water.
Yeasty	1/4 tsp baker's yeast (Fleishmann's Brand) in 5 mL distilled water
Oxidized	15g green apple chopped and left to oxidize overnight, with10mL distilled water and 5drops Sherry and one chopped roasted almond added
Canned Vegetable	10mL green bean brine and 5mL canned artichoke brine in 25 mL base wine

*Base wine was Franzia Chardonnay, which was floral in nature.

Table 2 continued	
Taste	*Recipe*
Hot (Ethanol)	150mL/L Vodka (Sobieski) in water
Astringent	312 mg/L alum in water
Bitter	800mg/L caffeine in water
Sweet	10 g/L sucrose in water
Sour	1.5g/L citric acid in water
Viscous	3 g/L Carboxymethyl cellulose (CMC) in water; Low concentration: 1,5 g/L CMC in water

Consumer Studies:

Participants for the consumer studies were selected based on frequency of wine consumption, as being required to consume wine at least once per week. Panelists were recruited using social media, email blasts to participants of prior consumer studies, posters, and by word of mouth. Three consumer studies took place, two in Virginia (193 total) and one in California (107 consumers). Upon age verification, participants were given a ten-question wine knowledge quiz as well as a demographic survey. After completing these two tasks, 6 of the 18 wines were selected for tasting. The consumer was asked to rate each of the wines on a 10 point scale for liking, with labels at 1 - Dislike extremely, 5 - Neither dislike nor like, 10 - Like extremely. 193 participants were recruited for the panel in Middleburg, Virginia and 107 panelists were recruited in Davis, California. An "incomplete block" design was employed to ensure a reasonable number of wines were tasted by each consumer and avoid tasting fatigue. As each consumer only tasted 6 of the 18 wines, the wines were distributed in such a way that each wine was tasted at least 30 times. Missing data for each consumer was imputed before analysis.

Statistical Analysis

All statistical analyses were performed using R: A Language and Environment for Statistical Computing, Version 3.0.1. (R Core Team 2013)

Descriptive Analysis

Three-Way Analysis of Variance (ANOVA) (Wine, Judge, Replication fixed effects) with two way interactions was performed on each sensory attribute. Attributes with significant wine effects in the absence of wine*judge or wine*rep interactions effects were retained for Principal Component Analysis (PCA). Pseudo-mixed models were used to further analyze attributes with both significant wine effects and a significant wine interaction effect. Sensory mean data from retained attributes was used for further analyses.

Principal component analysis was performed in R using the **prcomp** function.

Consumer preference data was imputed using the **imputePCA** function in the **missMDA** package (Husson and Josse, 2013), designed to impute missing data for exploratory multivariate analysis.

Sensory data from the descriptive analysis was combined with the consumer preference data to produce the external preference maps using the **carto** function in the **SensoMineR** package (Husson et al., 2013a).

Multifactor analysis (MFA) was performed on a combination of the sensory mean data and the wine chemical data. The **MFA** function in the **FactoMineR** package was used (Husson et al.,

Results:

Sensory Analysis: ANOVA of the sensory results found that in regard to product, the following attributes were found to be significantly different with no significant product interactions ($p \leq 0.05$): *overall product intensity, artificial fruit, honey, hot, stone fruit, sulfidic, tropical fruit, sweet, sour, astringent, viscosity,*and *hot mouthfeel.* Because *artificial fruit, honey*, and *tropical fruit* had significant judge, product, and judge*product interactions a pseudo-mixed ANOVA was run to determine if the significance was due to the variance among the judges or among the products. All three descriptors maintained statistical significance.

Table 3: Sensory aroma attribute means in Viognier wines from Virginia, France and California and LSD values.

Sensory aroma attribute means in Viognier wines from Virginia, France and California

OverallInt		*ArtificialFrt*		*Honey*		*Hot.Ethanol*		*StoneFrt*		*Sulfitic*		*TropicalFrt*	
FR5	5.31 a*	FR1	1.78 a	VA2	1.02 a	CA6	3.14 a	CA2	1.52 a	CA1	1.27 a	FR2	1.24 a
VA3	5.34 a	FR5	1.89 ab	FR2	1.04 ab	CA3	3.24 ab	FR3	1.67 ab	FR1	2.11 ab	VA5	1.72 ab
FR6	5.56 a	VA6	1.91 abc	FR3	1.07 ab	VA5	3.36 abc	VA3	1.84 ab	FR3	2.12 ab	FR4	1.76 ab
FR2	5.60 a	CA2	1.92 abc	VA4	1.16 abc	FR1	3.48 abcd	FR2	1.85 ab	VA4	2.28 ab	CA2	1.77 ab
FR1	5.66 a	FR3	1.95 abc	VA1	1.34 abc	FR4	3.53 abcd	VA2	1.87 abc	FR6	2.30 abc	FR1	1.81 ab
FR3	5.67 a	VA2	1.98 abc	CA4	1.34 abc	VA3	3.56 abcd	FR6	2.03 abcd	VA6	2.33 bc	VA3	1.83 ab
VA1	5.74 ab	FR2	2.00 abc	FR5	1.38 abc	VA2	3.57 abcd	FR5	2.08 abcd	VA3	2.36 bc	VA1	2.00 ab
VA6	5.75 ab	VA1	2.27 abc	FR1	1.49 abcd	FR2	3.58 abcd	VA4	2.15 abcd	CA4	2.37 bc	VA4	2.01 ab
CA1	5.82 abc	VA5	2.49 abc	CA5	1.53 abcd	FR6	3.81 abcd	VA6	2.25 abcd	CA6	2.46 bc	FR6	2.07 ab
CA2	5.83 abc	FR6	2.49 abc	CA2	1.55 abcd	VA1	3.93 abcde	VA1	2.46 bcde	FR5	2.53 bc	FR3	2.09 ab
FR4	5.87 abc	CA1	2.54 abcd	VA3	1.59 abcd	VA6	3.96 abcde	VA5	2.51 bcde	CA5	2.59 bc	VA2	2.12 ab
VA5	5.93 abc	VA4	2.65 abcde	CA3	1.71 abcde	FR5	4.01 bcdef	FR1	2.54 bcde	VA1	2.61 bc	VA6	2.13 ab
VA2	5.99 bc	VA3	2.77 abcde	FR6	1.74 bcde	CA4	4.18 cdef	FR4	2.54 bcde	VA5	2.63 bc	FR5	2.30 bc
VA4	6.35 bcd	CA3	2.87 bcde	VA6	1.84 cde	CA1	4.21 def	CA6	2.78 cde	FR4	2.64 bc	CA6	2.36 bc
CA3	6.41 cd	FR4	2.88 bcde	CA1	1.85 cde	CA2	4.23 def	CA1	2.89 de	VA2	2.96 bcd	CA1	3.03 cd
CA5	6.41 cd	CA5	2.91 cde	FR4	2.11 de	VA4	4.27 def	CA4	3.25 e	CA3	3.26 cd	CA4	3.51 de
CA4	6.65 d	CA4	3.55 de	CA6	2.38 e	CA5	4.74 ef	CA3	3.25 e	CA2	3.31 d	CA5	3.65 de
CA6	6.66 d	CA6	3.64 e	VA5	3.20 f	FR3	4.81 f	CA5	3.37 e	FR2	3.71 d	CA3	4.09 e
LSD	0.65		1.02		0.72	LSD	0.85		0.93	LSD	1.02	LSD	0.87

*Different letters in the same columns indicate significant difference at p<0.05.

Table 4: Sensory taste and mouthfeel attribute means in Viognier wines from Virginia, France and California and LSD values.

Sensory taste and mouthfeel attribute means in Viognier wines from Virginia, France, and California												
	Sweet			*Sour*			*Bitter*			*Viscosity*			*HotMF*	
FR4	2.38	a*	FR2	3.15	a	FR4	2.9	a	VA6	3.82	a	FR4	3.02	a
VA4	2.53	ab	VA6	3.53	ab	CA1	2.91	a	VA2	3.97	ab	CA3	3.05	a
FR1	2.61	abc	FR6	3.56	ab	VA5	2.95	a	FR4	3.98	ab	VA2	3.38	ab
CA6	2.61	abc	FR5	3.57	ab	CA3	3.01	a	CA1	3.99	ab	FR6	3.54	abc
CA2	3	abcd	CA4	3.61	ab	VA2	3.24	ab	VA1	4	abc	VA6	3.61	abc
FR2	3.05	abcd	CA6	3.66	ab	VA1	3.32	abc	CA3	4.03	abc	FR5	3.76	abcd
VA1	3.1	abcd	FR1	3.66	ab	FR3	3.4	abc	FR5	4.21	abcd	FR2	3.91	bcde
CA3	3.15	abcde	VA3	3.75	ab	FR5	3.46	abc	FR3	4.25	abcd	VA5	3.95	bcde
CA5	3.28	bcde	CA5	3.75	ab	FR6	3.46	abc	CA2	4.37	abcd	CA1	4.04	bcde
VA2	3.32	bcde	VA1	4.09	bc	VA6	3.75	abcd	CA6	4.48	abcde	VA3	4.13	bcde
VA3	3.4	cde	CA1	4.09	bc	VA4	3.82	abcd	FR1	4.58	abcde	CA6	4.23	cde
VA6	3.44	de	VA2	4.28	bc	VA3	3.83	abcd	VA4	4.6	abcde	FR1	4.25	cde
CA1	3.46	de	CA3	4.43	bc	CA4	4.01	bcd	FR6	4.71	bcde	VA4	4.27	cde
FR3	3.47	de	VA4	4.43	bc	CA5	4.02	bcd	CA5	4.73	bcde	VA1	4.38	de
FR5	3.54	de	CA2	4.74	c	FR1	4.22	cd	CA4	4.84	cde	CA2	4.41	de
FR6	3.54	de	VA5	4.8	c	CA2	4.26	cd	VA3	4.93	de	CA5	4.54	e
CA4	3.92	e	FR3	4.83	c	FR2	4.28	cd	FR2	5.28	e	FR3	4.58	e
VA5	4.82	f	FR4	4.9	c	CA6	4.58	d	VA5	5.29	e	CA4	4.63	e
LSD	0.8		LSD	0.91		LSD	0.98		LSD	0.85		LSD	0.77	
*Different letters in the same columns indicate significant difference at p<0.05														

Tables 3 and 4 show all of the significant attributes and the least significant differences for each. This table helps to organize the significant differences among the wines. The FR1, 2, 3, 5, and 6 are significantly different in *Overall Intensity* from VA 2 and 4 and CA 3, 4, 5, and 6. CA1, 2 and 5 and VA4 and FR3 are significantly higher in *hot ethanol* aroma than CA3 and 6 and VA5. *Hot mouth feel* corresponds well with the wines, which rated highly for *hot ethanol* aroma. For *stone fruit*, CA2, FR2 and 3 and VA3 are significantly less in intensity than CA1, 3, 4, 5, and 6 while most of the Virginia wines were not significantly different from either extreme. In *tropical fruit* intensity, CA1, 3, 4, and 5 are significantly greater than most of the other Viogniers.

Table 5: Chemical data for 18 Viognier wines from France, California and Virginia.

Chemical Data for 18 Viognier wines

Sample	pH	TA (g/L as tartaric)	VA (g/L as acetic)	Alcohol %	RS (g/L)	Malic Acid (g/L)
CA1	3.24	7.10	0.09	14.50	6.30	1.66
CA2	3.22	6.80	0.63	13.70	2.00	0.13
CA3	3.48	7.10	0.06	13.50	7.30	1.54
CA4	3.63	6.50	0.18	14.80	3.80	1.81
CA5	3.80	6.80	0.20	13.90	1.30	2.73
CA6	3.81	5.60	0.14	14.00	1.80	0.61
FR1	3.67	5.60	0.41	13.70	2.20	0.16
FR2	3.81	5.10	0.49	13.70	2.50	0.02
FR3	3.17	7.00	0.21	14.50	3.70	1.61
FR4	3.40	6.50	0.35	12.60	2.30	0.07
FR5	3.37	6.20	0.17	13.90	2.00	1.71
FR6	3.47	6.00	0.39	14.00	2.30	0.86
VA1	3.35	6.40	0.31	14.20	5.20	1.67
VA2	3.34	6.20	0.12	13.20	4.40	1.49
VA3	3.89	6.50	0.28	13.60	1.40	2.21
VA4	3.50	6.70	0.09	14.40	1.50	2.16
VA5	3.49	8.50	0.47	13.90	10.30	2.48
VA6	3.52	6.60	0.44	13.50	1.90	0.80

Shown in Table 5 is the chemical data collected for the 18 wines. pH, titratable acidity, volatile acidity, percent alcohol, residual sugar and malic acid were all performed for each wine.

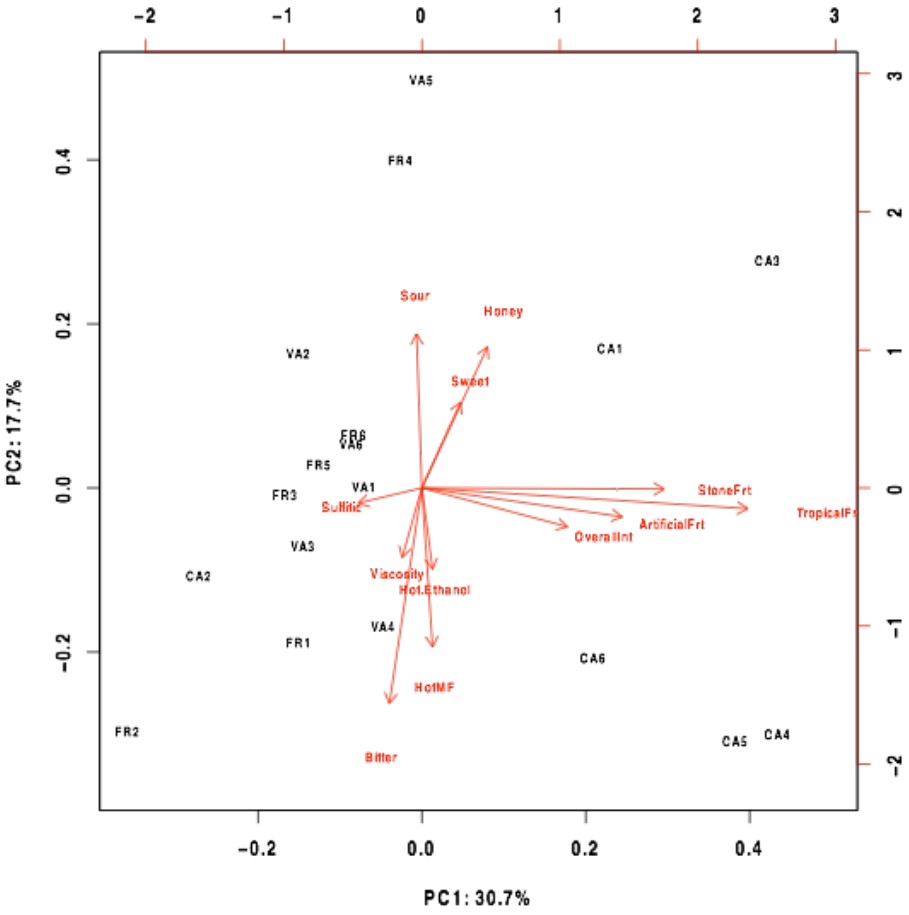


Figure 1: PCA of Virginian, French and Californian Viognier Wines

Figure 1 shows the Principal component analysis (PCA) of all of the wines. The vectors represent the significant attributes. Vectors with small angles between them indicate a high correlation between those attributes. Vectors that are 180 degrees apart from one another indicate a negative correlation and wines that are 90 degrees (perpendicular) to one another indicate that they are uncorrelated. If a wine falls on, near, or in the direction of a vector, that indicates that the wine was scored highly in those attributes. Wines falling in the opposite direction of the vector indicate that the wine was not as intense in that particular attribute. Wines that are plotted closely together on the PCA plot indicate their similarity.

In Figure 1, PC1 (x-axis) shows 30.7% of the total variation of the data and is primarily a function of *overall intensity* and the fruit aromas. The second dimension, PC2, accounts for 17.7% of the variation and is characterized by the taste attributes, the upper half of the graph by *sweet* and *sour*

and the lower half by *bitter* and *hot mouth feel*. Displayed in the PCA above are groupings of the significant attributes. There is a *fruity* group, a group consisting of *viscosity, ethanol, hot mouth feel* and *bitterness,* all presumably associated with the Alcohol content, and above there are the terms *honey* and *sweet* overlapping. Most of the Virginian and French wines are found on the left side of the axis, with less intense fruit aromas. All of the California wines, except CA2, are distributed on the right side of the axis, characterized by the intense fruit aromas. CA2, appearing on the plot closer to the Virginian and French wines, indicating that this wine was made more in the style of French and Virginian wines.. Wines above the x-axis are characterized by greater sweetness and wines below by higher alcohol content. The wines found on the right side of the x-axis are all greater in intensity in the fruit aromas as those found on the left. Wines with a positive loading on the y-axis are all greater in sweetness and sourness whereas wines that are negatively loaded are higher in alcohol and bitterness. The wines, CA3, CA4, and CA5 all exhibit high scoring in the *stone fruit, tropical fruit, artificial fruit,* and *overall intensity*. The CA3 however is more *sweet* and *sour*, whereas the CA4 and CA5 are not sweet, but higher in *hot mouth feel* and *bitter*. The same effect can be noted with the CA1 and CA6 wines.

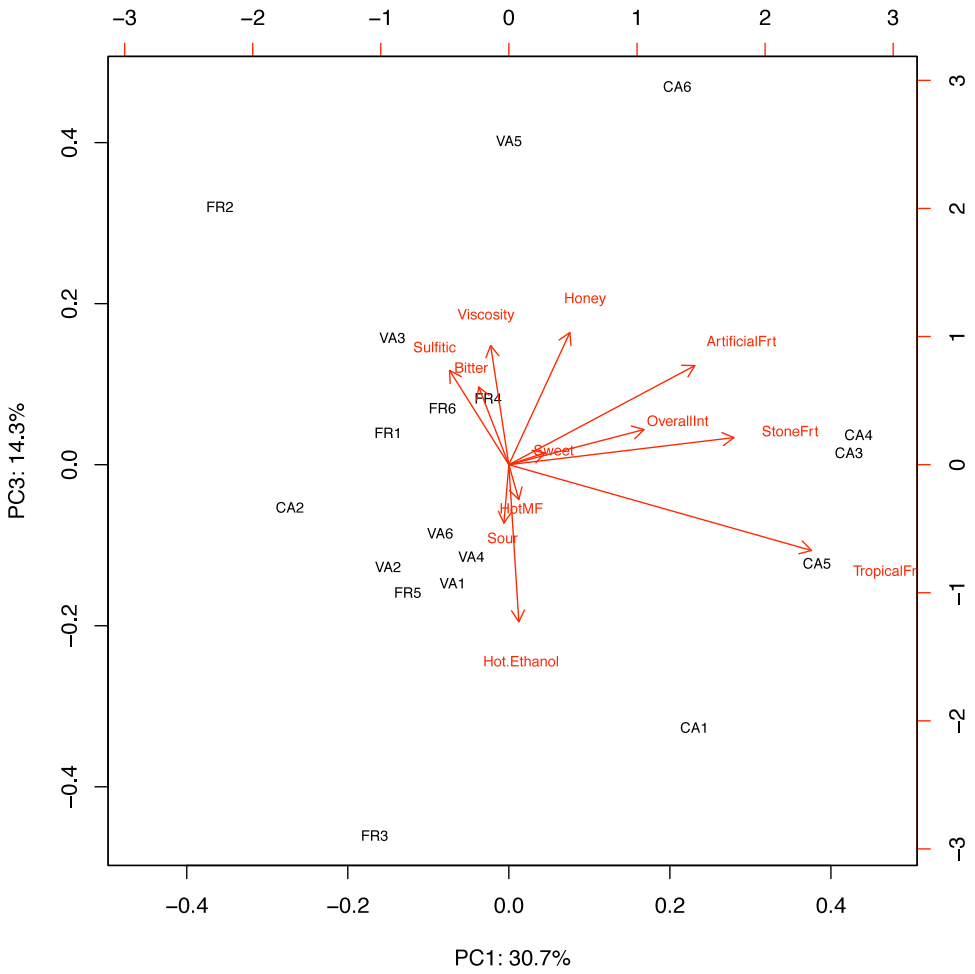


Figure 2: PCA of descriptive analysis of 18 Viognier wines showing PC1 and PC3.

A third dimension, principal component 3 (Figure 2) explains an additional 14.3% of the variance. In figure 2, PC1 and PC3 are plotted together. This third dimension helps to better clarify the correlations among the data. The y-axis shows negative correlations between *viscosity* and *hot ethanol aroma* and *sulfidic, bitter* and *viscosity* show a higher correlation to one another. The wines found in the center on the left side of the PCA in figure one are now broken into two groups. VA3, FR1 and the FR6 all exhibit greater *viscosity* while VA1, VA2, VA4, VA6 and FR5 show greater intensities of *hot ethanol*.

Figure 3 is a PCA using principal component 2 as the x-axis and principal component 3 as the y-axis. This PCA shows that *bitter* and *sour* are negatively correlated*, hot ethanol* and *honey* and also *sweet* and *hot mouth feel* are negatively correlated.

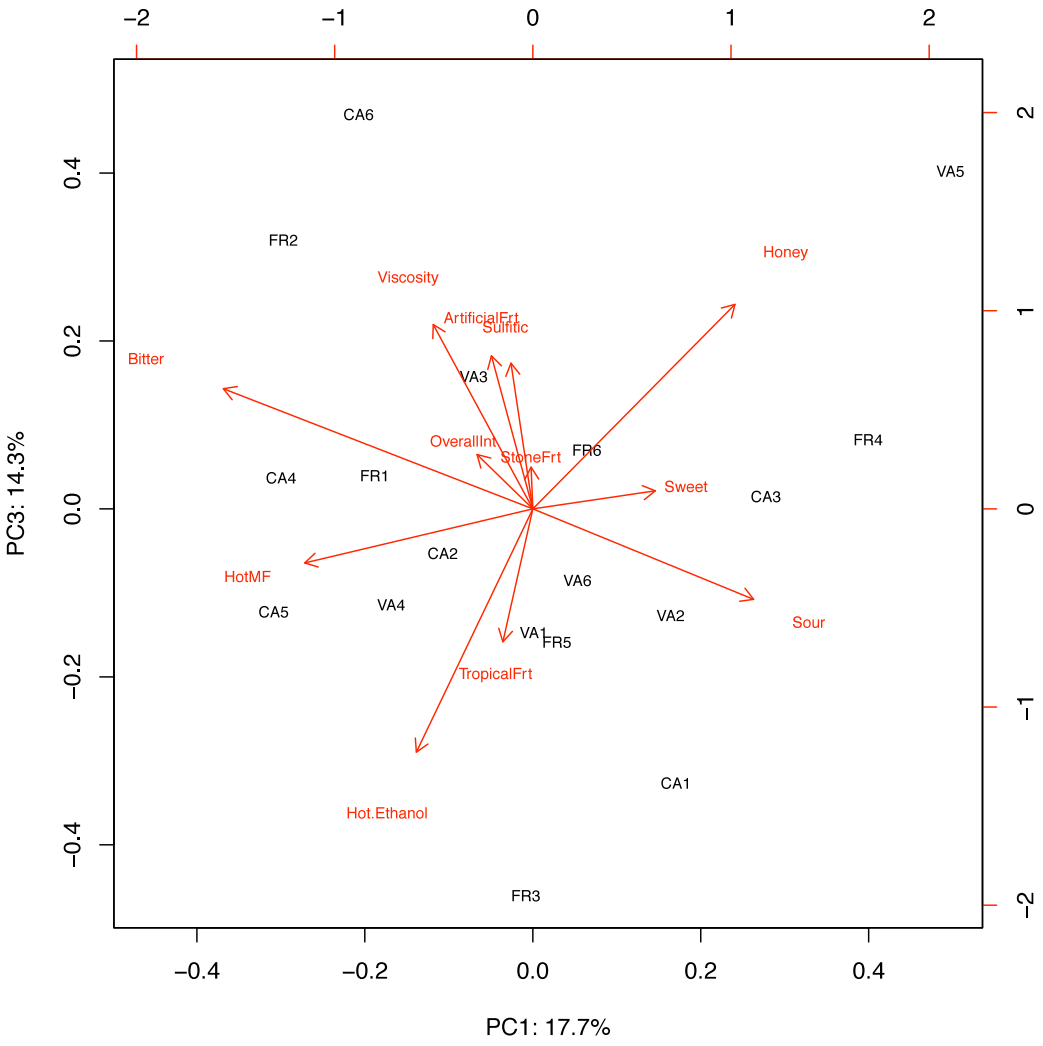


Figure 3: PCA of descriptive analysis of 18 viognier wines PC2 and PC3.

Principal component analysis was also performed with respect to place. Using this model, the following attributes were found to be significant among the three locations: *overall intensity, artificial fruit, stone fruit, tropical fruit,* and *woody*. Figure 4 is a PCA graph of the data analyzed with respect to place. The first two dimensions represent 86.2% of the variance. The wines from each region are connected using convex hulls, which connect the outermost points of a group of like products. If CA2 is omitted, then the Californian convex hull does not overlap the French and Virginian hulls (graph not shown).

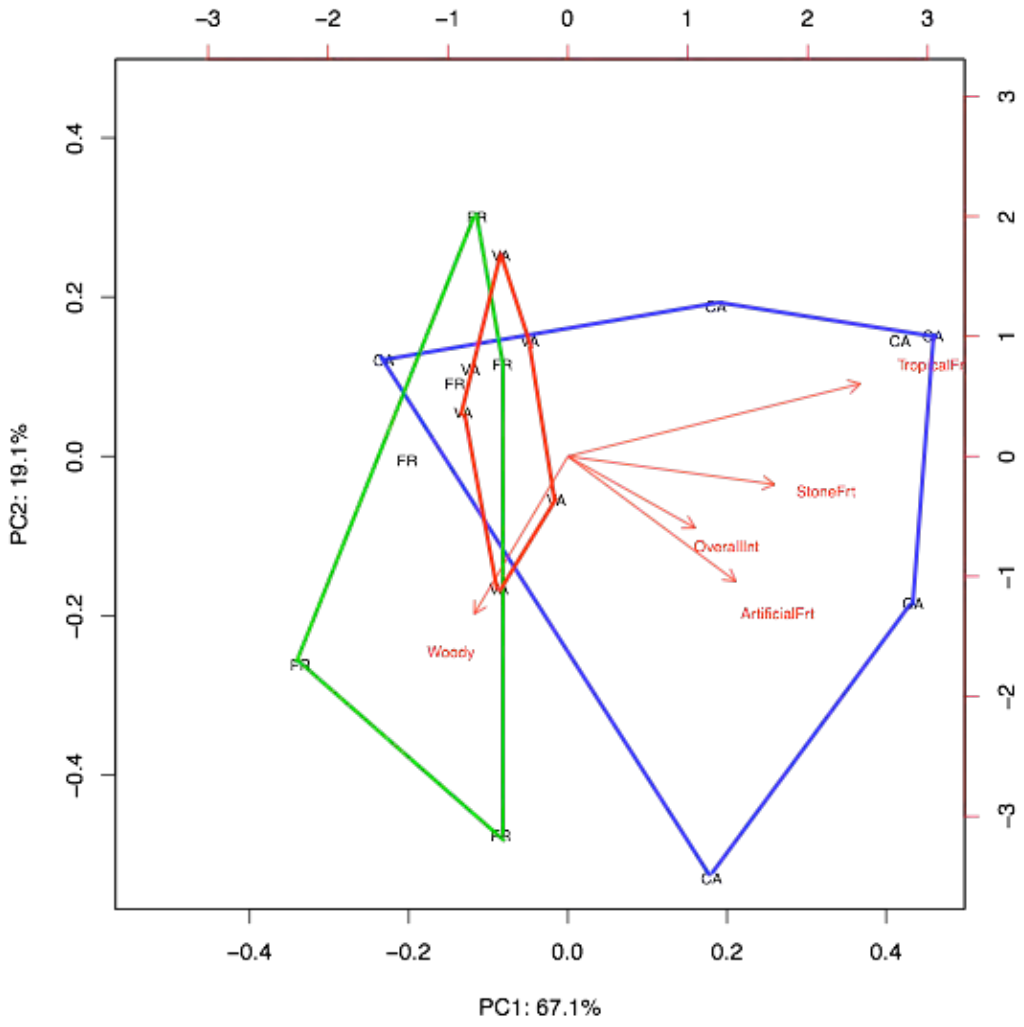


Figure 4: PCA of Viognier Wines by Country

Where the wines are situated in the graph indicate the intensities of the attributes they are plotted near. Five out of six of the California wines were rated more highly in *tropical fruit, stone fruit, artificial fruit,* and *overall intensity* attributes and are clearly separated from the French and Virginia wines. The French and Virginia wines are less intense in the fruit descriptors. The French

wines were rated more intensely in the *woody* descriptor. The Virginia wines seem to fall in the middle of the other two countries. They also appear to be more alike or focused than the other areas.

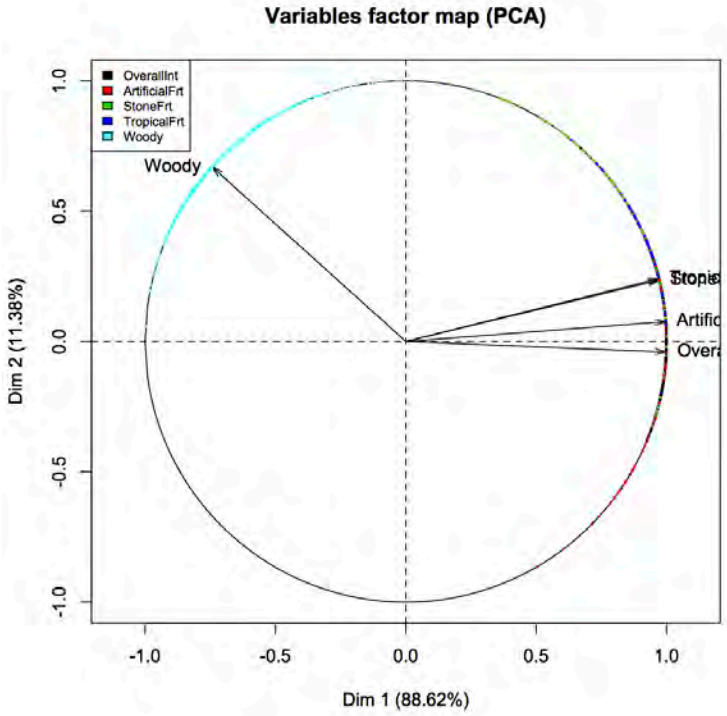


Figure 5: Variables Factor Map

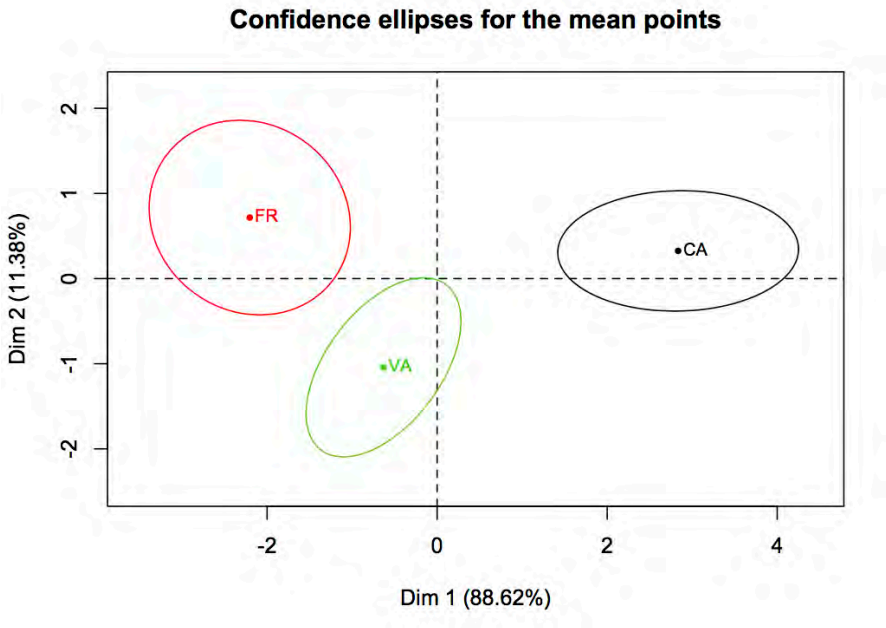


Figure 6: PCA with Confidence ellipses for Wines by Region

Figures 5 shows the significant attributes and Figure 6 illustrates that all three wine regions are distinguishable from one another. If the ellipses (confidence intervals, $p \leq 0.05$) do not overlap, then the wine regions are significantly different from one another. Interpreted together, the French and Virginian wines are less intense in the *Tropical fruit, Stone fruit, artificial Fruit* and *overall intensity*. The French wines are more intense in *Woody* than the Virginian wines. The Virginian wines are less intensely fruity than the Californian, but *more fruity and intense* than the French.

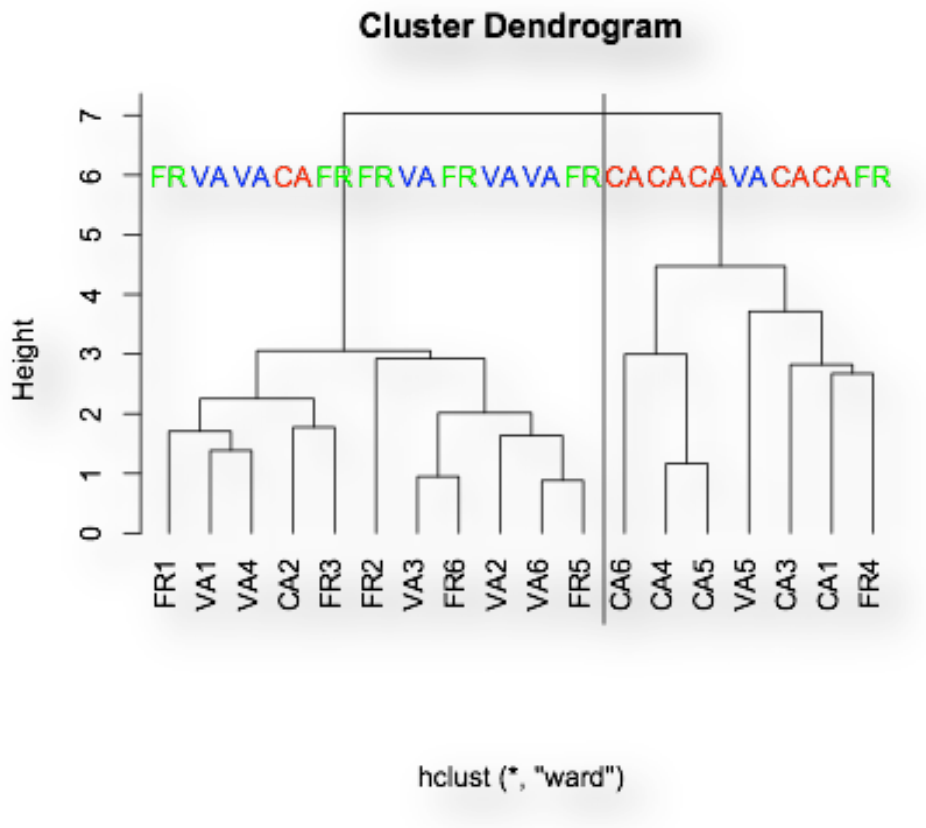


Figure 7: Hierarchial cluster dendrogram of descriptive analysis data of 18 Viognier wines.

A dendrogram is used to merge similar data points (products) into like-groups and provide a useful summary of the data. The height of the branches indicates how similar or dissimilar a product is from the next, the greater the height, the greater the difference among the products. Likewise, the shorter the height, the more similar the products are. Figure 7 shows the hierarchical clustering of the 18 Viognier wines based on the descriptive data. This dendrogram illustrates that the Californian wines are more different from the Virginian and French wines than the French and Virginian wines are from each other.

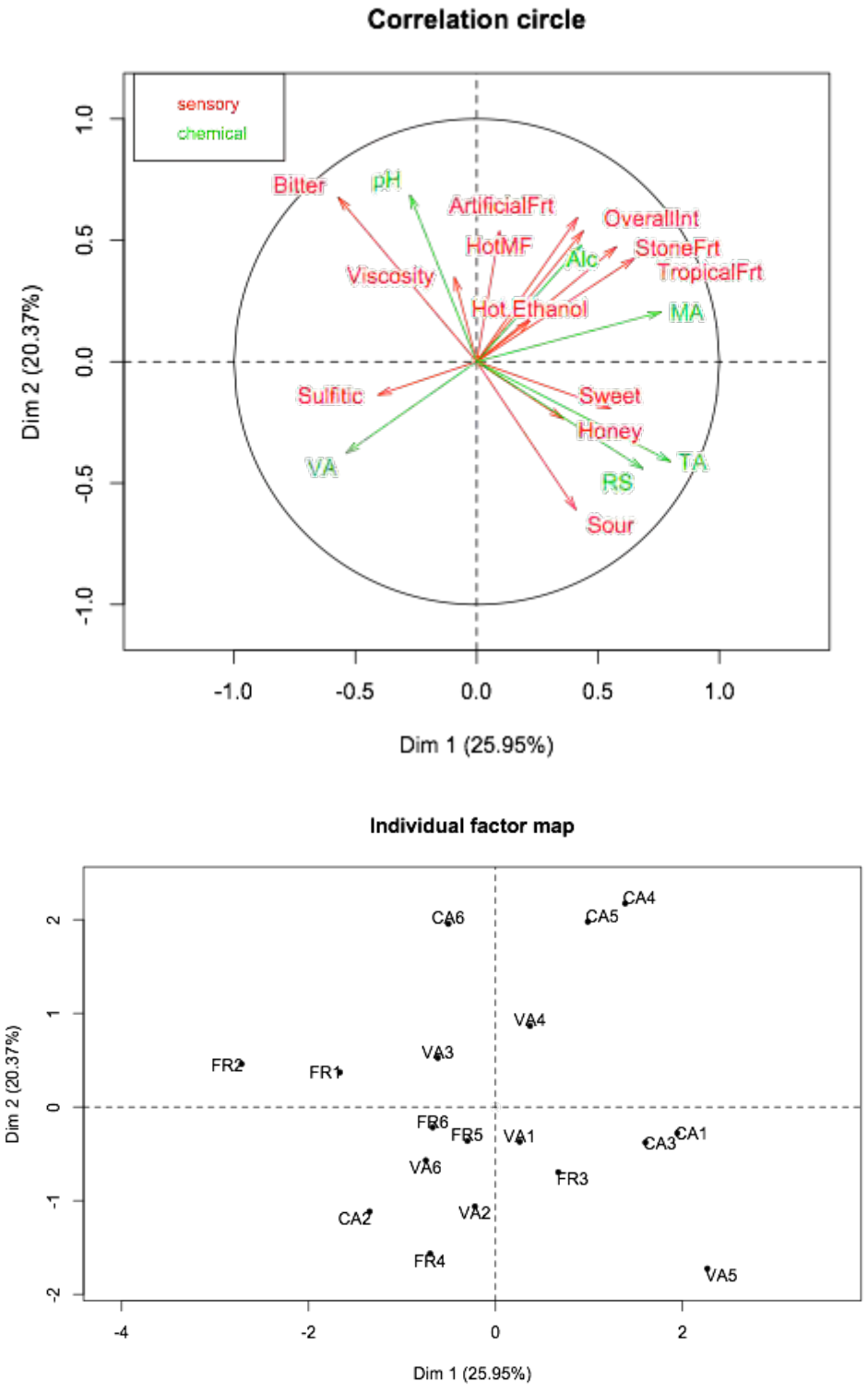


Figure 8: Multiple Factor Analysis of Descriptive Analysis data and chemical data of 18 Viognier wines.

In the multiple factor analysis (MFA) above (Figure 8) the chemical data was analyzed with the descriptive analysis data. The analysis of these two data sets together shows the relationships

between the descriptive traits and the chemical composition of the wines. Shown above in Figure 8, alcohol is closely associated with the *overall intensity* and many of the fruit aromas, however more importantly also associated with *hot ethanol* and not as closely related to the *hot mouth feel*. pH can be seen to be to be correlated with *viscosity* and also *bitterness*, as well as negatively correlated with *sourness*. VA and *sulfidic* are loaded closely together. *Sweet, honey* and *sour* are all loaded in the same quadrant as titratable acidity and residual sugar. Wines that were rated highly for *sweet* and *sour* attributes also tested more highly for titratable acidity and residual sugar. Wines that were scored highly for the *fruity attributes* also contained greater percentages of alcohol and malic acid. The higher alcohols are a result of riper grapes and could be associated with the fruity aromas.

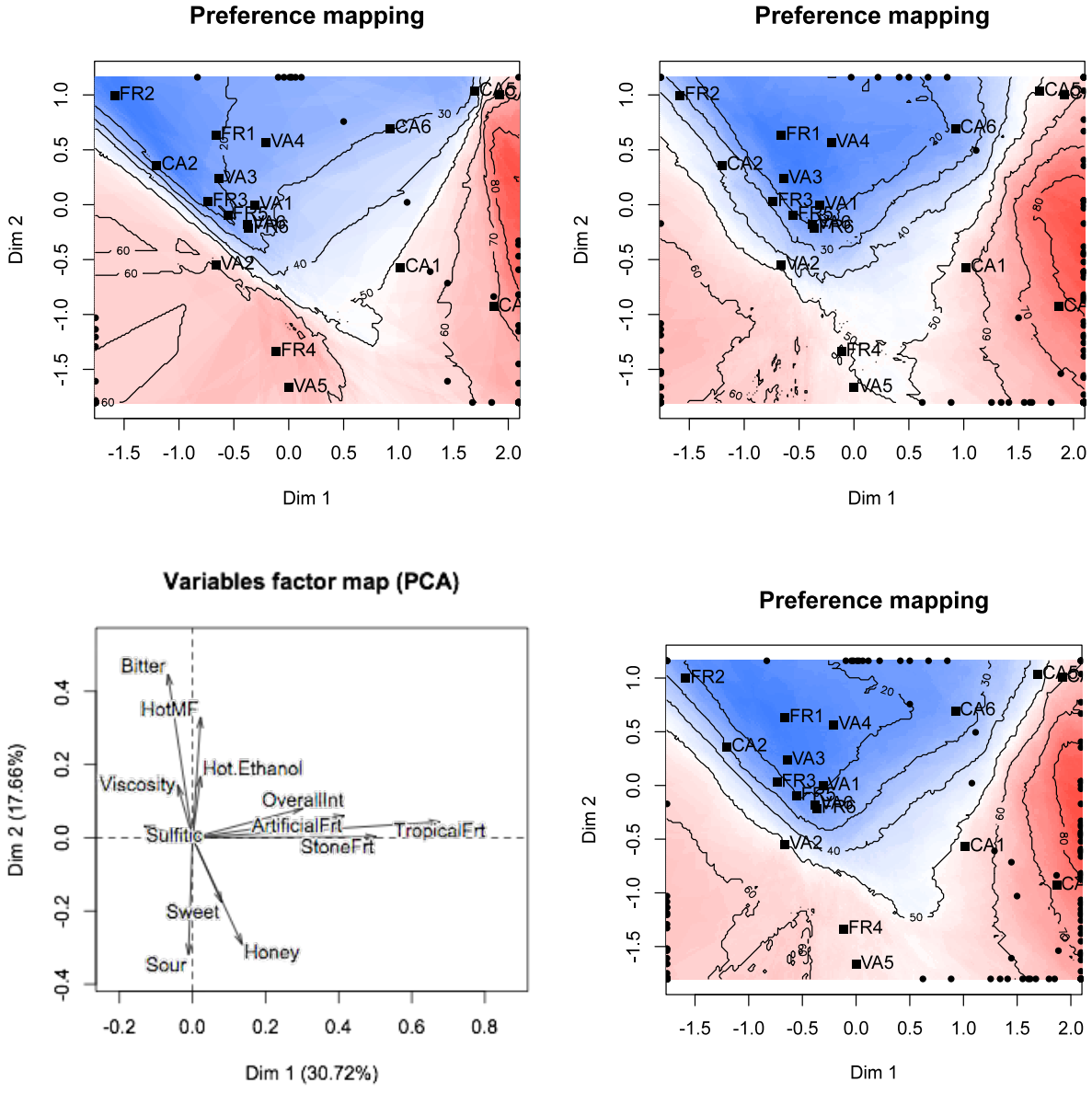


Figure 9: Preference mapping of consumer study of 18 Viognier wines. Upper left-Californian consumer results (n=109), upper right- Virginian consumer results (n=193), lower left- Variable factors map, lower right- combined consumer studies (n=302).

The preference data shown in figures 9 are preference maps. The graph is paired with the descriptive data loadings shown in the lower left-hand corner. The colors range from red (most preferred) to blue (least preferred). The black dots around the perimeter of the graph represent the consumers.

In the California data, shown in the upper left-hand corner of figure 9, there appear to be three groups of consumers. There is a group who prefer wines with high intensities of stone fruit, tropical fruit and artificial fruit. The wines plotted in those regions also have higher residual sugars. There is a group who prefer wines that are less intense in the fruit aromas but have higher intensities in sweet and sourness. And there is a group who prefer wines that are higher in viscosity, bitterness and alcoholic mouth feel.

In Virginia, the consumer study showed similar results to the consumer study in California. In this graph (upper right-hand corner) there appear to be three main consumer groups as well. Those who prefer wines which are greater in sour and sweet intensities and less fruity, a large group who prefer wines with greater fruit intensities and also residual sweetness, a group who prefer wines of greater fruit intensity and less residual sweetness and a smaller group who appear to prefer higher alcohol and less fruit intensities.

The combination of Californian and Virginian consumers shows three groups of consumers, shown in the lower right-hand corner of figure 9. Those who prefer the high intensity fruity wines (the majority), those who prefer the sweet and sour less fruity wines, and those who prefer the dry, more viscous and alcoholic wines.

Consumer demographics:

Demographic	CA Percent	VA Percent
Gender		
Female	46%	37%
Male	54%	63%
Age		
21-24	27%	7%
25-34	33%	31%
35-44	8%	19%
45-54	12%	25%
>55	20%	18%
Wine Consumption		
Once a day	15%	19%
3-4 times a week	34%	43%
1-2 times a week	33%	36%
2 times a month	15%	1%
1 time a month	3%	1%

Main household shopper		
Yes	82%	83%
No	18%	17%
Income		
<20000	29%	0%
20000-35700	9%	5%
35701-53550	15%	12%
53551-71400	7%	14%
71401-107010	16%	20%
>107010	24%	49%
Wine Preference		
White	9%	16%
Red	43%	30%
Both	48%	54%
Average Price spent on bottle		
<$7	13%	2%
$8-$10	31%	8%
$11-$14	14%	32%
$15-$21	18%	47%
$21-$29	19%	8%
>$30	5%	3%
Consume wine from the respective home state most often?		
Yes	92%	57%
No	8%	43%

Table 5: Demographic information from the Californian (n=107) and Virginian (n=192) wine consumers.

Table 5 shows the demographic information for both consumer studies. The notable differences are the younger age group in California, as many of the participants were students. Due to the age and stage in life, it is not surprising the difference in income and price paid per bottle of wine being lower than the Virginian participants. This may have to do with the method of advertisement for the two studies. In Virginia, many of the participants were recruited using social media and the Virginia wine marketing group, while in California many of the participants were recruited either by word of mouth (the students) or by having previously participated in consumer studies. Both

groups were selected based on frequency of wine consumption.

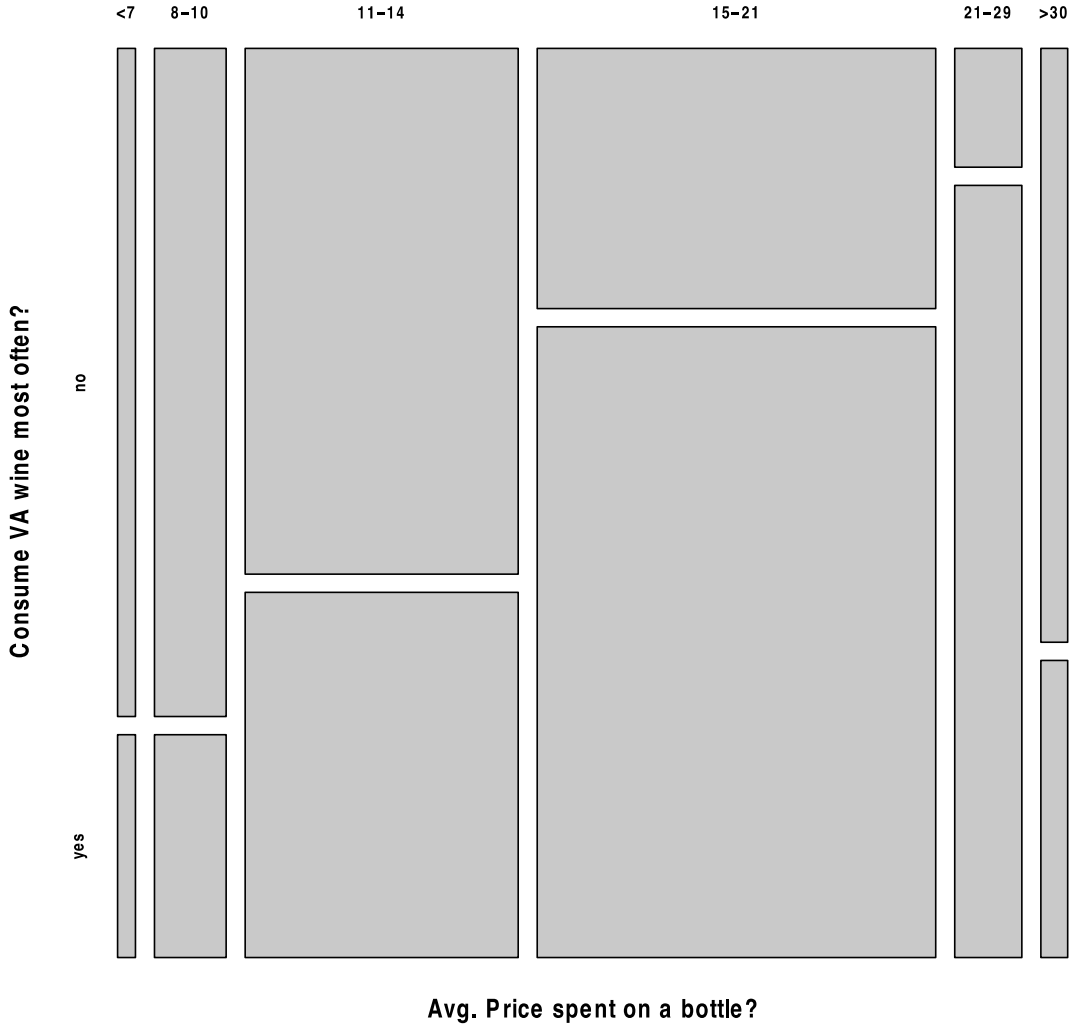


Figure 10: Price per bottle versus Virginia wine consumption.

Figure 10 shows an interesting comparison of Virginia wine consumers' preferences and purchasing behaviors. On the x-axis is a break-down of the average bottle price Virginian consumers spend on wine. This is plotted against if they consume Virginia wine most often on the y-axis. What is shown in this figure is that consumers living in Virginia who most often drink Virginia wine spend more on a bottle of wine on average, between $15 and $29, than those who do not consumer Virginian wine most often. What this graph does not clarify is if this is a consequence of the consumers choosing to support the local wineries and therefore buying wines at these price points or if the consumers ordinarily purchase wines between these price points and happen to enjoy Virginian wines.

Discussion:

This project was designed to discover if there are unique sensory attributes that distinguish Virginia Viognier from other well-known Viognier producing regions. This study found that all three regions are statistically distinguishable from one another based on five significant attributes. In general, Virginia Viognier was much more like the French wines than the Californian wines. The Virginian wines tended to be more restrained the fruity characteristics than the highly intense aromas of the Californian wines. However, the French wines are different from the Virginian wines in terms of the woody aromas. As is shown in Figure 6, Virginia wines were found to be between the two other regions in terms of fruitiness and woodiness. The winemaking practices from each region varied from one another. In Virginia, the fruit was picked at Brix ranging from 21.5 to 23, was fermented in stainless steel or neutral oak and prevented from undergoing malolactic fermentation. In California, the fruit had higher Brix at harvest (between 22.5 and 26.5), also mostly fermented in stainless steel and neutral oak. Two wines from California, CA2 and CA6, underwent malolactic fermentation, the other four Californian wines prevented this secondary fermentation. The French winemaking varied more from the American wines with a higher use of oak and MLF.

The descriptive analysis data used three countries and multiple regions to create a lexicon of descriptors that can be used to describe Viognier, which had not previously been compiled to this extent. A list of attributes, which describes this cultivar is included in the results section.

The first dimension of the principle component analysis shows that the attributes that contribute to the greatest amount of variation (as represented on the x-axis) are the fruity aromas of *stone fruit, tropical fruit,* and *artificial fruit.* These are characters that winemakers frequently use to describe Viognier wines. Five out of six of the Californian wines showed the greatest intensities in these attributes. CA2, the Californian wine that was the least like the others, had a style of winemaking more similar to the French wines. CA2 was fermented primarily in neutral oak and underwent malolactic fermentation (MLF). Most of the Californian wines were harvested between 22.5 And 25.6 brix, fermented in stainless steel and prevented from undergoing MLF to maintain the fruity style. The second dimension, further separated the wines according to sweet and sour tastes versus bitter and alcoholic taste and mouth feel. Previous research has shown that higher alcohols can accentuate bitterness in wine (Fisher and Noble, 1994). Higher alcohols also may cause detected sweetness in dry wines. An AWRI bulletin mentions that while higher alcohol percentages in white wine may not decrease the intensity of aromas in wine, it may increase the sensations of hotness and bitterness on the palate. A study in Australia found that for Australian and Chinese consumers, 40% and 50% respectively, reported lower liking for wine with higher alcohol percentages due to hotness and bitterness (http://www.awri.com.au/wp-content/uploads/reducing_alcohol_levels_in_wine.pdf).

It is interesting to see sweet and sour tastes closely correlated, as they tend to mask or balance one another. Research has shown sweetness to diminish the perception of acidity and vice versa (Jackson, 2007, Noordeloos and Nagel, 1972). It is likely that the wines with high residual sugar are balanced with high titratable acidities and therefore closely correlated. The descriptive analysis for the wines rated highly for residual sugar and TA correspond with the chemical data.

There does not appear to be a regional preference for wines produced in the region in which the consumers live. Rather, consumers on both coasts tended to prefer wines that were high in fruity aromas and residual sugar. This is in agreement with a recently published article by Lesschaeve *et al, 2012*. Lesschaeve *et al*. found in their study of consumer preferences of commercial white wines that approximately 77% of wine consumers prefer wines that are rated more highly in fruitiness and sweetness regardless of age, frequency of wine consumption, stated wine preference or income bracket. There was a group of consumers who preferred wines that were more dry, burning, and oaky in flavor consisting of the remaining 23%. This group tended to be of an older generation and more casual wine consumption. These consumers tended to drink wine in the privacy of their own homes with meals and as a way to wind down from a long day.

It should be noted that the wines tasted by the consumers were small volumes that would be used to assess a wine and quickly decide liking, similar to what is poured at a wine tasting at a winery or retail store. The wines were not tasted in context to food or in a relaxed environment, which can impact the perception of a wine. Wines were tasted blindly, thereby removing any marketing impact of brand or region loyalty, which also influences a consumer's preference. Additionally, the wines were tasted at room temperature. There has been research to support that the serving temperature of white wine can significantly impact the perceived intensities of sweetness and acidity in addition to aroma (Ross and Weller, 2007).

The MFA shows wines that were scored higher in the fruity attributes also contained higher alcohol percentages. This could be due to the ripeness of the fruit at date of harvest. Anecodotal accounts within the Virginia wine industry suggest, , that Viognier only starts to develop the stone fruit and tropical fruit aromas particularly late in maturity, at around 23-24 brix levels. The more restrained aromatics of Virginian and French Viognier wines may be due to the physiological maturity of the grapes at harvest. The Virginian wines were made from fruit that were harvested between 21.5 and 23 Brix, while the Californian wines were made from fruit that was harvested between 22.5 and 25.6 Brix, thus resulting in greater intensities of stone fruit and tropical fruit and higher alcohols. Further research is required into the effect of brix at harvest or number of days post-veraison after which the fruit was harvested on the physiological maturity of the grape in terms of aroma and flavor to substantiate these assumptions.

Conclusions:

This research helped to create an extensive list of descriptors for Viogner based on wines from three different regions. It was found that Viognier wines from California, France and Virginia are all distinguishable from one another. Californian wines are greater in the fruit intensities than the French and Virginian wines. The French wines were greater in woody intensity than Californian and Virginian wines. The consumer study found that there was a majority preference for wines that were greater in fruity aromas and possessing slight residual sweetness with a smaller group preferring wines with higher alcohol and bitterness. These findings were in agreement with those of previous consumer studies (Lesschaeve et al., 2012).

1. Does Virginia Viognier possess unique sensory attributes distinctive from other well known Viognier producing regions?
2. What sensory or chemical attributes distinguish Virginia Viognier from other Viogniers?
3. Do consumers in Virginia and California have different palates in terms of Viognier?
4. Is Virginia Viognier addressing the consumer's likes and dislikes?

Virginia Viognier is separated from the French and Californian wines by possessing a lighter, less intense aroma profile than California with less oak aroma. For those who prefer French wines, Virginia can provide a wine that is elegant and lighter in composition without the wood component. Virginia wines also provide an alternative to more intensely fruity wines with higher alcohols.

By nature, many consumers gravitate towards wines that possess greater fruity character and slight sweetness and less towards wines that possess bitter components to them, possibly because many bitter plants are poisonous. However, it is not the opinion of this author that all wines in Virginia should be made with residual sugar in order to target this consumer group. It seems that most of the consumers who purchase wines in the price bracket from which Virginia offers its Viognier wines, prefer Virginian wines and select them over other wine regions.

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