Descriptive analysis of Frontenac gris and Brianna wine grape and wine varieties

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"One of the things my parents taught me, and I'll always be grateful as a gift, is to not ever let anybody else define me; that's for me to define myself…"
-Wilma Mankiller

ABSTRACT

Interest in producing cold-hardy wine grape cultivars has developed over the past few years, and Frontenac gris and Brianna are two such cultivars that have recently been released by the University of Minnesota breeding program. The first objective of this study was to describe the aroma and flavor attributes of Frontenac gris and Brianna wine grapes and wine and to determine how the ripening process affects changes in sensory attributes of the grapes and their respective wines. The second objective was to develop a set of descriptors that define aromas and flavors of Frontenac gris and to determine whether each of these descriptors are perceived in a majority of Frontenac gris wines.

For the first objective, wine grapes and wines from one winery in South Dakota were evaluated over different harvest dates. For the second objective, 19 Frontenac gris wines from various wineries were evaluated. For both objectives, members of the trained panel from the Sensory Center at the University of Minnesota learned a standardized technique to taste wine grapes and/or wine and developed a lexicon of flavors and aromas occurring in these grapes and wines. Panelists participated in testing sessions during which they rated the intensity of the attributes in each of the grapes and in each of the wines.

As Brianna grapes ripened, they increased in fermented fruit, artificial grape, and sweetness, and decreased in sourness, bitterness, citrus flavor, and green apple flavor. The following attributes increased in intensity with progressively later harvest dates for Brianna wine: mushroom, soy sauce, sauerkraut, corned beef, and sweetness. The following attributes decreased in intensity with progressively later harvest dates for Brianna wine: sourness, fresh raspberry, fresh grapefruit, and green apple. As Frontenac gris grapes ripened, the grapes decreased in the dried grape flavor attribute. For Frontenac gris wine, the fresh grapefruit aroma increased in intensity and then decreased in intensity with later harvest dates.

Attributes found to define 75% or more of the Frontenac gris wines were dried apricot aroma & flavor, dried cherry aroma & flavor, citrus fruit aroma & flavor, dried fruit aroma & flavor, fresh strawberry aroma & flavor, green wood aroma & flavor, fresh green flavor, canned peach aroma, and canned pineapple flavor.

Paired with information about the chemical maturity of the Frontenac gris and Brianna grapes, this knowledge will improve determination of the ideal maturity of the wine grapes for maximizing the overall quality of these wines. Also, paired with information about location, yeast, residual sugar, and alcohol percentage, wineries can decide which of the defining attributes of Frontenac gris they want to be dominant in their wines.

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INTRODUCTION

The University of Minnesota has one of the oldest plant breeding programs in North America, tracing back to 1865 (Luby, 1991). The program supports the upper Midwest region that experiences temperatures ranging from 35^0 C in the summer to as low as -40^0 C in the winter, with varying amounts of snow. This does not seem to be ideal for grape growing, however, huge strides have been made in developing fruit cultivars that can survive these harsh conditions. The emergence of cold-hardy grape cultivars began in the 1990's and has led to an expanding industry of small vineyards and wineries in the Upper Midwest (Tuck & Gartner, 2013). The growth habit and fruit composition differ from traditional grape hybrids, and so, new viticulture and enological techniques have been developed to correct for these differences and to withstand the harsh climate conditions. Two such cultivars that have been developed are Frontenac gris and Brianna.

Frontenac gris is described as having small to medium round berries that are a grayish amber color with clear juice (Hemstad, 2003). The wines have been reported to have good body and aroma with little herbaceous qualities that are commonly associated with *Vitis riperia*. The color of wine typically ranges from pale gold to rich amber, and the flavor has been described as highly fruity and having intense peach and tropical fruit flavors. These qualities allow Frontenac gris to be a great semi-sweet or dessert wine.

Brianna was bred by Elmer Swenson in 1983 (Thull & Luby, 2016). Brianna can be made into a semi-sweet wine with pineapple aroma and flavor or a light table wine with grapefruit, tropical, and floral flavors. Overall, the wine grapes produce a sweet, medium-bodied wine with notes of peaches, apricots, grapefruit, and pineapple.

After learning this information, there was still a need to continue to advance the cold-hardy grape and wine production, so I studied the aroma and flavor attributes of Frontenac gris and Brianna wine grapes and wine and determined how the ripening process affects changes in sensory attributes of the grapes and their respective wines. In addition, I wanted to develop a set of descriptors that more broadly define aromas and flavors of Frontenac gris. Paired with information about the chemical maturity of the Frontenac gris and Brianna grapes, this knowledge will improve determination of the ideal maturity of the wine grapes for maximizing the overall quality of these wines. The aroma and flavor attributes that are similar over varying conditions will characterize Frontenac gris and may assist the industry in marketing their product to wine consumers unfamiliar with the Frontenac gris grape variety.

Chapter 1: Literature Review

1.1 Terroir features that influence wine characteristics

"Terroir" is a French term that refers to the geographical and environmental origins of wine grapes (Conde et al., 2007). This includes everything from climate, location, sunlight, soil, and winemaking practices that have evolved in specific locales, to even microorganisms found on the skin of the grape (Conde et al., 2007). A terroir offering good conditions for a particular grape cultivar produces plants with the most optimal and high quality wine grapes (Conde et al., 2007). Conde et al. (2007) has shown that the most important part of terroir is climate, or more specifically, temperature. A moderate climate with adequate to high rainfall provides the ideal conditions for fragrant white wines and full-bodied red wines (Conde et al., 2007). However, wine growers have found ways to successfully produce wine when adapting to differing and non-optimal conditions all around the world (Conde et al., 2007).

Terroir can influence the sensory properties of grapes and their respective wines. Witbooi and Carey (2010) compared differences among the same Sauvignon blanc wine grapes grown in different locations of South Africa. South African terroir is characterized by a Mediterranean climate, slopes and hills, mountains, and the ocean nearby. Grape-growers picked the grapes from five different vineyards across South Africa, all at the same maturity. Researchers then proceeded to perform a descriptive analysis of said grapes (Witbooi & Carey, 2010). Differences of tropical notes, acidity, and berry juiciness were observed among the five vineyards (Witbooi & Carey, 2010).

In another study, Douglas, Cliff, and Reynolds (2001) looked at the uniqueness and magnitude of the terroir differences among 14 different Riesling wines from grape growers and wine makers who used grapes from the three distinct viticulture areas (‘bench’, ‘plains’, and ‘lake’) in Ontario, Canada. They performed descriptive analysis to show these differences. Wines from the ‘bench’ area had higher tropical fruit aromas, higher acidity, and higher lemon and lime flavor that the ‘plains’ wines. Additionally, ‘plains’ wines had the most diesel and petrol characteristics (Douglas, Cliff, & Reynolds, 2001).

1.1.1 Wine grape maturity

Harvesting wine grapes at the ideal level of maturity is an important part of successfully creating high-quality wines (Kader, 1999). In general, the complexity of aroma and flavor increases as ripening increases (Watson, 2003). Miranda-Lopez (1992) compared odor profiles of Pinot noir wines from grapes that were harvested at different maturities by using a gas chromatography-olfactometry technique (Osme). She found that the number of aroma-intense compounds were twice as high in Pinot Noir wines from grapes that were harvested one to two weeks later than the same grapes harvested in the earlier stages (Miranda-lopez, 1992). Wines made from grapes harvested at the later dates had a more floral and fruity aroma character, and more than half of those aroma compounds were not found in the wines produced from grapes harvested in the earlier stages (Miranda-lopez, 1992).

In another study, Holt, Birchmore, Herderich, and Iland (2010) looked at the effect of maturity on berry weight (specifically its importance for flavor), anthocyanin content, and phenolic composition among Cabernet Sauvignon wines. The researchers looked at late stage berry harvest of the wine grapes. They evaluated berry weight and composition at three different maturity stages (early, middle, and late) and three vintages (Holt et al., 2010). This produced a wide variety of berry sizes and phenolic compositions. Principal components analysis indicated strong vintage effects on berry composition (Holt et al., 2010). Also, in all vintages, both early stage and middle stage had higher berry weights than late stage (Holt et al., 2010). For all three vintages, there were no differences in anthocyanin concentration across the three maturity stages (Holt et al., 2010). The phenolic content was lowest in the most mature grapes (late stage) (Holt et al., 2010). Thus, more mature wine grapes may lead to less astringent wines.

1.1.2 Location

The most successful vineyards start with selecting a suitable vineyard site. It is the most important decision to be made by the grape growers (Kurtural, 2007). This decision affects yield and profits from twenty to forty years to come. Winegrowers have found that some areas of vineyards deliver better grapes, and thus, better wines than others (Van Leeuwen & Seguin, 2006).

To show the importance of vineyard location, King et al (2014) sought to compare Malbec wine sensory attributes from various regions in Mendoza, Argentina and from California. Sixteen wines from regions in Argentina and fifteen wines from regions of California were used in the study, all using the same Malbec grape variety (King et al., 2014). Sensory profiles of the wines were developed using descriptive analysis approximately three months after bottling (King et al., 2014). Malbec wines from Mendoza generally had more sweetness, ripe fruit, and higher alcohol levels, while the

Californian Malbec wines had more artificial fruit aroma, citrus aroma, and bitter taste (King et al., 2014).

1.1.3 Climate

Climate also influences the sensory properties of wine. To show this, De la Presa-Owens and Noble (1995) had an objective to study three distinct climate differences in Penedes, Spain and to determine how those differences affect sensory characteristics of the resulting wines. Three wineries from each of the three distinct climate areas of Penedes provided wines for this study. Each of the three wineries grew the same three Spanish white wine varieties as the others. Descriptive analysis of the white wine varieties was performed (De la Presa-Owens & Noble, 1995). The lower region of Penedes, Spain was characterized with higher nutty and shoe polish attributes. The central region was characterized by higher tropical, black pepper, and floral notes. The high region was characterized by citrus fruit notes. Additionally, the wines could be correctly classified into the different climate regions.

1.2 Winemaking techniques that influence wine characteristics

The aromatic and flavor properties of wines are qualities that make wine the most enjoyable. Both growers and winemakers are aware that any deficiencies in the quality of the wine grapes will affect not only these wine aroma and flavor qualities, but also profitability (Wine Institute, 2012). Therefore, in addition to terroir considerations, there are certain winemaking techniques that winemakers follow to influence positive wine characteristics.

1.2.1 Primary fermentation

Yeast choice in wine-making is an important decision that drives primary fermentation (Wine Institute, 2012). Yeast strains help to minimize wine faults such as hydrogen sulfide or volatile acidity production, boost a target flavor profile, or create a distinct wine flavor profile that may be considered more intricate (Jolly, Augustyn, & Pretorius, 2006). There are many different yeast strains available to wine-makers that create entirely different sensory characteristics of wines (Cook, n.d.). The growth of each yeast species is characterized by a specific metabolic activity, which in turn determines the concentration of flavor compounds in the resulting wine (Romano, Fiore, Paraggio, Caruso, & Capece, 2003).

To improve the regional flavor of Cabernet Sauvignon wines in the bottom of Helan Mountains in China, eight strains of Saccharomyces cerevisiae were evaluated analytically and by sensory analysis (Liu et al., 2016). The wines presented significant differences in the concentration of certain acetates, esters, and alcohol (Liu et al., 2016). The wine made with yeast N11424, for example, had honey, pepper, and fruit flavors (Liu et al., 2016). Wines made with yeast N8422 had more red currant attributes and wines made with yeast N1134 had more smoky and green attributes (Liu et al., 2016). The different wine attributes that were caused by different yeast showed that the choice of yeast is important in producing certain wine characteristics (Liu et al., 2016).

1.2.2 Secondary fermentation

Secondary fermentation, or malolactic fermentation, is a process following alcoholic fermentation that does not involve yeast. Instead, this process involves the transformation of wine by strains of bacteria of the genus *Lactobacillus*, *Leuconostoc*, *and Pediococcus* (Wine Institute, 2012). These lactic acid bacteria influence wine aroma and flavor by producing volatile metabolites and modifying aroma and flavor compounds derived from grapes and yeast (Knoll et al., 2012). Seven authors studied the impact of different malolactic fermentation inoculation scenarios on cool climate Riesling wines with two different *Oenococcus oeni* strains (Knoll et al., 2012). They chose four different timings for inoculation of the Riesling wines (Knoll et al., 2012). Compared to sequential inoculation, co-inoculation produced higher concentrations of ethyl esters and acetate esters (Knoll et al., 2012).

1.2.3 Alcohol and sugar concentration

The quality of wine, and its sensory attributes, depends on several compounds from the grapes (Wine Institute, 2012). One of those compounds is sugar and, consequently, the amount of alcohol in wines after alcoholic fermentation.

The sugar used as food for the yeast is developed in the grape vine and stored in the grape. The development of grape sugar is different for each grape varietal. For instance, *V. vinifera* sugar content can reach 20% or more at maturity while other species such as *V. labrusca* almost never reach 20% (Calwineries, 2017). The specific sugar content of the grape leads to varying alcohol levels. Elevated alcohol levels were shown to increase the perceived warmth or hotness of wine (The Australian Wine

Research Institute, 2016). Additionally, ethanol increases the perception of bitterness in both red and white wines (The Australian Wine Research Institute, 2016). In a recent study, ethanol did not cause significant changes in the intensity of white wine aroma when the ethanol concentration varied within 11.6 % v/v and 13.6 % v/v (The Australian Wine Research Institute, 2016). However, elevated ethanol levels increased the hotness, bitterness, drying, roughness, and metallic sensations (The Australian Wine Research Institute, 2016).

1.3 Cold-hardy wine grapes and wine

V. riperia has become a popular breeding rootstock due to its resistance against many grapevine pathogens and its ability to withstand colder climate conditions (Terral et al., 2010). Although knowledge of cold-hardiness has been studied and advanced in the past few years, cold-hardiness is still immensely complex so detecting consistent genetic differences remains a daunting task (Luby, 1991). Grape breeding in Minnesota is built upon the key role of the germplasm of the species *V. riparia*. Settlers figured out that the other types of cultivars that were being used for grape breeding were often injured in the winter. Thus, in response to that knowledge, *V. riparia* was originally crossed with “Concord”, which was the beginning of successful cold-hardy grape breeding for years to come (Luby, 1991).

1.3.1 <u>Cold-hardy wine grape production</u>

In 2013, of the 157,470 total planted cold-climate white grape vines in 13 states of the Northern region of the United States that were surveyed, 28,909 were

Frontenac gris and 21,014 were Brianna vines (Tuck, 2013). In addition, there were around 456 planted acres of Frontenac gris and 331.5 acres of Brianna among all of the states. From that, vines and acreage has only grown.

Crosses between *V. riparia* and French hybrids or *V. vinifera* by the University of Minnesota researchers have resulted in cold-hardiness and disease resistance (Hemstad & Luby, 2000). In 1996, vineyard temperatures reached -38°C. Bud survival of these species versus others known for their cold-hardiness were compared. The new species crosses showed greater survival, with one such cross being that between a French hybrid and *V. riperia* (the Frontenac gris grape) (Hemstad & Luby, 2000).

1.3.2 <u>Sensory attributes of cold-hardy wine grape production</u>

With the emergence of cold-hardy wines, researchers at the University of Agriculture in Krakow, Poland wanted to study how the sensory properties of said wines compared to those of traditional *vinifera* wines (Tarko, Duda-Chodak, Satora, Sroka, & Gojniczek, 2014). They studied 11 varieties of cold-hardy wines from one vineyard in Poland and assessed their sensory properties using the point method, where panelists assessed each of the sensory descriptors (taste, aroma, color, and clarity) on a 5-point liking scale (Tarko et al., 2014). The researchers found that the ethanol content, residual sugar, and acidity parameters of the cold-hardy wines were within the Regulation of European Commission limits and were rated highly by the sensory panel (receiving approximately 4 points on the 5-point liking scale) (Tarko et al., 2014). They showed that cold-hardy wines could be comparable in liking with wines from traditional wine-making countries (Tarko et al., 2014).

Since the arrival of cold-hardy grape varieties, there has been interest in evaluating their flavor development. In Canada, researchers studied how the ripening of Frontenac and Marquette wine grapes in two vineyards affected aroma and flavor compound development (Pedneault, Dorais, & Angers, 2013). They used chemical methods to measure specific compounds within the grapes (Pedneault et al., 2013). They found that quality attributes and aroma compounds showed that both hydroxycinnamic esters (responsible for the "fruity" smells in wines (Moss, 2015)) and flavonoids (responsible for color and astringency in wine (Oberholster, 2003)) increased during ripening, reached their maximum levels at 1333 GDD (growing degree day), and declined until harvest (Pedneault et al., 2013). In both Frontenac and Marquette, aromatic maturity was assessed using the ratio of cis-3-hexenol to trans-2-hexenal, which showed a constant decrease until maturity (Pedneault et al., 2013). The longer harvest time of grapes after veraison (characterized by berry softening and the beginning of berry color change) in the southwest vineyard resulted in more flavor development of the grapes, as compared to grapes from the other vineyards (Pedneault et al., 2013). During ripening, more C_6 compounds (fatty acid degradation products) and monoterpenes led to more developed aroma profiles of both wines (Pedneault et al., 2013). C_6 compounds produce a green, grassy, earthy, and mushroom signature (Lloyd, n.d.) while monoterpenes add fruit-like characteristics (Mateo & Jiménez, 2000).

1.3.3 Sensory problems with cold-hardy wine grape production

While there are many high quality wines that have been made in cold climates with cold-hardy grapes, there are also some sensory problems that occur with cold-hardy wine production that cause problems for wine-makers. Overall, extreme low temperatures have led to a short production season, which in turn, led to high acid wines (Zabadal et al., 2007). The typical acidity measurement in wine is titratable acidity (TA), which is often compared with the sensory perception of a wine's acidity (Leonardelli, 2013). During the berry's progression to veraison, acid accumulates within the berry. Once it reaches veraison, the acidity then decreases. Having to harvest wine grapes earlier due to cold weather leads to less time for the acidity to decrease after veraison and, thus, a higher final acidity (Leonardelli, 2013).

Researchers studied the sensory acceptability of acidic wines by looking at the effect of varying titratable acidity concentrations and pH on the sensory attributes of Sauvignon blanc and Riesling wines (Nagel, Amistoso, & Bendel, 1982). Quantitative descriptive analysis was used to determine the influence of pH on fruitiness, body, acidity, and aftertaste (Nagel et al., 1982). Generally, they found that a titratable acidity of 0.9% or greater or a pH of greater than 3.4 received poor acceptability ratings (Nagel et al., 1982). The Riesling with a pH of 3.0 was found to be significantly more acidic and have more aftertaste than the same wine at a pH of 3.6 (Nagel et al., 1982). A Sauvignon blanc with a pH of 3.6 was found to have more body than the other wines of differing pH values, whereas the Sauvignon blanc with a pH of 3.0 was fruitier than the other wines of differing pH values (Nagel et al., 1982).

Another common sensory problem with cold-hardy wines is high sugar content (Mansfield, n.d.). Sugar is often added to cold-hardy wines in order to balance out the high acidity (Blackman, Saliba, & Schmidtke, 2010). Blackman, Saliba, and Schmidtke (2010) studied consumer preference of two Hunter Valley Semillion wines with varying amounts of glucose among a panel of novice consumers, experienced consumers, and winemakers. Wine A had a pH of 3.4, titratable acidity of 7.7 g/L, and residual sugar of 3.3 g/L, while wine B had a pH of 3.2 titratable acidity of 6.8 g/L, and residual sugar of 8.2 g/L (Blackman, Saliba, & Schmidtke, 2010). Paired comparison tests were conducted where panelists were asked to compare the base wine with each of the wines with varying levels of added sugar (2.0, 4.0, 8.0, 16.0, and 32.0 g/L glucose) and to indicate their preference (Blackman et al., 2010). The maximum level of glucose that could be added and still preferred by the novice group in comparison to the base wine was found to be 16.0 g/L glucose for wine A and 4.0 g/L glucose for wine B (Blackman et al., 2010). Experienced consumers preferred wine A with up to an additional 13.5 g/L glucose, and wine B sweetened with an additional 2.0-4.0 g/L glucose (Blackman et al., 2010). Finally, fewer of the experienced group preferred the wines sweetened with the 16.0 and 32.0 g/L glucose additions than the novice group (Blackman et al., 2010). Overall, experienced consumers and winemakers preferred the wines with less sugar added (Blackman et al., 2010).

1.4 Sensory evaluation of cold-hardy wine grapes and wines

In order for grape growers and wine makers to make decisions about when to harvest grapes, a technique called Berry Sensory Assessment (BSA) has been used for the past 18 years (O. Mantilla et al., 2010). Berry Sensory Assessment is any form of aroma, taste, or flavor evaluation of wine grape berries (S. M. O. Mantilla, 2013). One of the most common BSA techniques is descriptive analysis (O. Mantilla et al., 2010). Descriptive analysis uses panels of individuals who are instructed to rate and evaluate the intensity of specific sensory characteristics within and between products (O. Mantilla et al., 2010).

1.4.1 <u>Cold-hardy wine grape descriptive analysis</u>

Cold-hardy wines are a recent introduction and, thus, only a few descriptive analyses have been performed including the analyses of Frontenac, Marquette, and La Crescent wines (Del Bel, 2014) (Mansfield & Vickers, 2009) (Savits, 2014). The first structured evaluation of common sensory characteristics of Frontenac was performed in 2006 (Mansfield & Vickers, 2009). The objective of the study was to determine whether the typically described characteristics of Frontenac (cherry, black current, plum, and spice) were perceived in a majority of Frontenac wines (Mansfield & Vickers, 2009). Wines were sourced from different wineries throughout Minnesota (Mansfield & Vickers, 2009). A descriptive analysis was performed and thirteen descriptors were found to be typical of Frontenac wines (including, but not limited to, black currant, cooked vegetable, cherry, and earthy) (Mansfield & Vickers, 2009).

Del Bel (2014) sought to create a list of descriptors to describe the aroma, flavor, and astringency attributes of Marquette and Frontenac wine grapes and to explore the changes to these sensory attributes that occur during the ripening process and the resulting changes in their respective wines. Through descriptive analysis, she found that sweetness increased with later harvest dates and sourness decreased with later harvest dates (Del Bel, 2014), Attributes such as floral, fresh green, geranium, woody, hay, dried mushroom, cooked berry, and spice aroma and flavor attributes were found in Frontenac wines (Del Bel, 2014). Characteristics such as cooked vegetable, black currant aroma, black currant flavor, ethanol, and cheese attributes were found in Marquette wines (Del Bel, 2014).

Savits (2014) sought to describe the distinct aroma characteristics specific to La Crescent wines over two different vintages. To do this, descriptive analysis was performed (Savits, 2014). Juice was provided by an Iowa winery. Descriptive analysis of the wines was conducted using a Moscato wine as a comparison (Savits, 2014). Six aroma descriptors (grapefruit and pineapple being the most intense) were identified in year one and seven aroma descriptors (rose and lychee being the most intense) were identified in year two (Savits, 2014). Principal components analysis showed that wines were separated by acidity and sweetness on the first principle component (Savits, 2014). Over both vintages, the most important descriptors for La Crescent wines were found to be grapefruit, pineapple, rose, and lychee (Savits, 2014).

Chapter 2: Objectives and Hypotheses

Objective A: To describe the aroma and flavor attributes of Frontenac gris and Brianna wine grapes and wine and to determine how the ripening process affects changes in sensory attributes of the grapes and their respective wines.

Hypothesis A: As Frontenac gris and Brianna grapes mature on the vine, the following will occur in both the grapes and the wines:

- Sweetness will increase
- Sourness will decrease
- Astringency will decrease
- Fruity and floral aroma and flavor attributes will increase

Objective B: To develop a set of descriptors that more broadly define aromas and flavors that define Frontenac gris wines.

Chapter 3: Methods

3.1 Methods – Part 1: To determine how the ripening process affects changes in sensory attributes of the grapes and their respective wines.

3.1.1 Participants

Participants of this study were members of the trained panel from the Sensory Center at the University of Minnesota. They were screened for their ability to discriminate samples well and to thoroughly describe attributes (Appendix A-F). All were 6-*n*-propylthiouracil (PROP) tasters or supertasters, meaning that they experience more bitterness sensations than non-PROP tasters do. Panelists had previous training on citric acid taste and butanol aroma scales. Twelve members (67% female) participated in the Brianna and Frontenac gris grape harvest date testing. Eleven members (64% female) participated in the Frontenac gris wine descriptive analysis tests. Ten members (60% female) participated in the Brianna wine descriptive analysis tests. The University of Minnesota's Institutional Review Board approved all recruiting and experimental procedures (Appendix G). Participants were compensated $10 for each training session and $15 for each testing session.

3.1.2 Products:

Grapes

Grape and wine samples consisted of two varieties: Frontenac gris and Brianna. Grapes were grown at Tucker's Walk vineyard in Garretson, South Dakota. Frontenac gris grapes were harvested on the following dates: 9/24/15, 10/1/15 and 10/9/15. Brianna grapes were harvested on the following dates: 9/4/15, 9/11/15, 9/18/15 and 9/24/15. Both varieties were picked and immediately crushed. Two fermentations (batches of wine) were made for each time point. The batches differed in that they were made from grapes grown in different locations of the vineyard. One bottle of wine from each batch was used for training, and two were used for testing (as replicates).

Grapes were stored around -10°C for the duration of the study. Before training and/or testing, grapes were removed from the freezer and placed into 60 mL translucent sample cups (ProPak, Hunt Valley, Maryland), blinded with random three-digit codes. Four grapes were placed into each cup and each cup was then topped with a lid. The cups were then placed into the refrigerator for about 2 hours and taken out about one hour before the training and/or testing began each day. At this time they were pulled out of the refrigerator and placed on tables in order to equilibrate to room temperature.

Wine

Panelists received 30 mL of each wine in clear wine tasting glasses with dimensions of height 155 mm and volume capacity 215 mL (Libbey, Toledo, Ohio). Each wine glass was topped loosely with a 60 mL soufflé cup lid (ProPak, Hunt Valley, Maryland) and blinded with a random three-digit code.

Frontenac gris (

Table 1) and Brianna (Table 2) wine samples used for training sessions were donated by or purchased at local wineries.

Table 1. Wineries whose Frontenac gris wine was used in the training of panelists year one.

Winery	Location	Vintage
Crofut Family Winery	Jordan, MN	2011
Crow River Winery	Hutchinson, MN	2015
Two Rivers Vineyard and Winery	Ramsey, MN	2015
St. Croix Vineyards	Stillwater, MN	2014

Table 2. Wineries whose Brianna wine was used in the training of panelists year one.

Winery	Location	Vintage
Fireside Winery	Marengo, IA	2015
Calico Skies Vineyard and Winery	Inwood, IA	2014
Parley Lake Winery	Waconia, MN	2015
Coyote Moon Vineyards	Clayton, NY	2015

3.1.3 Training:

Grapes

On the first day of grape training, panelists were trained on how to taste wine grapes using a standardized tasting procedure (Del Bel, 2014). Panelists practiced standardized techniques for tasting the grapes (pulp and skin). They evaluated them in the following manner: (1) opened the lid of sample, (2) evaluated the aroma, (3) put on a nose clip, (4) placed one grape berry in mouth, (5) separated the skin using fingers/mouth, (6) removed skin and put back in sample cup. For step seven, panelists rated basic tastes (sweetness, sourness, bitterness), they then removed their nose clip and evaluated flavor. Finally, in step 8, they spit out the pulp and rated the aftertaste. They then repeated steps 7 and 8 with the skin.

After they had learned the tasting protocol, panelists were asked to taste the samples provided, talk out loud with each other, and generate aroma and flavor vocabulary. Both Frontenac gris and Brianna grape samples were provided blindly at each training session in order to find differences between the two grape varieties. Additionally, grapes provided spanned the range of harvest dates in order to illustrate as many different aromas, flavors, and taste intensities as possible. During the second training session, panelists reviewed the new aroma and flavor lexicon and references. They were asked to again try grapes using the standardized tasting procedure and were again instructed to talk out loud with each other about which aromas and flavors they perceived, and at what intensity. Then, they referred to the lexicon generated at the previous training session and decided if they needed to change/add/delete descriptors. Subsequent training sessions consisted of making tweaks to the lexicon. After the panelists decided that the Lexicon was set, they took a practice test using SIMS2000™ (Sensory Computer Systems, Berkeley Heights, NJ) computer data collection software. The performance of panelists was monitored using PanelCheck software. If panelists did not seem to agree in their ratings of a few attributes, then another training session occurred in order to practice those specific attribute ratings, review references, and discuss the meaning of the words. Following this, a second practice test occurred.

Wine

Wine training followed a similar procedure. On the first day of wine training, panelists learned the standardized wine tasting protocol by practicing tasting wine samples. They were first instructed to remove the plastic lid that was placed loosely on the wine and to smell the wine in order to rate aromas. Next, they were asked to place a nose clip on their nose and take a sip of the wine in order to rate taste. Finally, panelists removed the nose clip, took a sip of wine, and rated the flavors of the wine. Based on this method of tasting, panelists tried different samples of wine and generated an aroma and flavor lexicon. On the second wine training session, the panelists practiced the standardized wine tasting protocol. Then, they tasted more samples of wine and discussed with each other about which aromas and flavors they perceived, and at which intensity. They then referred to the generated lexicon and decided which descriptors should be changed, added, or deleted. Subsequent training sessions consisted of making final tweaks to the lexicon. After the panelists decided that the lexicon was set, they took a practice test using SIMS2000 software. The performance of panelists was monitored using PanelCheck software. If panelists did not seem to match in their ratings of a few attributes, then another training session occurred in order to practice those specific attribute ratings. Following this, a second practice test occurred.

The panelists went through the training sessions described with Frontenac gris wine first. At each session, they evaluated anywhere from two to four samples of

Frontenac gris wine from different wineries. Once they completed practice tests and final tests, they then moved on to evaluating Brianna wine. During the training sessions, two to three samples of Brianna wine from different wineries were evaluated at each session.

3.1.4 Experimental Procedure:

Panelists participated in a total of eight testing sessions. Four sessions were for grape testing (two sessions for Frontenac gris and then two sessions for Brianna) and four sessions were for wine testing (two sessions for Frontenac gris and then two sessions for Brianna). Only one grape variety or one wine variety was evaluated at any single grape or wine testing session. Replicates occurred at the second session of Frontenac gris grape, Brianna grape, Frontenac wine and Brianna wine tests.
Panelists were provided a subset of butanol aroma and citric acid flavor scale points as references (intensities 3, 5, 7 and 10). Before each testing session began, panelists would self-calibrate their aroma and flavor intensity scales by testing a blinded butanol and citric acid scale point. They would rate what intensity they believed the samples were at and then were immediately given feedback as to the actual intensity (Appendix P).

Samples were served to participants balanced for order and carryover effects. Panelists were instructed to evaluate each sample following the tasting protocol that they had learned and practiced during training. Attributes were those generated by the panel in the training session. References were provided based on the list of Lexicon attributes created (Appendices L-N). Panelists were asked to rate the intensity of the attributes on 12 cm line scales with 20 markings. Markings began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense” (Appendix Q). All ratings were collected using the SIMS2000 software.

3.1.5 Data Analysis:

Analyses of variance (ANOVA) (SAS® PROC GLM) with Student-Neuman-Keuls (SNK) multiple comparisons tests were used to determine whether specific attributes of the grapes and wines differed among the harvest dates and which harvest dates differed significantly ($p < 0.1$) from which others. The specific attribute intensities were the dependent variables. The predictors were panelist, harvest date, batch (nested within harvest date) and sensory replicate (Appendix R).

```
Proc glm data = xxx.frontgris4dates outstat=fgwinestats4;
class Judge harvest Rep bottle;
model

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A
Mushroom_A … Bitterness_AT

=Judge harvest Rep  / solution;
            means harvest/snk alpha=0.1;
```

3.2 Methods – Part 2: To develop a set of aroma and flavor descriptors that define Frontenac gris.

3.2.1 Participants:

Participants of this study were ten members of the trained panel from the Sensory Center at the University of Minnesota, with a breakdown of 70% females and 30% males. All participants were screened for their ability to discriminate samples well and thoroughly describe attributes (Appendix A-F). All were PROP tasters or supertasters. Panelists had previous training on citric acid taste and butanol aroma scales. The University of Minnesota's Institutional Review Board approved all recruiting and experimental procedures (Appendix G). Participants were compensated $10 for each training session and $15 for each testing session.

3.2.2 Products:

Nineteen different Frontenac gris wines were obtained from local wineries and used in this study (Table 3). Three bottles of each wine were purchased. One bottle of each wine was used for training and the other two were used for two testing sessions. Wines were selected in order to differ in the following categories: vineyard location, vineyard condition, vintage, method of picking, and choice of yeast.

Panelists received 30 mL of each wine in clear wine tasting glasses with dimensions of height 155 mm and volume capacity 215 mL (Libbey, Toledo, Ohio). Each wine glass was topped loosely with a 60 mL soufflé cup lid (ProPak, Hunt Valley, Maryland) and blinded with random three-digit codes.

Table 3. Frontenac gris wine information year two (full version found in Appendix U). All information was provided by the winery or found on the wine label.

Winery	Winery Location	Vintage	Sweetness	Residual Sugar (%)	Alcohol (%)
Winehaven Winery	Chisago City, MN	2013	off-dry	0.75 or less	12.1-14
Saint Croix Vineyards	Stillwater, MN	2015	semi-sweet	0.76-1.5	10.1-12
Carlos Creek Winery	Alexandria, MN	2015	semi-sweet	2.6-6.0	10.1-12
Crow River Winery	Hutchinson, MN	2015	dry	0.75 or less	12.1-14
Sovereign Estate	Waconia, MN	2015	dry	0.75 or less	10.1-12
Burr Vineyards	Brandon, MN	2015	dry	0.75 or less	14.1-16
Fireside Winery	Marengo, IA	2015	semi-sweet	2.6-6.0	10.1-12
Vines & Rushes Winery	Ripon, WI	2015	semi-sweet	2.6-6.0	12.1-14
Soldier Creek Winery	Fort Dodge, IA	2013	semi-sweet	1.6-2.5	12.1-14
Soldier Creek Winery	Fort Dodge, IA	2014	semi-sweet	2.6-6.0	10.1-12
Tucker's Walk Vineyard and Farm Winery	Garretson, SD	2014	semi-sweet	1.6-2.5	12.1-14
Tucker's Walk Vineyard and Farm Winery	Garretson, SD	2015	semi-sweet	1.6-2.5	12.1-14
Coyote Moon Vineyards	Clayton, NY	2014	dry	0.76-1.5	12.1-14
Grape Mill Vineyard & Winery	East Grand Forks, MN	2015	semi-sweet	1.6-2.5	12.1-14
Richwood Winery	Richwood, MN	2012	semi-sweet	1.6-2.5	12.1-14
Santa Maria Winery	Carroll, IA	2016	semi-sweet	2.6-6.0	10.1-12
Parley Lake Winery	Waconia, MN	2015	N/A*	N/A*	N/A*
Indian Island Winery	Janesville, MN	N/A	semi-sweet	N/A*	N/A*
Round Lake Vineyards and Winery	Round Lake, MN	2015	N/A*	N/A*	N/A*

* The winery did not provide this information

3.2.3 Training:

On the first day of wine training, panelists learned the standardized wine tasting protocol and practiced tasting wine. They were instructed to first remove the plastic lid that was placed loosely on the wine and to smell the wine in order to rate aromas. Next, they were asked to place a nose clip on their nose and take a sip of the wine in order to rate taste. Finally, panelists removed the nose clip, took a sip of wine, and rated the flavors of the wine. Based on this method of tasting, panelists tried different samples of wine and generated an aroma and flavor lexicon. On the second wine training session, the panelists practiced the standardized wine tasting protocol. Then, they tasted more samples of wine and discussed with each other about which aromas and flavors they perceived, and at which intensity. They then referred to the generated lexicon and decided which descriptors should be changed, added, or deleted. Subsequent training sessions consisted of making final tweaks to the lexicon. After the panelists decided that the lexicon was set, they took a practice test using SIMS2000™ software. The performance of panelists was monitored using PanelCheck software.

3.2.4 Experimental Procedure:

Panelists participated in a total of four testing sessions. The third and fourth testing sessions were replicates of the first and second sessions. Panelists were provided a subset of butanol aroma and citric acid flavor scale points for calibration (intensities 3, 5, 7 and 10). Before each testing session began, panelists self-calibrated their aroma and flavor intensity scales by testing blinded butanol and citric acid samples representing scale points. They rated what intensity they believed said samples were at and then were immediately given feedback as to the actual intensity (Appendix P).

Wine samples were served to participants balanced for order and carryover effects. Panelists were instructed to evaluate each sample following the tasting protocol that they had learned and practiced during training. Attributes were those generated by the panel in the training session. References were provided based on the list of lexicon attributes created (Appendix O). Panelists were asked to rate the intensity of the attributes on 12 cm line scales with 20 markings. Markings begin at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense” (Appendix Q). All ratings were collected using the SIMS2000 software.

3.2.5 Data analysis:

To determine which attributes were considered to define Frontenac gris wines, we selected attributes that had mean intensities of one or above in greater than 75% of the wines.

Analyses of variance (ANOVA) (SAS PROC GLM) with Student-Neuman-Keuls (SNK) multiple comparisons tests were used to determine whether specific attributes of the wines differed among the 19 wines and, if so, which wines differed significantly ($p < 0.1$) from which others. The specific attribute intensities were the dependent variables. The predictors were panelist, wine sample, sensory replicate, and taste position (Appendix S).

For subsequent analyses, we eliminated any variables that did not differ significantly among the 19 wines. In order to do this, we used analyses of variance (SAS PROC GLM), with attribute intensities as the dependent variables. Attributes with a p-value greater than 0.05 were eliminated because those attributes were not significantly different between wines.

Multiway parallel factor analysis (parafac) (Harshman, 1970), an extension of PCA for a data tensor, was used to identify important features of the data. It decomposed a multi-dimensional array in order to focus on the aroma, flavor, and taste features that were of interest and it provided illustrations showing the variation among wines (Appendix T). The three dimensional array consisted of wineries, attributes, and judges. The attributes in the array were centered across wineries and judges and then analyzed using the multiway package in R (Helwig, 2017).

Chapter 4: Results

4.1 Results – Part 1: To determine how the ripening process affects changes in sensory attributes of the grapes and their respective wines.

4.1.1 Brianna grapes

The following attributes increased in intensity with progressively later harvest dates: fermented fruit aroma, artificial grape aroma, pulp sweetness, pulp fermented fruit flavor, and pulp sweetness aftertaste; pulp sourness, pulp bitterness, pulp citrus flavor, pulp green apple flavor, pulp sourness aftertaste, pulp bitterness aftertaste, skin sourness, and skin sourness aftertaste decreased in intensity (Table 4 and Figure 1).

Table 4. Mean (n = 12) attribute ratings of Brianna grapes over different harvest dates. Scale markings began at "0" on the left end of the line labeled "none" and ended at "20" on the right end of the line labeled "intense". F and p-values corresponded to the predictor "harvest date". Grey shaded rows show attributes that differed significantly ($p < 0.1$) among harvest dates.

Attributes	Harvest Dates (2015)				F	P
	9/4	9/11	9/18	9/24		
Overall intensity of aroma	4.7	4.8	4.3	5.3	2.1	0.11
Fresh fruit aroma	1.6	1.7	1.5	2.1	1.8	0.15
Dried fruit aroma	1.3	1.4	1.2	1.5	0.6	0.59
Citrus fruit aroma	0.5^{ab}	0.5^{ab}	0.4^{b}	0.7^{a}	3.4	0.02
Jammy aroma	1.0	0.9	1.0	1.0	0.2	0.89
Fermented fruit aroma	1.5^{b}	1.8^{ab}	1.5^{b}	2.1^{a}	2.8	0.05
Fresh green aroma	0.9	1.2	1.1	1.4	2.4	0.08
Green wood aroma	1.4	1.9	1.6	1.7	0.8	0.47
Earthy aroma	0.6	0.6	0.8	0.8	1.4	0.24
Hay aroma	1.1	1.1	1.2	1.2	0.1	0.96
Floral aroma	0.4	0.7	0.8	0.9	2.1	0.11
Metallic aroma	0.3	0.2	0.2	0.3	0.9	0.44
Green apple aroma	0.7	1.4	1.0	0.9	2.1	0.11
Dried grape aroma	0.8	0.8	1.0	0.8	0.8	0.49
Artificial grape aroma	0.7^{b}	0.6^{b}	0.6^{b}	1.0^{a}	3.2	0.03
Other aroma	0.2	0.0	0.2	0.2	0.6	0.61
Pulp sweetness	2.3^{c}	3.3^{b}	3.6^{b}	4.2^{a}	13.4	< 0.001
Pulp sourness	3.8^{a}	2.2^{b}	2.0^{b}	1.3^{c}	16.0	< 0.001
Pulp bitterness	0.9^{a}	0.5^{b}	0.4^{b}	0.5^{b}	3.4	0.02
Pulp overall intensity of flavor	5.1	5.3	5.1	5.1	0.3	0.83
Pulp fresh fruit flavor	2.2	2.1	2.5	2.4	0.9	0.43
Pulp dried fruit flavor	1.1	1.4	1.3	1.4	0.7	0.53
Pulp citrus flavor	1.7^{a}	1.2^{a}	1.4^{a}	0.7^{b}	4.8	< 0.001
Pulp jammy flavor	1.2	1.4	1.5	1.8	2.0	0.12
Pulp fermented fruit flavor	1.6^{b}	2.1^{a}	2.1^{a}	2.3^{a}	3.5	0.02
Pulp fresh green flavor	1.2	1.3	1.1	1.1	0.6	0.60
Pulp green wood flavor	1.4	1.5	1.4	1.5	0.1	0.96
Pulp earthy flavor	0.6	0.6	0.6	0.7	0.4	0.76
Pulp hay flavor	1.1	0.9	0.8	1.0	0.8	0.49
Pulp floral flavor	0.8	1.2	1.1	1.3	1.6	0.20
Pulp metallic flavor	0.4	0.3	0.3	0.3	0.6	0.61
Pulp green apple flavor	1.5^{a}	1.8^{a}	1.4^{a}	0.9^{b}	4.3	0.01
Pulp dried grape flavor	0.6	0.7	0.8	0.9	1.1	0.34
Pulp artificial grape flavor	1.0	1.3	1.4	1.7	1.6	0.20
Pulp other flavor	0.3	0.0	0.0	0.2	0.7	0.53
Pulp astringency	2.4	2.1	2.0	2.0	0.9	0.45
Pulp overall aftertaste	2.4	2.7	2.5	2.8	1.4	0.25
Pulp sweetness aftertaste	1.2^{b}	1.6^{a}	1.9^{a}	2.0^{a}	8.2	< 0.001
Pulp sourness aftertaste	1.8^{a}	1.5^{ab}	1.3^{b}	0.8^{c}	10.5	< 0.001

Attributes	Harvest Dates (2015)				F	P
	9/4	9/11	9/18	9/24		
Pulp bitterness aftertaste	0.6 [ab]	0.8 [a]	0.6 [ab]	0.5 [b]	2.8	0.05
Skin sweetness	1.8	2.1	1.9	2.4	2.6	0.06
Skin sourness	2.2 [a]	1.8 [ab]	1.7 [ab]	1.4 [b]	3.4	0.02
Skin bitterness	0.9	0.9	0.8	0.8	0.4	0.75
Skin overall intensity of flavor	3.6	3.3	3.5	3.6	1.0	0.39
Skin fresh fruit flavor	1.2	1.4	1.3	1.4	1.0	0.42
Skin dried fruit flavor	1.1	1.5	1.2	1.2	1.3	0.28
Skin citrus fruit flavor	1.3	0.9	0.9	0.7	2.5	0.07
Skin jammy flavor	0.6	0.8	0.8	1.0	1.6	0.20
Skin fermented fruit flavor	1.2	1.5	1.1	1.3	1.0	0.40
Skin fresh green flavor	1.2	1.1	1.4	1.1	1.1	0.35
Skin green wood flavor	1.6	1.6	1.8	1.5	0.7	0.55
Skin earthy flavor	0.7	0.7	0.8	0.7	0.2	0.89
Skin hay flavor	1.0	1.2	1.2	1.3	0.7	0.54
Skin floral flavor	0.4	0.6	0.6	0.8	2.1	0.11
Skin metallic flavor	0.5	0.5	0.5	0.4	0.7	0.53
Skin green apple flavor	1.0	0.8	0.9	0.8	0.5	0.65
Skin dried grape flavor	0.6	0.8	0.6	0.8	0.8	0.48
Skin artificial grape flavor	0.5	0.6	0.7	0.9	1.0	0.40
Skin other flavor	0.0	0.0	0.0	0.2	1.1	0.37
Skin astringency	2.4	2.1	2.4	2.1	1.0	0.41
Overall skin aftertaste	2.0	2.1	1.9	2.1	0.5	0.66
Skin sweetness aftertaste	0.8	1.0	1.0	1.3	2.6	0.06
Skin sourness aftertaste	1.5 [a]	1.4 [a]	1.2 [a]	0.8 [b]	4.7	< 0.001
Skin bitterness aftertaste	0.7	0.8	0.7	0.6	0.9	0.44

[abc] Mean ratings within a row having letter superscripts in common do not differ significantly (SNK test, $p > 0.05$).

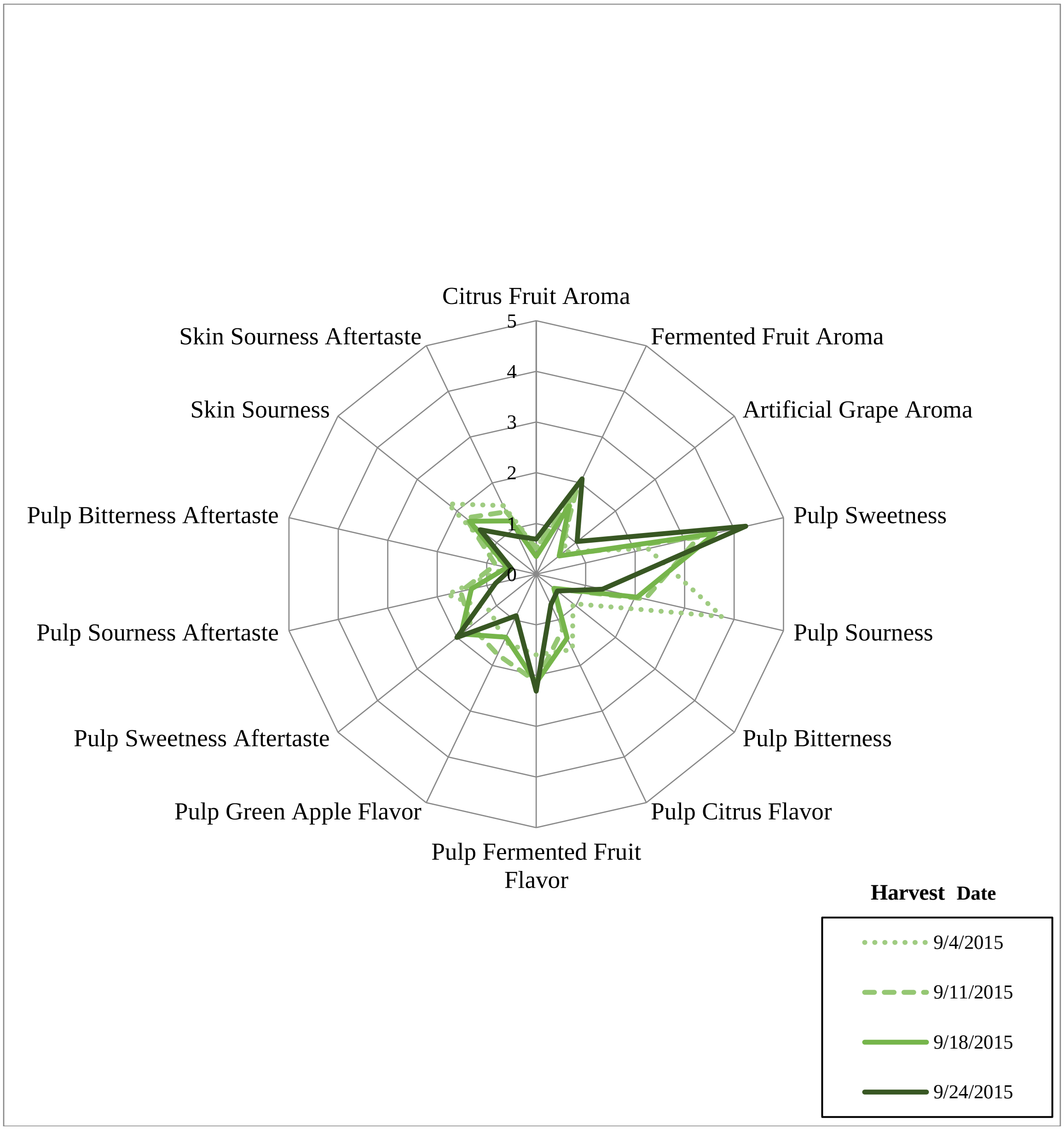

Figure 1. Mean (n = 12) attribute intensities of Brianna grapes that differed significantly among harvest dates. Scale markings began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense”.

4.1.2 Frontenac gris grapes

Skin dried grape flavor decreased with progressively later harvest dates (Table 5). None of the other attributes differed among the harvest dates (Table 5).

Table 5. Mean (n = 12) attribute ratings of Frontenac gris grapes over different harvest dates. Scale markings began at "0" on the left end of the line labeled "none" and ended at "20" on the right end of the line labeled "intense". F and p-values corresponded to the predictor "harvest date". Grey shaded rows show attributes that differed significantly ($p < 0.1$) among harvest dates.

Attributes	Harvest Dates (2015)			F	P
	9/24	10/1	10/9		
Overall intensity of aroma	4.8	4.8	4.9	0.1	0.94
Fresh fruit aroma	1.5	1.3	1.5	0.2	0.80
Dried fruit aroma	1.7	1.7	1.7	0.0	1.00
Citrus fruit aroma	0.3	0.3	0.3	0.1	0.88
Jammy aroma	1.1	1.0	0.9	0.6	0.55
Fermented fruit aroma	1.5	1.9	2.1	2.8	0.07
Fresh green aroma	1.3	1.2	1.2	0.3	0.74
Green wood aroma	1.8	2.0	2.2	1.9	0.16
Earthy aroma	0.8	0.8	1.1	2.1	0.14
Hay aroma	1.8	2.2	1.8	1.1	0.34
Floral aroma	0.4	0.3	0.4	0.3	0.77
Metallic aroma	0.4	0.3	0.4	0.6	0.57
Green apple aroma	0.5	0.5	0.5	0.1	0.86
Dried grape aroma	1.2	1.3	1.1	0.4	0.67
Artificial grape aroma	0.7	0.5	0.6	1.2	0.31
Other aroma	0.0	0.0	0.0	2.0	0.14
Pulp sweetness	3.3	3.3	3.1	0.3	0.76
Pulp sourness	3.7	4.3	3.5	1.6	0.22
Pulp bitterness	0.6	0.6	0.6	0.2	0.79
Pulp overall intensity of flavor	5.4	5.5	5.6	0.1	0.92
Pulp fresh fruit flavor	2.0	1.5	2.0	2.7	0.08
Pulp dried fruit flavor	1.5	1.4	1.7	2.2	0.12
Pulp citrus flavor	1.1	1.4	0.9	2.7	0.08
Pulp jammy flavor	1.6	1.7	1.9	1.0	0.38
Pulp fermented fruit flavor	2.1	2.5	2.7	2.7	0.08
Pulp fresh green flavor	0.8	0.9	0.9	0.5	0.61
Pulp green wood flavor	1.5	1.7	1.6	0.5	0.62
Pulp earthy flavor	0.7	0.6	0.6	0.3	0.72
Pulp hay flavor	1.3	1.4	1.4	0.1	0.92

Attributes	Harvest Dates (2015)			F	P
	9/24	10/1	10/9		
Pulp floral flavor	0.6	0.6	0.7	0.5	0.60
Pulp metallic flavor	0.4	0.4	0.3	1.8	0.18
Pulp green apple flavor	1.0	1.2	1.1	1.1	0.35
Pulp dried grape flavor	1.2	0.9	1.1	0.8	0.45
Pulp artificial grape flavor	1.3	1.4	1.2	0.8	0.45
Pulp other flavor	0.0	0.1	0.0	0.6	0.58
Pulp astringency	2.2	2.7	2.7	2.9	0.07
Pulp overall aftertaste	2.3	2.5	2.5	0.5	0.58
Pulp sweetness aftertaste	1.6	1.5	1.3	1.4	0.25
Pulp sourness aftertaste	1.8	2.0	1.8	0.4	0.65
Pulp bitterness aftertaste	0.4	0.4	0.5	0.3	0.77
Skin sweetness	1.7	1.7	1.8	0.1	0.88
Skin sourness	1.9	2.0	1.8	0.1	0.88
Skin bitterness	0.7	0.8	0.8	0.3	0.77
Skin overall intensity of flavor	2.9	3.2	3.3	1.5	0.24
Skin fresh fruit flavor	1.0	1.1	1.1	0.3	0.75
Skin dried fruit flavor	1.4	1.1	1.2	3.0	0.06
Skin citrus fruit flavor	0.6	0.6	0.6	0.0	0.97
Skin jammy flavor	0.8	0.9	0.8	0.4	0.68
Skin fermented fruit flavor	1.0	1.2	1.3	1.0	0.39
Skin fresh green flavor	1.0	0.9	0.8	0.6	0.55
Skin green wood flavor	1.4	1.5	1.3	0.9	0.42
Skin earthy flavor	0.8	0.7	0.6	1.6	0.21
Skin hay flavor	1.3	1.1	1.2	0.4	0.68
Skin floral flavor	0.3	0.3	0.3	0.1	0.88
Skin metallic flavor	0.5	0.4	0.4	1.0	0.37
Skin green apple flavor	0.7	0.5	0.6	0.5	0.61
Skin dried grape flavor	0.9 [a]	0.5 [b]	0.6 [b]	3.6	0.04
Skin artificial grape flavor	0.4	0.6	0.5	1.2	0.32
Skin other flavor	0.0	0.0	0.0	0.4	0.66
Skin astringency	1.6	1.7	1.6	0.1	0.93
Overall skin aftertaste	1.5	1.5	1.4	0.3	0.71
Skin sweetness aftertaste	0.8	0.9	0.8	0.4	0.68
Skin sourness aftertaste	0.8	1.0	0.9	1.2	0.30
Skin bitterness aftertaste	0.6	0.7	0.7	0.4	0.67

[abc] Mean ratings within a row having letter superscripts in common do not differ significantly (SNK test, $p > 0.05$).

4.1.3 Brianna wine

The following attributes increased in intensity with progressively later harvest dates: mushroom aroma, soy sauce aroma, sauerkraut aroma, corned beef aroma, sweetness, mushroom flavor, soy sauce flavor and corned beef flavor. Sourness, fresh raspberry flavor, fresh grapefruit flavor, green apple flavor, astringency aftertaste and sourness aftertaste decreased (Table 6 and Figure 2).

Table 6. Mean (n = 10) panelist attribute ratings of Brianna wine over different harvest dates. Two bottles of wine were provided for each harvest date (winemaking replicates). Means were taken over both the winemaking replicates and the sensory replicates. Scale markings began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense”. F and p-values corresponded to the predictor “harvest date”. Grey shaded attributes differed significantly ($p < 0.1$) among harvest dates.

Attributes	Harvest Dates (2015)				F	P
	9/4	9/11	9/18	9/24		
Overall intensity of aroma	5.1	5.1	5.6	5.5	1.5	0.21
Fresh raspberry aroma	1.3	1.4	1.5	1.2	0.7	0.53
Fresh blackberry aroma	1.1	1.0	1.2	1.0	0.4	0.73
Fresh pineapple aroma	1.4	1.4	1.5	1.4	0.1	0.98
Fresh peach aroma	1.7	1.7	1.9	1.6	1.1	0.35
Fresh grapefruit aroma	1.3	1.1	1.4	1.2	2.2	0.10
Fresh blueberry aroma	0.8	0.8	0.9	0.9	0.1	0.95
Green apple aroma	1.0	0.8	0.9	0.6	2.6	0.05
Fresh strawberry aroma	1.3	1.2	1.4	1.0	2.5	0.06
Fresh banana aroma	0.5	0.6	0.6	0.7	0.9	0.46
Fresh apricot aroma	1.6	1.4	1.5	1.3	1.5	0.23
Fresh green aroma	0.6	0.5	0.6	0.7	0.7	0.56
Green bell pepper aroma	0.4	0.3	0.3	0.3	0.2	0.87
Mushroom aroma	0.6 [b]	0.6 [b]	0.6 [b]	1.1 [a]	3.8	0.01
Dried apricot aroma	1.3	1.3	1.1	1.3	0.7	0.58
Oak aroma	0.9	1.0	0.8	0.9	0.4	0.76
Honey aroma	0.6	0.7	0.7	0.6	0.2	0.90
Floral aroma	0.8	0.8	1.1	0.8	1.0	0.38
Soy sauce aroma	0.5 [b]	0.7 [ab]	0.7 [ab]	0.9 [a]	2.8	0.04
Sauerkraut aroma	0.6 [b]	0.8 [b]	0.5 [b]	1.3 [a]	5.9	< 0.001
Canned peach aroma	1.3	1.4	1.3	1.2	0.6	0.59

Attributes	Harvest Dates (2015)				F	P
	9/4	9/11	9/18	9/24		
Corned beef aroma	0.5 [b]	0.6 [b]	0.4 [b]	1.0 [a]	4.4	0.01
Sweetness	1.4 [b]	1.9 [a]	1.8 [a]	2.1 [a]	3.2	0.02
Astringency	2.6	2.8	2.5	2.3	1.7	0.16
Sourness	3.3 [a]	3.1 [a]	3.1 [a]	2.1 [b]	10.2	< 0.001
Bitterness	1.1	1.3	1.2	1.3	0.5	0.67
Overall intensity of flavor	5.0	4.9	5.2	4.7	2.1	0.10
Fresh raspberry flavor	1.6 [a]	1.5 [a]	1.5 [a]	1.0 [b]	5.7	< 0.001
Fresh blackberry flavor	1.0	0.8	1.0	0.7	2.0	0.12
Fresh pineapple flavor	1.1	1.2	1.2	1.1	0.5	0.72
Fresh peach flavor	1.4 [ab]	1.6 [a]	1.5 [a]	1.2 [b]	3.1	0.03
Fresh grapefruit flavor	1.8 [a]	1.8 [a]	1.7 [a]	1.0 [b]	7.9	< 0.001
Fresh blueberry flavor	0.7	0.6	0.8	0.6	0.9	0.44
Green apple flavor	0.9 [a]	0.9 [a]	0.8 [a]	0.6 [b]	3.2	0.03
Fresh strawberry flavor	1.0	0.9	1.1	0.8	1.6	0.20
Banana flavor	0.4	0.5	0.6	0.5	0.5	0.66
Fresh apricot flavor	1.3	1.4	1.5	1.3	0.8	0.49
Fresh green flavor	0.8	0.7	0.8	0.8	0.5	0.71
Green bell pepper flavor	0.2	0.4	0.3	0.4	2.4	0.07
Mushroom flavor	0.3 [b]	0.5 [b]	0.5 [b]	1.3 [a]	12.8	< 0.001
Dried apricot flavor	1.4 [ab]	1.7 [a]	1.3 [b]	1.2 [b]	3.1	0.03
Oak flavor	1.1	1.1	1.0	1.2	0.4	0.75
Honey flavor	0.4	0.5	0.5	0.5	0.7	0.55
Floral flavor	1.1	0.8	0.9	0.7	1.7	0.16
Soy sauce flavor	0.4 [b]	0.6 [b]	0.6 [b]	0.9 [a]	4.7	< 0.001
Sauerkraut flavor	0.6	0.6	0.5	0.7	0.8	0.51
Corned beef flavor	0.2 [b]	0.4 [b]	0.5 [b]	1.0 [a]	4.6	< 0.001
Canned peach flavor	1.2	1.1	1.2	1.2	0.3	0.83
Astringency aftertaste	2.5 [a]	2.6 [a]	2.4 [a]	2.0 [b]	3.7	0.01
Overall aftertaste	3.2 [a]	3.2 [a]	2.8 [a]	2.9 [a]	3.1	0.03
Sweetness aftertaste	1.1	1.2	1.2	1.4	1.0	0.40
Sourness aftertaste	2.3 [a]	2.3 [a]	2.0 [a]	1.5 [b]	11.9	< 0.001
Bitterness aftertaste	0.9	1.0	1.1	1.2	0.7	0.57

[abc] Mean ratings within a row having letter superscripts in common do not differ significantly (SNK test, $p > 0.05$).

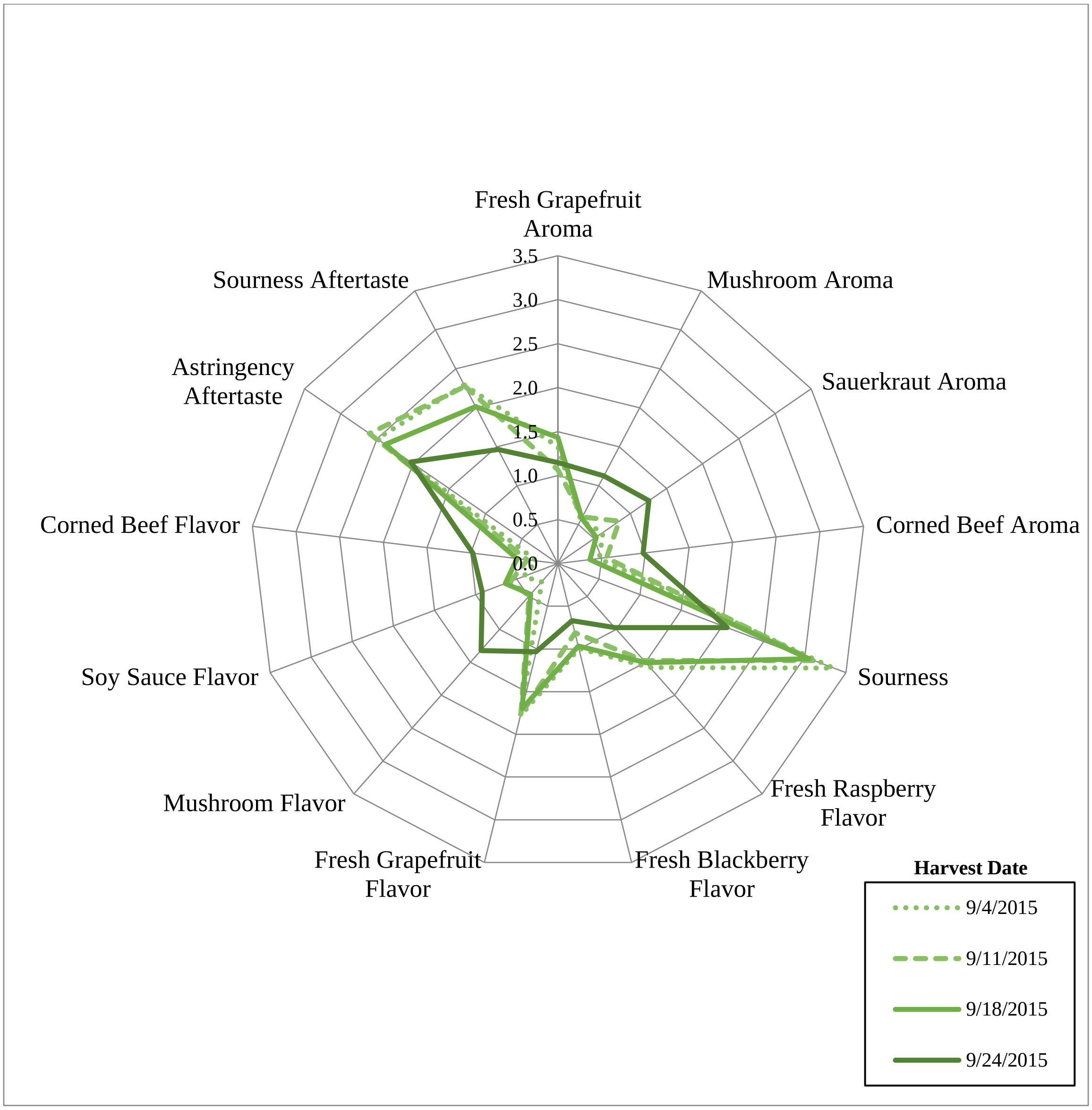

Figure 2. Mean (n = 10) attribute intensities of Brianna wine that differed significantly among harvest dates. Scale markings began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense”.

4.1.4 Frontenac gris wine

Fresh grapefruit aroma increased at the second harvest date and then decreased again at the third harvest date (Table 7). None of the other attributes differed among the harvest dates (Table 7).

Table 7. Mean (n = 11) panelist attribute ratings of Frontenac gris wine over different harvest dates. Two bottles of wine were provided for each harvest date (winemaking replicates). Means were taken over both the winemaking replicates and the sensory replicates. Scale markings began at "0" on the left end of the line labeled "none" and ended at "20" on the right end of the line labeled "intense". F and p-values corresponded to the predictor "harvest date". Grey shaded attributes differed significantly ($p < 0.1$) among harvest dates.

Attributes	Harvest Dates (2015)			F	P
	9/24	10/1	10/9		
Overall intensity of aroma	5.5	5.7	5.7	0.4	0.68
Dried apricot aroma	1.7	1.4	1.6	1.3	0.27
Dried cherry aroma	1.3	1.4	1.5	0.3	0.74
Mushroom aroma	0.7	0.6	0.7	0.4	0.67
Soy sauce aroma	0.9	1.0	0.9	0.3	0.74
Citrus fruit aroma	1.0	1.0	1.1	0.4	0.65
Dried fruit aroma	1.2	1.1	1.1	0.1	0.92
Green apple aroma	0.8	0.7	0.7	0.5	0.59
Banana aroma	1.0	1.0	1.2	0.9	0.42
Fresh peach aroma	1.5	1.6	1.7	0.5	0.59
Fresh apricot aroma	1.4	1.6	1.6	0.7	0.49
Fresh raspberry aroma	0.8	1.1	1.1	2.2	0.12
Fresh grapefruit aroma	1.0 [b]	1.4 [a]	1.1 [b]	4.3	0.02
Strawberry jam aroma	0.6	0.7	0.6	0.2	0.80
Fresh green aroma	0.6	0.6	0.5	0.9	0.39
Leather aroma	0.5	0.5	0.7	0.4	0.66
Green bell pepper aroma	0.6	0.5	0.4	0.9	0.42
Black pepper aroma	1.1	1.1	1.0	0.9	0.40
Corned beef aroma	0.9	0.7	0.8	1.0	0.35
Sauerkraut aroma	0.8	0.9	0.9	0.1	0.91
Canned peach aroma	1.3	1.5	1.4	0.4	0.70
Canned tomato aroma	1.0	1.0	1.2	0.6	0.56
Canned pineapple aroma	1.5	1.5	1.4	0.7	0.49
Oak aroma	0.7	0.6	0.8	1.4	0.25

Attributes	Harvest Dates (2015)			F	P
	9/24	10/1	10/9		
Sweetness	2.0	2.3	2.1	1.0	0.37
Astringency	3.0	3.1	2.8	1.1	0.34
Sourness	4.1	4.0	3.8	0.5	0.60
Bitterness	1.4	1.5	1.7	1.2	0.30
Overall intensity of flavor	5.6	5.7	5.4	1.0	0.36
Dried apricot flavor	1.3	1.7	1.4	1.9	0.15
Metallic flavor	0.8	0.7	0.9	1.7	0.18
Dried cherry flavor	1.3	1.4	1.3	0.1	0.88
Mushroom flavor	0.8	0.7	0.5	2.3	0.10
Soy sauce flavor	0.7	0.7	0.5	1.5	0.22
Citrus fruit flavor	1.4	1.5	1.2	1.6	0.21
Dried fruit flavor	0.9	0.9	0.8	0.3	0.72
Green apple flavor	1.0	1.0	1.2	1.1	0.34
Banana flavor	0.7	0.6	0.7	0.3	0.77
Fresh peach flavor	1.5	1.7	1.5	1.2	0.29
Fresh apricot flavor	1.7	1.4	1.4	1.2	0.30
Fresh raspberry flavor	1.3	1.2	1.0	0.9	0.42
Fresh grapefruit flavor	1.6	1.7	1.7	0.2	0.85
Strawberry jam flavor	0.6	0.5	0.5	0.4	0.70
Leather flavor	0.4	0.3	0.2	1.0	0.36
Oak flavor	0.9	0.9	1.0	0.8	0.45
Green bell pepper flavor	0.5	0.5	0.5	0.0	0.97
Black pepper flavor	1.0	1.1	1.1	0.2	0.85
Corned beef flavor	0.7	0.7	0.6	0.2	0.85
Sauerkraut flavor	1.0	0.9	0.7	2.0	0.15
Canned pineapple flavor	1.6	1.4	1.3	2.3	0.10
Canned tomato flavor	0.9	0.8	0.9	0.3	0.72
Canned peach flavor	1.1	1.2	1.2	0.3	0.75
Fresh green flavor	0.6	0.6	0.7	1.2	0.31
Astringency aftertaste	2.7	2.9	2.8	0.4	0.68
Overall aftertaste	3.5	3.4	3.3	1.2	0.31
Sweetness aftertaste	1.3	1.1	1.2	0.7	0.52
Sourness aftertaste	2.6	2.7	2.4	2.5	0.09
Bitterness aftertaste	1.2	1.2	1.5	1.4	0.24

^{abc} Mean ratings within a row having letter superscripts in common do not differ significantly (SNK test, $p > 0.05$).

4.2 Results – Part 2: To develop a set of aroma and flavor descriptors that define Frontenac gris.

Attributes found to define Frontenac gris wine were dried apricot aroma and flavor, dried cherry aroma and flavor, citrus fruit aroma and flavor, dried fruit aroma and flavor, fresh strawberry aroma and flavor, green wood aroma and flavor, fresh green flavor, canned peach aroma, and canned pineapple flavor (Table 8, Table 9, Figure 3, and Figure 4).

Table 8. Aroma attributes that define Frontenac gris wine. An attribute was labeled as defining if a panelist's intensity rating was rated at level one or above and was returned in greater than 75% of samples.

Attribute	Percentage of wine samples containing the attribute
Dried apricot aroma	78
Dried cherry aroma	77
Citrus fruit aroma	81
Dried fruit aroma	88
Fresh strawberry aroma	79
Green wood aroma	77
Canned peach aroma	82

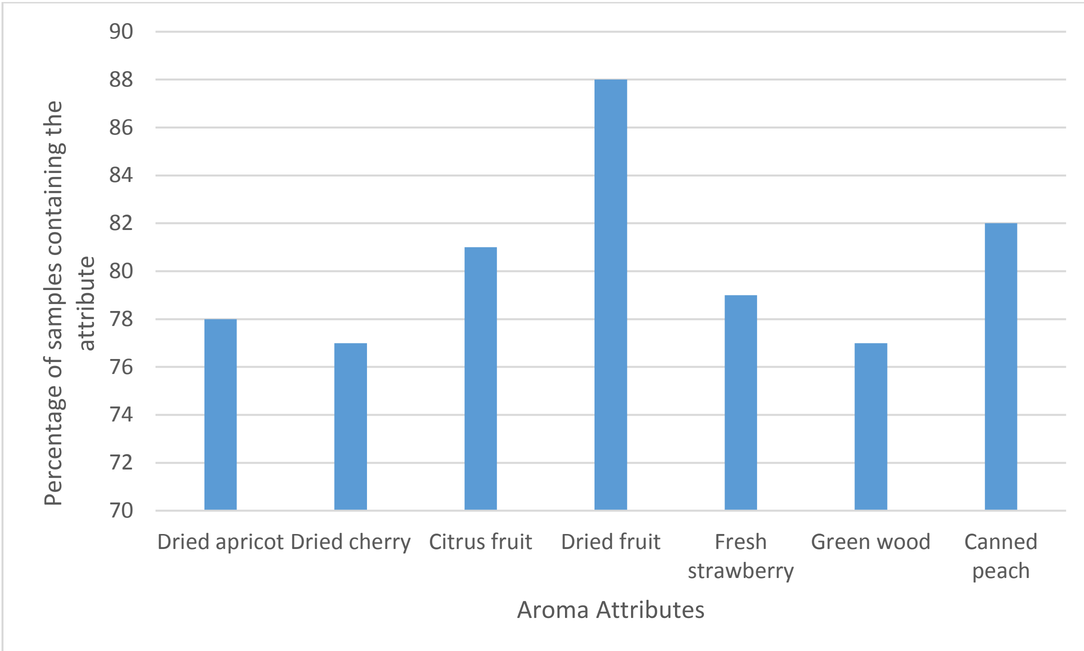

Figure 3. Aroma attributes that define Frontenac gris wine. An attribute was labeled as defining if a panelist's intensity rating was rated at level one or above and was returned in greater than 75% of samples.

Table 9. Flavor attributes that define Frontenac gris wine. An attribute was labeled as defining if a panelist's intensity rating was rated at level one or above and was returned in greater than 75% of samples.

Attribute	Percentage of wine samples containing the attribute
Dried apricot flavor	77
Dried cherry flavor	80
Citrus fruit flavor	86
Dried fruit flavor	86
Fresh strawberry flavor	77
Green wood flavor	81
Fresh green flavor	75
Canned pineapple flavor	77

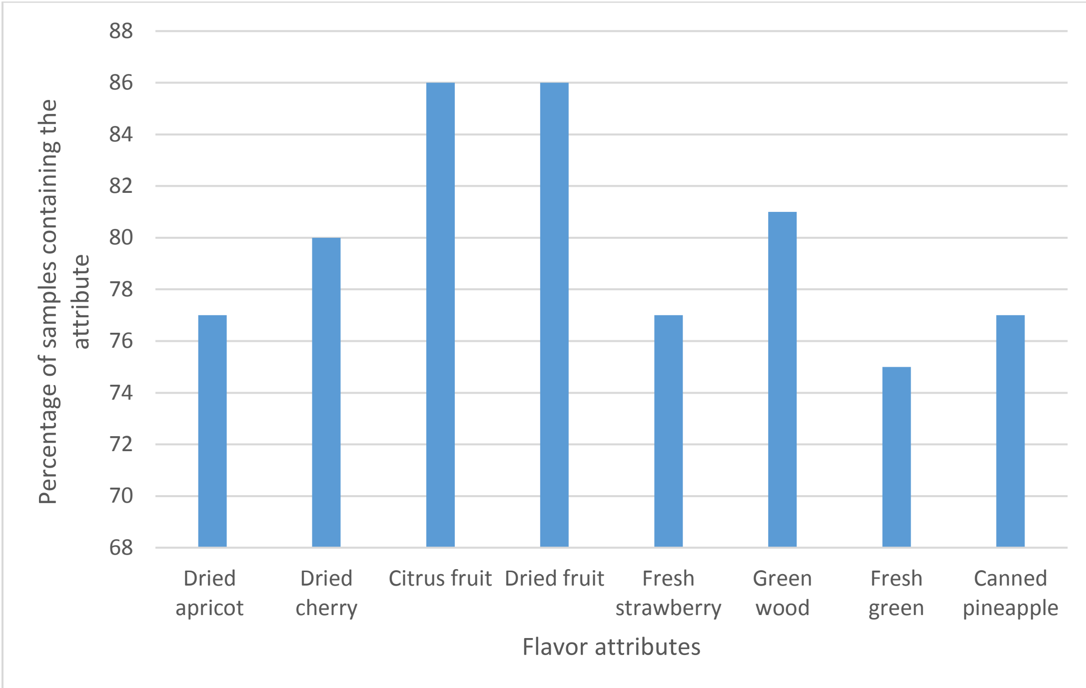

Figure 4. Flavor attributes that define Frontenac gris wine. An attribute was labeled as defining if a panelist's intensity rating was rated at level one or above and was returned in greater than 75% of samples.

Mean panelist ratings of attributes common to Frontenac gris wine over all judges and wineries showed high sweetness and sourness taste attributes (Figure 5 and Figure 6). In addition, dried fruit aroma and flavor, dried apricot aroma, and citrus fruit flavor had the highest intensity ratings (Figure 5 and Figure 6). Specific mean panelist ratings of the attributes common to Frontenac gris wine for each winery can be found in Appendix V.

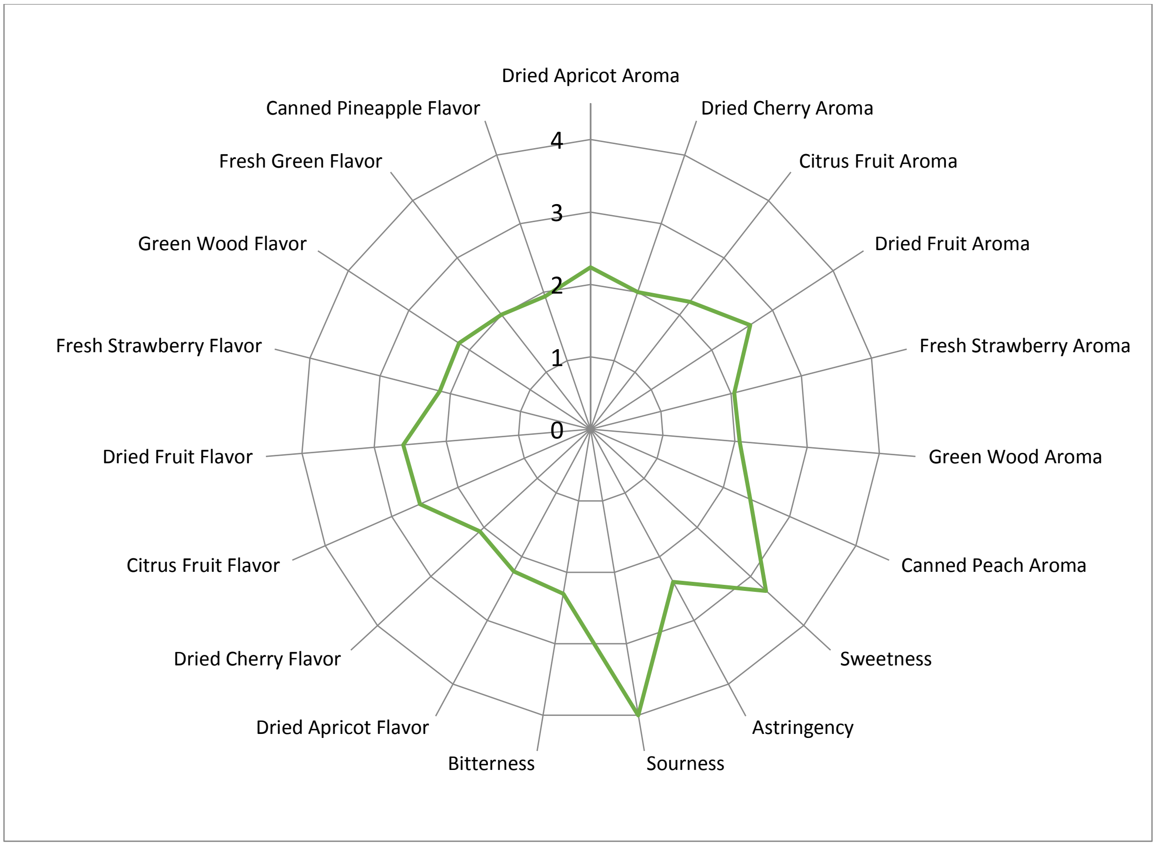

Figure 5. Mean panelist (n = 10) values of all attributes that define Frontenac gris wine over all judges and wineries. Scale labels began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense”.

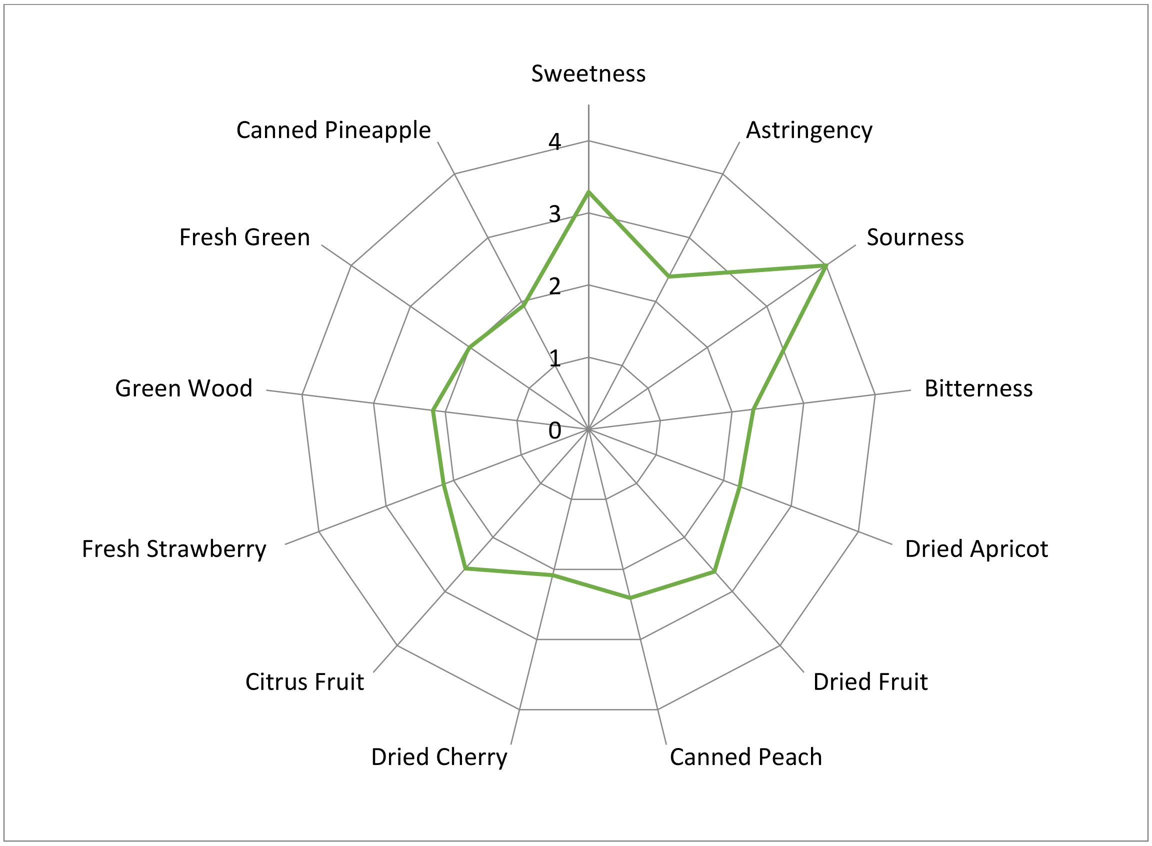

Figure 6. Reduced version of mean panelist (n = 10) values of attributes that define Frontenac gris wine over all judges and wineries. To reduce, for each attribute we selected the flavor or the aroma term with the highest mean intensity. Scale labels began at “0” on the left end of the line labeled “none” and ended at “20” on the right end of the line labeled “intense”.

Parafac analysis showed that high positive loadings on Dimension 1 were associated with sweetness, whereas high negative loadings on Dimension 1 were associated with sourness and bitterness (Figure 7). High positive loadings on Dimension 2 were associated with fruity attributes, whereas high negative loadings on Dimension 2 were associated with savory attributes (Figure 7).

Parafac analysis also showed where wineries are located on Dimension 1 and 2 in comparison to the attributes (Figure 8). Fireside and Santa Maria wineries were located at the highly positive end of Dimension 1 (the sweetness Dimension). Winehaven winery was located at the highly negative end of Dimension 1 (the sourness and bitterness Dimension). Fireside and Winehaven wineries were located at the highly positive end of Dimension 2 (the fruity Dimension). Vines and Rushes winery was located at the highly negative end of Dimension 2 (the savory attribute dimension).

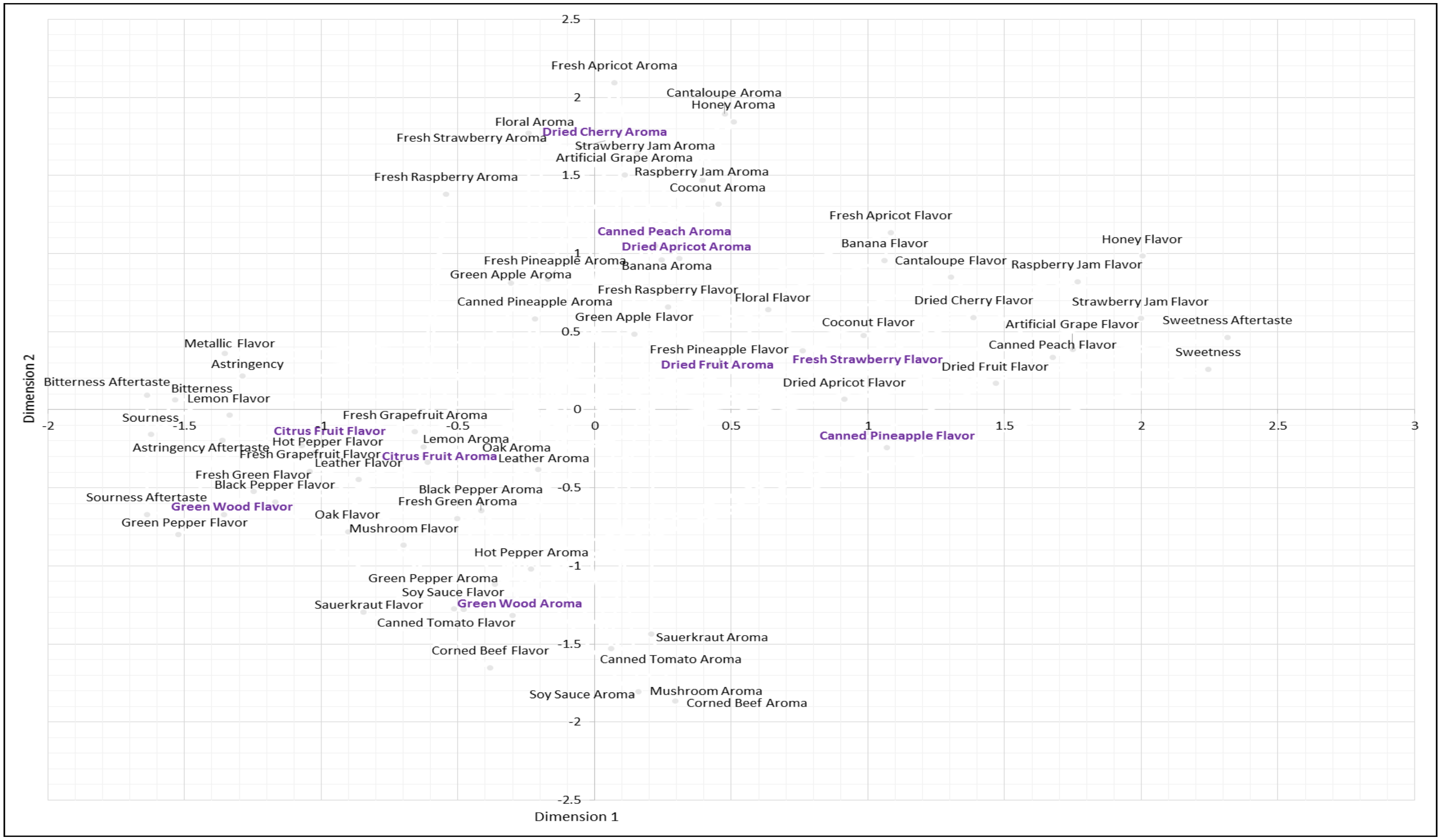

Figure 7. Parafac results of Dimension 1 and Dimension 2 Frontenac gris attribute loadings. Purple bolded attributes are those that are define Frontenac gris wine.

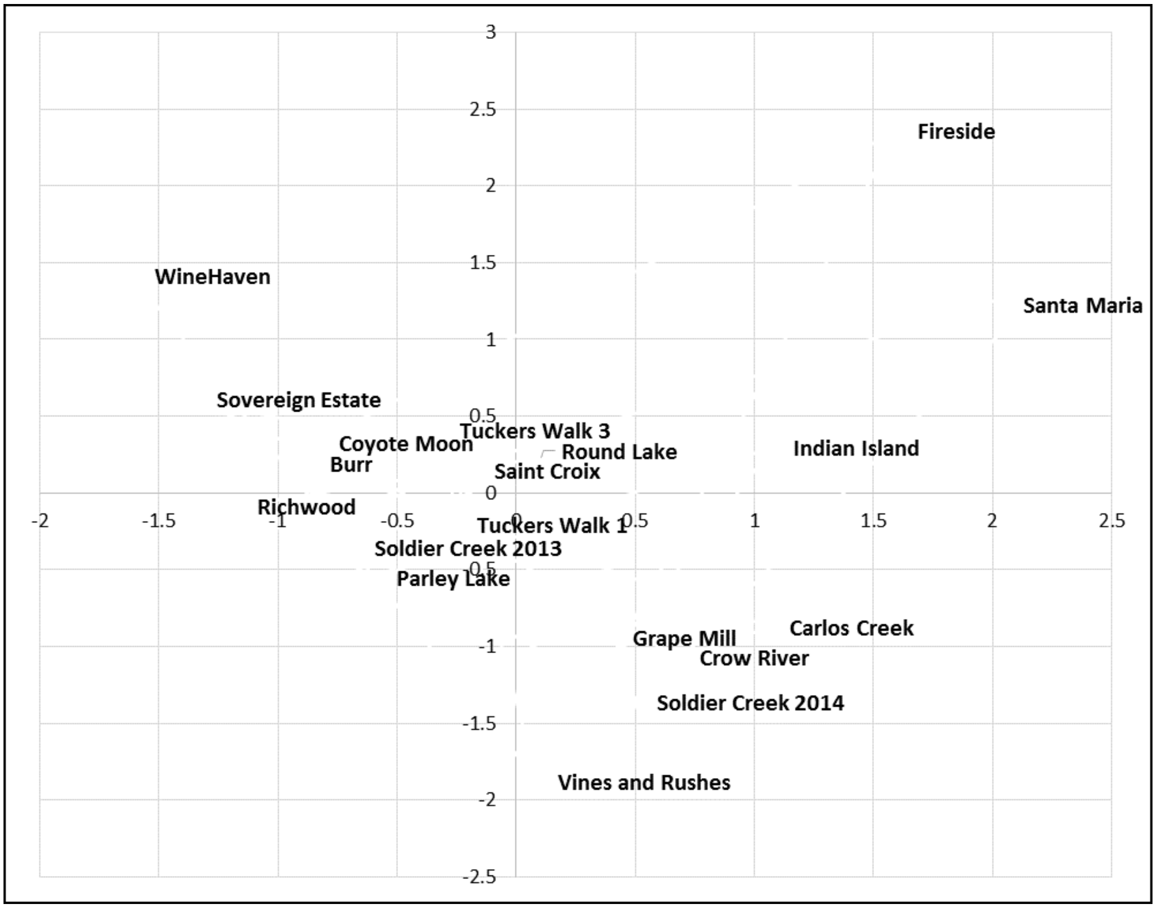

Figure 8. Parafac results of Dimension 1 and Dimension 2 Frontenac gris winery loadings.

Chapter 5: Discussion

Only one change occurred over harvest dates with both Frontenac gris grapes and wines. This is very uncommon, especially with the taste attributes of sour and sweet. For Brianna wines, for example, sweetness increased and sourness decreased over time, which is exactly what we hypothesized. There may not have been a significant change in most of the attributes because the length of time between the harvest dates selected may not have been long enough to allow for the sensory attributes to change. The Brianna grapes were harvested over only a 20 day period and the Frontenac gris grapes were harvested over only a 14 day period.

The sweetness and acidity differences seen with later harvest dates were significant, but small in the overall scale. For instance, Brianna wine sweetness went from a mean intensity level of 1.4 to 2.1 across the range of harvest dates out of a 20-point scale. This small range may be because sweetness is largely controlled by the wine-maker (Wine Institute, 2012). Acidity, on the other hand, should definitely lower the later a grape is harvested, even if just by a few intensity levels (Wine Institute, 2012). As seen with the Brianna wine, wine acidity went from a mean intensity level of 3.3 to 2.1 across the range of harvest dates out of a 20-point scale.

Taste and aroma interactions occur continuously when we drink, and both contribute to an overall impression of flavor (Eschenbruch, 1974). Specifically, on ingestion, the intensity of fruity flavors of beverages are enhanced by sweetness or sourness (Eschenbruch, 1974). This was true with the Frontenac gris wines in this study and may also be an explanation for why the Brianna wines that were harvested later had higher levels of some aroma and flavor characteristics. Common to cold-hardy wines, each Brianna and Frontenac gris wine had a high sweetness level (Hemstad & Luby, 2000). Thus, the fruity aroma and flavor characteristics of the wines in this study may have been given higher intensity ratings (than what they would have said if the wines were less sweet) due to the high intensity of sweetness. Thus, the perceived intensity of tastes increases when we taste flavored solutions, especially when there is a logical associated between them, such as between sweetness and fruitiness (Eschenbruch, 1974).

We also obtained residual sugar information from each of the bottles of wine that was used in the study (Appendix U). The wines that had the higher percent residual sugar (Table 3 and Appendix U) had high positive loadings on dimension one (the sweetness side of the dimension) on the parafac plot (Figure 8). These wines included Santa Maria, Soldier Creek, Vines and Rushes, Fireside, and Carlos Creek. Also, the wines that had the lower percent residual sugar (Table 3 and Appendix U) had high negative loadings (the sourness side of the dimension). These wines included Coyote Moon, Burr, Sovereign Estate, and Winehaven.

In addition, savory attributes such as corned beef, sauerkraut, and canned tomato, are not common in wines and are usually considered flaws in fresh white wines (Wine Institute, 2012). These attributes may be caused by sulfur containing compounds such as methanethiol, ethanethiol, dimethyl disulfide, diethyl sulfide, or other sulfites and sulfides (Wine Institute, 2012). Sulfites and sulfides are formed by wine yeasts during the fermentations of grapes (Wine Institute, 2012). Vines and Rushes wine was the most highly negative loaded wine of the second dimension on the parafac plot (Figure 8), which represents the savory attributes. This winery used Epernay 2 yeast strain in their Frontenac gris wine production (Appendix U). Epernay 2 is a yeast strain that does not have high alcohol tolerance and can struggle with adequate nutrition and temperature management (Nagel et al., 1988). Thus, there may have been an issue with the particular yeast or, more likely, an issue with poor sanitation in the winery, poor oxygen management, poor temperature management, or poor storage management (Wine Institute, 2012). A struggling fermentation due to temperature and/or yeast nutrition issues can also lead to sulfur-like aromas (rotten egg, etc.) (Wine Institute, 2012). In addition, Frontenac gris wines from Vines and Rushes, Soldier Creek, Crow River, Grape Mill, and Carlos Creek (those located at the most negative end of the second dimension of Figure 8's parafac plot) most likely went through secondary or malolactic fermentation or some sort of spoilage due to bacteria remaining in the wines after bottling. Sauerkraut smell in particular is a common clue for lactic-acid spoilage (Wine Institute, 2012).

Another atypical attribute found in the wines throughout my study were "canned" aromas and flavors. Typically, any kind of "canned" fruit or vegetable aroma attribute (such as "canned peach" or "canned pineapple") indicates that the wine is going through a reductive state in the bottle due to poor oxygen management and/or improper use of sulfites (Wine Institute, 2012).

Overall, a fresh and well made Frontenac gris wine should contain fresh fruit aromas and flavors such as peach, apricot, citrus, ripe melon, pineapple, apple, and even certain sweet "muskiness" attributes or floral notes (Hemstad, 2003). While panelists found some of the savory and canned attributes throughout the study, the attributes included in the lexicon and those found to define Frontenac gris included most of those fruit aromas and flavors mentioned by Hemstad.

CONCLUSION

With later harvest dates, Brianna *grapes* increased in sweetness and in some fruity aroma and flavor attributes such as citrus fruit aroma, pulp jammy flavor, and pulp green apple flavor. With later harvest dates, Brianna grapes decreased in sourness and bitterness. Frontenac gris grapes decreased in skin dried grape flavor with later harvest dates.

With later harvest dates, Brianna *wine* increased in sweetness and in some fruity aroma and flavor attributes such as fresh raspberry, fresh peach, and fresh grapefruit flavors. With later harvest dates, Brianna wine decreased in sourness. Frontenac gris wine increased in fresh grapefruit aroma at the second harvest date and then decreased at the third harvest date.

Attributes found to define Frontenac gris wine were: dried apricot aroma and flavor, dried cherry aroma and flavor, citrus fruit aroma and flavor, dried fruit aroma and flavor, fresh strawberry aroma and flavor, green wood aroma and flavor, fresh green flavor, canned peach aroma, and canned pineapple flavor. Frontenac gris wine is high in sweetness and sourness.

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APPENDICES

Appendix A: Screener Objective A

Hello!

We are recruiting trained panelists for participation in a white wine study that will last approximately 5 weeks beginning in mid/end March (not including Spring Break). **The study will be held in Room FScN-1 and Room 97b of the Food Science and Nutrition building on the University of Minnesota St. Paul campus**.

We need people with the following qualifications:
Available to attend up to four 1-hour sessions a week.
Available to attend sessions during the noon hour.
Have no food allergies
At least 21 years of age

There will be around 20 training/testing sessions total scheduled. I will ask each panelist to complete 4-5 sessions per week (you are allowed to complete more than one session per day with at least one hour between sessions). Each session will last about an hour. You must be available for all 5 weeks of the study to participate. You will be compensated $10/hour for training and $15/hour for testing. Payment will be made to you at the end of the study.

-

If you are interested in taking part in this study, please follow this link: https://umn.qualtrics.com/SE/?SID=SV_1YdIG1Xq7Jtzhu5
Your response will be evaluated to see if you qualify to be part of the study. Your responses to any questions on this form will be kept confidential. We will contact you after reviewing all of the responses.

Thank you!
Jenna

Appendix B: Screening Prep Instructions

Task #1: make PROP solution

- 1 L beaker

0.545g of 6-n-propylthiouracil for 1 L solution

Mix on hot plate until completely dissolved

Cool, then pour into labeled 1 oz. cups with lids, about ½ full – use code 2

Task #2: make a salty solution

- 1 L beaker

Make intensity 10 by mixing 9.612 g in 1 L solution

Pour into labeled 1 oz. cups with lids, about ½ full-use code 1

Task #3: make sweet solutions of 4 different concentrations

- 1 L flasks
- Labeled 1 oz. cups
- 1 oz. lids

Use concentrations in reference table – make 1 L solutions of intensities 4, 5, 6, and 7

Pour into labeled 1 oz. cups with lids, about ½ full

Task #4: make sour solutions of 4 different concentrations

- 1 L flasks
- Labeled 1 oz. cups
- 1 oz. lids

Use concentrations in reference table – make 1 L solutions of intensities 4, 5, 6, and 7

Pour into labeled 1 oz. cups with lids, about ½ full

Task #5: Grapes

- 2 oz. cups
- 2 oz. lids

Wash both varieties of grapes. Place two whole grapes into a 2 oz. cup. Label A and B

Task #6: Create apple juice dilutions

- Flasks
- Labeled 1 oz. cups
- 1 oz. lids

Make 0%, 5%, 10%, and 15% dilutions of apple juice and pour into four 1 oz. cups. If there is a major color difference between the samples, put red food dye into the solutions (ask Jenna first).

CODES

Solution	Code
Salty	1
PROP	2

Sweet solution codes:

Scale Value	Code
4	643
5	276
6	184
7	823

Sour solution codes:

Scale Value	Code
4	352
5	785
6	930
7	412

Apple Juice dilution solution codes:

Scale Value	Code
0%	525
5%	193
10%	337
15%	605

Solution	Code
Grape 1	A
Grape 2	B

Appendix C: Screening booth instructions

Welcome to the Descriptive Analysis Panel Sensory Screening!

- Please slide your Panelist ID card through to receive your first set of samples.
- You will receive a total of five questionnaires, each with a different task.
- **Please write your Panelist ID number at the top of each questionnaire.**
- Push your tray through when done to receive your payment and sign your receipt.

Appendix D: Screening ranking ballot

Panelist #______

Please rank the samples from least sweet to most sweet

Least Sweet ________ ________ ________ ________ Most Sweet

Appendix E: Descriptive analysis screening ballot

Panelist #_____

Welcome to the Descriptive Analysis Screener!

Your task is to smell and taste the two food products in front of you and list attributes that would describe them (for example: sweet, hard, and salty). List as many attributes as you think apply to that product.

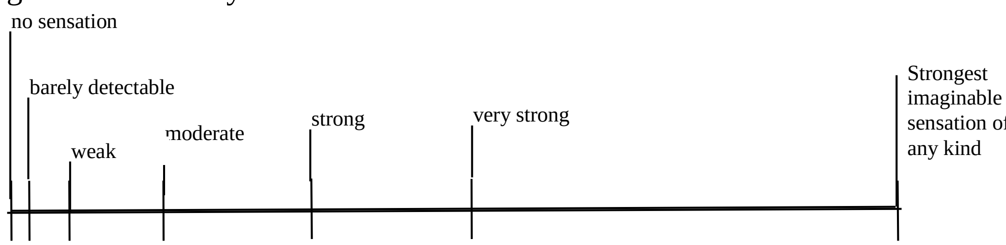
A	**B**

Appendix F: PROP screening ballot

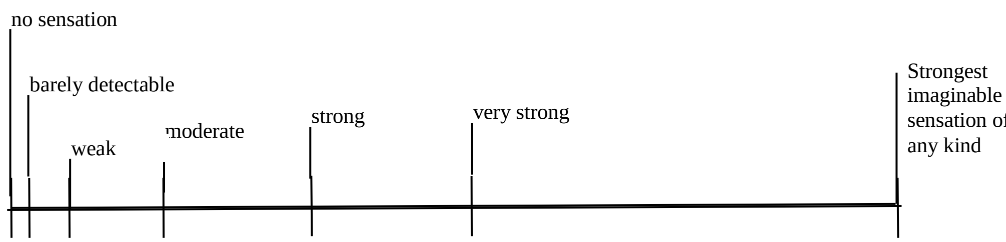
Panelist # _____

Please rate the intensity of the following sensations on the scales provided by placing a vertical mark at the position that best describes how intense you remember/imagine that sensation to be.

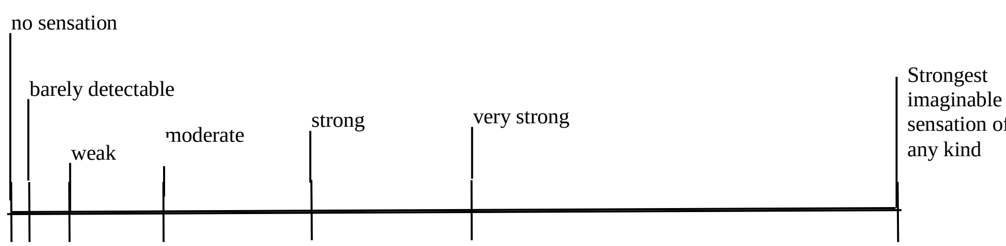
1. Brightness of a dimly lit restaurant



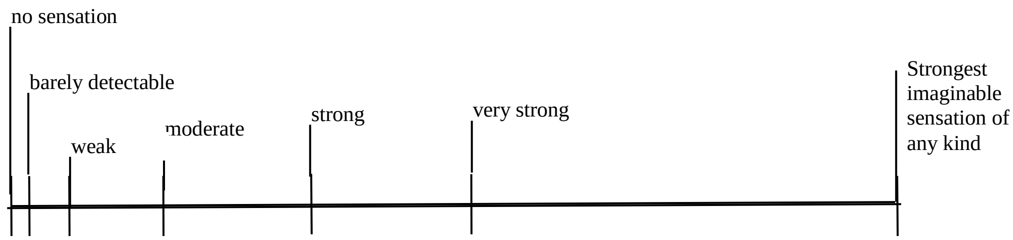
2. Brightness of the sun when looking directly at it



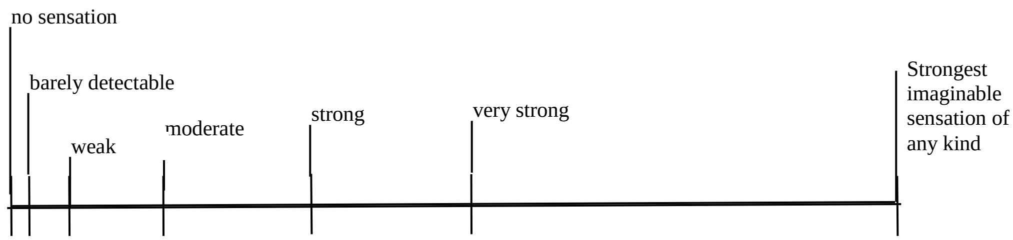
3. Loudness of a whisper



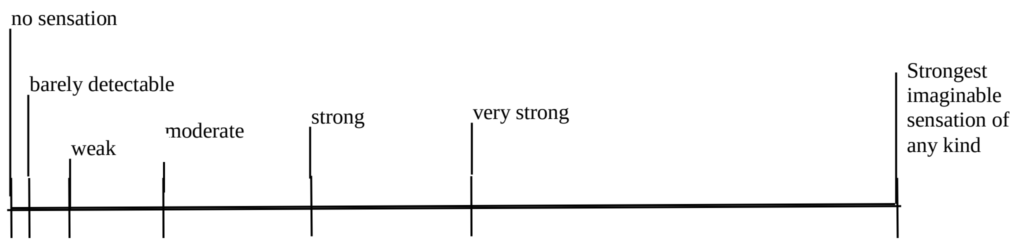
4. Loudness of a normal conversation



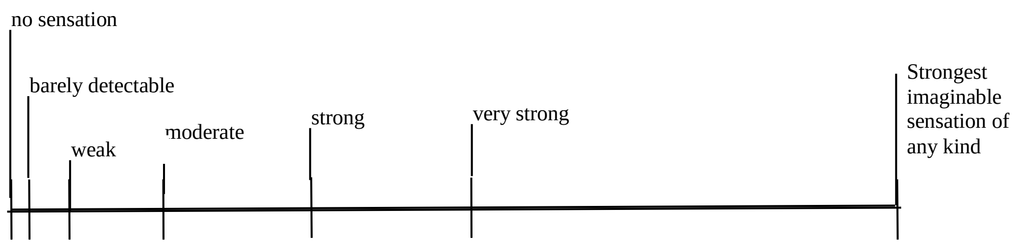
5. Warmth of warm bread in your mouth



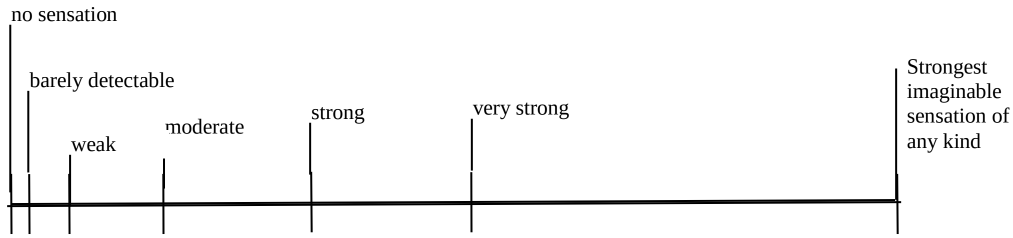
6. Smell of a rose



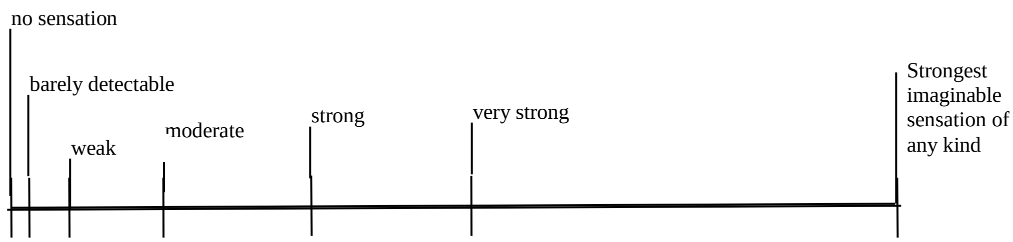
7. Bitterness of black coffee



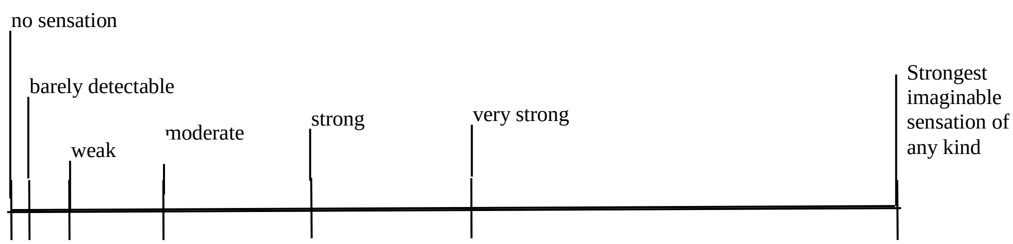
8. Saltiness of potato chips



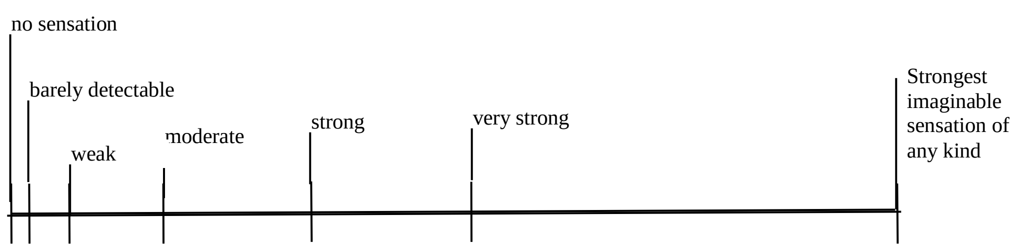
9. Loudness of a plane taking off 10 feet from you



10. Strongest sweetness experienced



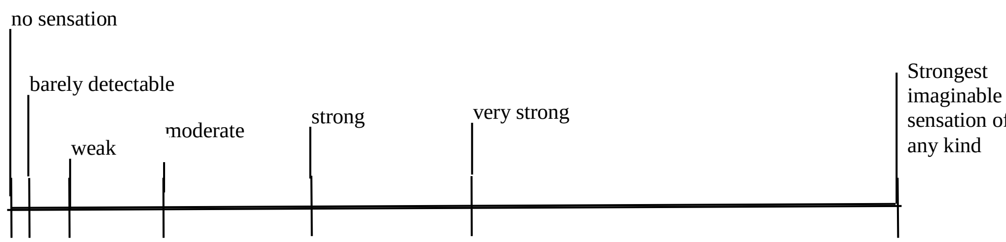
11. Sourness of a fresh lemon slice



13. Brightness of this room

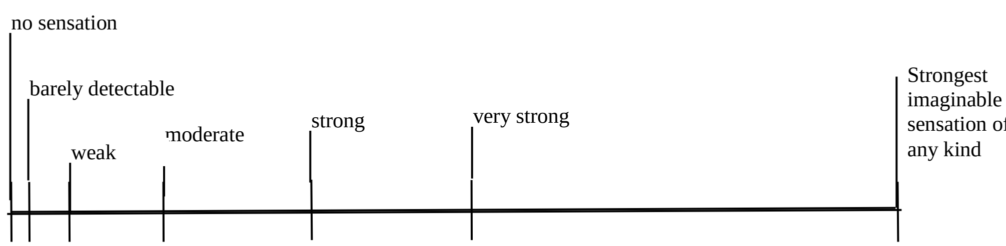
PLACE ALL OF SAMPLE 1 IN YOUR MOUTH, SWISH IT AROUND, THEN EXPECTORATE IT INTO THE CUP PROVIDED.

14. Rate the taste intensity of solution 1



PLACE ALL OF SAMPLE 2 IN YOUR MOUTH, SWISH IT AROUND, THEN EXPECTORATE IT INTO THE CUP PROVIDED.

14. Rate the taste intensity of solution 2



Appendix G: Consent form

Descriptive Analysis Panel Screening

You are invited to be in a research study of the quality of wine grapes and wine. You were selected as a possible participant because you are over 21 years of age, consume wine, you are not pregnant, and have no food allergies. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by: Jenna Brady and Zata Vickers, from the Sensory Center in the Department of Food Science and Nutrition.

Background Information
The purpose of this study is to characterize the sensory qualities and compare several samples of wine grapes and wine. All products were prepared using Alcohol, Tobacco, Tax and Trade Bureau (TTB) and Food and Drug Administration (FDA) approved ingredients and good manufacturing procedures.

Procedures
If you agree to be in this study, we would ask you to do the following things: Rate the intensity of a variety of sensations from memory and from actual samples, and describe wine grapes and wine.

Risks and Benefits of being in the Study
The study has no risks beyond those of normally consuming wine grapes and wine.
The study has no benefits for you other than the compensation.

Compensation:
You will be compensated $10/hour for training, and $15/hour for testing. Payment will be made to you at the end of each month.

Confidentiality:
The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any questions or withdraw at any time without affecting those relationships.

Contacts and Questions:
The researchers conducting this study are: Jenna Brady and Zata Vickers. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact them at Room 97 or 140, Food Science and Nutrition, (612) 625-3712, brady270@umn.edu, and zvickers@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent:
In order to participate in the study, verbal consent must be obtained. Please verbally confirm that you have read the information above, asked questions, and received answers.

Appendix H: Sample training ballot

Sample Code	Rank Intensity (1=lowest, 10=highest)
528	
822	
815	
827	
167	
396	
506	
914	
953	
521	

Sample Code	Intensity
293	
946	
919	
874	
289	

Sample Code	Intensity
840	
166	
330	
519	

Sample Code	Intensity
119	
426	

Appendix I: Flavor intensity training

On the first day of training, panelists are trained to rate taste intensity on a citric acid scale.

1. Panelists receive the 20 citric acid samples representing levels 1-20 and are asked to taste each sample up the scale to familiarize themselves with the taste intensity scale.
2. They are then given a set of 10 of the citric acid samples coded with 3 digit random codes and asked to place the samples in ascending order (Intensity levels of 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20).
3. The panelists are given the answers and asked to refer back to their full 20 sample citric acid scale if they had any samples out of order.
4. Next the panelists are given a set of 5 citric acid samples (Intensity levels of 3, 7, 8, 10, and 0) and asked to assign the samples an intensity score of 0-20. They are encouraged to use their reference scale to help in their evaluation.
5. Next they are given samples of 5 other tastes (Salty intensity level of 5, salty intensity level of 10, sweet intensity level of 5 and sweet intensity level of 5) and asked to rate these taste solutions using the citric acid scale as a taste intensity reference.
6. Lastly, panelists are given samples of the apple juice beverages – one regular and one with 15% added sugar and they are asked to rate the sweetness of the each sample.
7. We explain how the citric acid scale is to be used to make ratings for all taste and flavor evaluations.

Citric Acid Flavor Intensity Scale

Intensity value	**%**	**g citric acid/L water**
1	0.010%	0.173
2	0.019%	0.310
3	0.028%	0.462
4	0.038%	0.634
5	0.050%	0.839
6	0.066%	1.105
7	0.082%	1.366
8	0.099%	1.649
9	0.119%	1.990
10	0.144%	2.402
11	0.174%	2.899
12	0.210%	3.499
13	0.253%	4.224
14	0.305%	5.100
15	0.368%	6.158

16	0.445%	7.436
17	0.532%	8.904
18	0.929%	15.612
19	1.622%	27.454
20	2.833%	48.539

- Make 6 trays of everything
- Make all 20 solutions of citric acid intensities (1-20)

20 citric acid samples coded with their respective codes (1oz cups with lids)-one big tray

Intensity	Code	Intensity	Code
1	1	11	11
2	2	12	12
3	3	13	13
4	4	14	14
5	5	15	15
6	6	16	16
7	7	17	17
8	8	18	18
9	9	19	19
10	10	20	20

10 citric acid samples, 1 of each intensity, with a 3-digit random code for panelists to correctly order (1oz cups with lids)-2nd big tray

Intensity	code
2	914
4	396
6	506
8	815
10	167
12	953
14	822
16	528
18	521
20	827

5 citric acid samples with random 3-digit codes for panelists to assign a score (1oz cups/lids)-3rd small tray

Intensity	code
3	919
7	946
8	293
10	874
0	289

4 samples of different tastes with random 3-digit codes (1oz cups/lids)-4th small tray in front

Sample	Intensity	code
0.14% NaCl	5	840
0.44% NaCl	10	166
3.22% sucrose	5	330
8.75% sucrose	10	519

Product Samples (2oz cups/lids)-4th small tray in back

Sample	Code
Apple Juice	119
Apple Juice w/ 15% sugar	426

Appendix J: Aroma intensity training

On the second day of training, panelists are trained on the aroma intensity butanol scale.

1. Panelists receive the 12 butanol samples for intensity level 1-12 and are asked to smell each sample up the scale to familiarize themselves with the aroma intensity scale.
2. Next, they are then given a set of 7 of the butanol samples coded with 3 digit random codes and asked to place the samples in ascending order (Intensity levels of 1, 3, 5, 7, 9, 11, and 12).
3. The panelists are given the answers and asked to refer back to their full 12 sample butanol scale if they had any samples out of order.
4. Next the panelists are given a set of 5 3-digit random coded butanol samples (Intensity levels of 3, 7, 8, 10, and 0) and asked to assign the samples an intensity score of 0-12. They are encouraged to use their reference scale to help in their evaluation.
5. Next they are given samples of 5 other aromas (flour, lemon rind, peanut butter, raspberry jam) and asked to rate these samples using the butanol scale as an aroma intensity reference.
6. Lastly, panelists are given samples of the apple juice beverages – one regular and one with 1% added lemon flavoring and they are asked to rate the apple and lemon aroma of the each sample.
7. A discussion is held about using the butanol scale as a reference point when making aroma evaluations for foods.

Table 2: Butanol Aroma Intensity Scale

Scale value	Concentration of Butanol (ppm)
1	10
2	20
3	40
4	80
5	160
6	320
7	640
8	1,280
9	2,560
10	5,120
11	10,240
12	20,480

- Make 6 trays of everything
- Make all 12 solutions of butanol intensities (1-12)-Put into lidded containers on shelves

Tray 1- 10 samples coded with their respective codes **(in order on the trays)**-on one big tray

Intensity	Code
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12

Tray 2- 7 samples, 1 of each of the following intensities for panelists to correctly order **(randomize order on the trays)**-on 2nd small tray

Intensity	code
1	452
3	363
5	519
7	171
9	475
11	291
12	526

Tray 3- 5 samples for panelists to assign a score **(randomize order on the trays)**-on 3rd small tray

Sample	code
1	452
4	926
8	769
10	352
12	526

Tray 3- 5 samples of different aromas **(randomize order on the trays)**-on 4th small tray in front

Sample	code
flour	125

lemon rind	486
peanut butter	160
raspberry jam	237

Tray 3- Product Samples-on 4th small tray in back

Sample	Code
Apple Juice with 1% lemon flavor	847
Apple Juice plain	643

Appendix K: Flavor and aroma intensity training review

On the third day of training, panelists review taste intensity and aroma intensity.

1. Flavor: Panelists receive the standard 4 citric acid samples representing levels 3,5,7, and 10 and are asked to taste each sample to familiarize themselves with the taste intensity scale.
2. Aroma: Panelists receive the standard 4 butanol samples for intensity level 3,5,7, and 10 and are asked to smell each sample to familiarize themselves with the aroma intensity scale.
3. Next the panelists are given a set of 4 3-digit random coded butanol samples (Intensity levels of 2, 5, 7, and 8) and asked to assign the samples an intensity score of 0-12. They are encouraged to use their reference scale to help in their evaluation.
4. Lastly, panelists are given samples of the apple juice beverages – one regular and one with 1% added orange flavoring and they are asked to rate the overall aroma intensity and the apple aroma intensity of the each sample.

Tray 1- 4 citric acid samples (in order on the trays)-1oz cups

Intensity	Code
3	3
5	5
7	7
10	10

Tray 2- 4 butanol samples coded with their respective codes (in order on the trays)

Intensity	Code
3	3
5	5
7	7
10	10

Tray 3 Front- 5 butanol samples for panelists to assign a score (randomize order on the trays)

Sample	code
2	784
5	519
7	171
8	769

Tray 3 Back- Product Samples

Sample	Code
Apple Juice with 1% coconut flavor	573
Apple Juice plain	802

Appendix L: Wine grape lexicon Objective A

Aroma & Flavor

Descriptive Term	Definition	Reference
Overall Intensity	The overall intensity of the aroma/flavor	
Fresh Fruit	Aromatic associateed with a mixture of non-specific fresh fruits	Apples, pears, strawberries, plums, blueberries, and raspberries. **intensity=10**
Dried Grape	A browned, sweet, fruit aromatic reminiscent of raisins.	5 Raisins (SunMaid)
Dried Fruit	A browned, sweet, fruit aromatic reminiscent of dried prunes or figs	2 pieces of dried prunes and 2 pieces of dried figs
Citrus Fruit	Aromatic associated with general impression of citrus fruits	Lemon peel, lime peel, orange peel
Fermented Fruit	The aroma associated with overripe fruit	Old "Fresh Fruit"
Jammy	A fruity cooked aroma associated with jam	Smucker's Red Raspberry Fruit Spread
Fresh Green	A "green" aroma/flavor typical of fresh grass	Asparagus/Green Bean
Green Wood	A vegetative aroma associated with grape stems	Grape stems
Earthy/Musty	The aromatics associated with wet earth, decay, and decomposition	Wet potting soil, **intensity=6**
Hay	Aromatic associated with sweet dry grasses	Hay
Floral	A sweet fragrant aromatic associated with flowers	Crushed violet pastilles
Metallic	An aromatic associated with metals.	0.005% Ferrous Sulfate (0.025g/500ml)
Artificial Grape	The aroma associated with artificial grape flavor	Grape Jolly Rancher
Green Apple	Aromatic associated with green apples	Granny smith apple pieces

Basic Tastes

Descriptive Term	Definition	Reference
Sweetness	The taste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness	The taste stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitterness 2	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.014% caffeine in distilled water (.071g/500ml) **intensity=2**
Bitterness 6	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml) **intensity=6**

Texture

Descriptive Term	Definition	Reference
Astringency 2	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.062% alum in distilled water (0.31g /500mL); **intensity=2**

Astringency 12	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.25% alum in distilled water (1.25g /500mL); **intensity=12**

Aftertaste

Descriptive Term	Definition	Reference
Overall aftertaste	The overall intensity of the flavor aftertaste	
Sweetness aftertaste	The overall intensity of the aftertaste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness aftertaste	The intensity of the aftertaste stimulated by stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitter	Intensity of bitter aftertaste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml)

Appendix M: Frontenac gris wine lexicon Objective A

Aroma & Flavor

Descriptive Term	Definition	Reference
Overall Intensity	The overall intensity of the aroma/flavor	
Dried Apricot	A browned, sweet, fruit aroma/flavor indicative of apricots	1 whole dried Good Sense® apricot, halved
Dried Cherry	A browned, sweet, fruit aroma/flavor indicative of cherries	5 dried cherries from bulk bin at local grocery store
Dried Fruit	A browned, sweet, fruit aroma/flavor indicative of dried prunes or figs	2 whole dried prunes (Sunsweet™) and 2 whole dried figs (Sun-Maid®)
Citrus Fruit	Aroma/flavor associated with citrus fruits	Equal parts lemon peel, lime peel, and orange peel
Mushroom	Aroma/flavor associated with fresh mushrooms	A few cut pieces of white mushroom from local grocery store
Strawberry Jam	A fruity cooked aroma/flavor associated with strawberry jam	Smucker's® Strawberry Jam
Fresh Green	A "green" aroma/flavor typical of fresh grass	2 asparagus and 2 green bean pieces (~2 inches each); crushed open
Soy Sauce	Aroma/flavor associated with fermented soybeans	1T Kikkoman® Naturally Brewed Soy Sauce in 500 mL water
Fresh Raspberry	Sweet, fruit aroma/flavor associated with fresh raspberries	Raspberries from local grocery store, halved
Fresh Banana	Fruit aroma/flavor associated with fresh/ripe bananas	One slice from local grocery store, halved
Fresh Peach	Fruit aroma/flavor associated with fresh white peaches	One piece of fresh white peach with skin from local grocery store
Metallic	An aroma/flavor associated with metals	0.005% Ferrous Sulfate (0.025g/500ml)
Fresh Apricot	Fruit aroma/flavor associated with fresh apricots	One piece of fresh apricot with skin from local grocery store
Green Apple	Fruit aroma/flavor associated with green apples	Granny smith apple pieces
Fresh Grapefruit	Fruit aroma/flavor associated with fresh red grapefruit	One fresh grapefruit piece from local grocery store
Leather	Strong aroma/flavor associated with real leather	2 cubic inch piece of leather from Michaels® Arts & Crafts
Oak	Strong aroma/flavor associated with dried oak chips	LD Carlson Company® Oak chips
Green Bell Pepper	Aroma/flavor associated with fresh green peppers	One piece of fresh green bell pepper from local grocery store
Black Pepper	Aroma/flavor associated with fresh black peppercorns	4 black McCormick® peppercorns, crushed, in 500 mL Franzia® Crisp White boxed wine
Corned Beef	Aroma/flavor associated with fresh deli corned beef	One slice of deli corned beef (from local grocery store) broken up and stirred into 500 mL Franzia Crisp White boxed wine
Sauerkraut	Aroma/flavor associated with canned sauerkraut	15 mL canned Del Monte® Sauerkraut juice in 500 mL Franzia Crisp White boxed wine
Canned Pineapple	Aroma/flavor associated with canned pineapples	20 mL canned Del Monte Pineapple Slices juice in 500 mL Franzia Crisp White boxed wine
Canned Tomato	Aroma/flavor associated with canned tomatoes	50 mL canned Hunt's® Whole Tomato juice in 500 mL Franzia Crisp White boxed wine

Canned Peach	Aroma/flavor associated with canned peaches	22 mL canned Del Monte Peach juice in 500 mL Franzia Crisp White boxed wine

Basic Tastes

Descriptive Term	Definition	Reference
Sweetness	The taste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness	The taste stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitterness 2	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.014% caffeine in distilled water (.071g/500ml) **intensity=2**
Bitterness 6	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml) **intensity=6**

Texture

Descriptive Term	Definition	Reference
Astringency 2	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.062% alum in distilled water (0.31g /500mL); **intensity=2**
Astringency 12	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.25% alum in distilled water (1.25g /500mL); **intensity=12**

Aftertaste

Descriptive Term	Definition	Reference
Overall aftertaste	The overall intensity of the flavor aftertaste perceived a few seconds after swallowing.	
Sweetness aftertaste	The overall intensity of the aftertaste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness aftertaste	The intensity of the aftertaste stimulated by stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitter	Intensity of bitter aftertaste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml)

Appendix N: Brianna wine lexicon Objective A

Aroma & Flavor

Descriptive Term	Definition	Reference
Overall Intensity	The overall intensity of the aroma/flavor	
Fresh Blackberry	Fruit aroma/flavor associated with fresh blackberries	One blackberry from local grocery store, halved
Fresh Pineapple	Fruit aroma/flavor associated with fresh pineapple	One piece of fresh pineapple (skin off) from local grocery store
Fresh Apricot	Fruit aroma/flavor associated with fresh apricots	One piece of fresh apricot with skin from local grocery store
Fresh Blueberry	Fruit aroma/flavor associated with fresh blueberries	A few fresh blueberry pieces from local grocery store, halved and crushed
Mushroom	Aroma/flavor associated with fresh mushrooms	A few pieces of white mushroom from local grocery store
Fresh Strawberry	Fruit aroma/flavor associated with fresh strawberries	A few pieces of fresh strawberries (stemless) from local grocery store
Fresh Green	A “green” aroma/flavor typical of fresh greens	2 asparagus and 2 green bean pieces (~2 inches each); crushed open
Soy Sauce	Aroma/flavor associated with fermented soybeans	1T Kikkoman® Naturally Brewed Soy Sauce in 500mL water
Fresh Raspberry	Sweet, fruit aroma/flavor associated with fresh raspberries	Raspberries from local grocery store, halved
Fresh Banana	Fruit aroma/flavor associated with fresh/ripe bananas	One slice from local grocery store, halved
Fresh Peach	Fruit aroma/flavor associated with fresh white peaches	One piece of fresh white peach with skin from local grocery store
Metallic	An aromatic associated with metals.	0.005% Ferrous Sulfate (0.025g/500ml)
Honey	Aroma/flavor associated with fresh honey	Gunter’s® Pure Honey
Green Apple	Aromatic associated with green apples	Granny smith apple pieces
Fresh Grapefruit	Fruit aroma/flavor associated with fresh red grapefruit	One fresh grapefruit piece from local grocery store
Floral	Aroma/flavor associated with fresh flowers	One piece of Choward’s® Violet pastel, crushed
Oak	Strong aroma/flavor associated with dried oak chips	LD Carlson Company® Oak chips
Green Bell Pepper	Aroma/flavor associated with fresh green peppers	One piece of fresh green bell pepper from local grocery store
Corned Beef	Aroma/flavor associated with fresh deli corned beef	One slice of deli corned beef (from local grocery store) broken up and stirred into 500 mL Franzia® Crisp White boxed wine
Sauerkraut	Aroma/flavor associated with canned sauerkraut	15 mL canned Del Monte® Sauerkraut juice in 500 mL Franzia Crisp White boxed wine
Canned Peach	Aroma/flavor associated with canned peaches	22 mL canned Del Monte Peach juice in 500 mL Franzia Crisp White boxed wine
Dried Apricot	A browned, sweet, fruit aroma/flavor indicative of apricots	1 whole dried Good Sense® apricot, halved

Basic Tastes

Descriptive Term	Definition	Reference
Sweetness	The taste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness	The taste stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitterness 2	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.014% caffeine in distilled water (.071g/500ml) **intensity=2**
Bitterness 6	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml) **intensity=6**

Texture

Descriptive Term	Definition	Reference
Astringency 2	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.062% alum in distilled water (0.31g /500mL); **intensity=2**
Astringency 12	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.25% alum in distilled water (1.25g /500mL); **intensity=12**

Aftertaste

Descriptive Term	Definition	Reference
Overall aftertaste	The overall intensity of the flavor aftertaste perceived a few seconds after swallowing.	
Sweetness aftertaste	The overall intensity of the aftertaste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness aftertaste	The intensity of the aftertaste stimulated by stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitter	Intensity of bitter aftertaste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml)

Appendix O: Frontenac gris wine lexicon Objective B

Aroma & Flavor

Descriptive Term	Definition	Reference
Overall Intensity	The overall intensity of the aroma/flavor	
Dried Apricot	A browned, sweet, fruit aroma/flavor indicative of apricots	1 whole dried Good Sense® apricot, halved
Dried Cherry	A browned, sweet, fruit aroma/flavor indicative of cherries	5 dried cherries from bulk bin at local grocery store
Dried Fruit	A browned, sweet, fruit aroma/flavor indicative of dried prunes or figs	2 whole dried prunes (Sunsweet™) and 2 whole dried figs (Sun-Maid®)
Citrus Fruit	Aroma/flavor associated with citrus fruits	Equal parts lemon peel, lime peel, and orange peel
Mushroom	Aroma/flavor associated with fresh mushrooms	A few cut pieces of white mushroom from local grocery store
Strawberry Jam	A fruity cooked aroma/flavor associated with strawberry jam	Smucker's® Strawberry Jam
Fresh Green	A "green" aroma/flavor typical of fresh grass	2 asparagus and 2 green bean pieces (~2 inches each); crushed open
Soy Sauce	Aroma/flavor associated with fermented soybeans	1T Kikkoman® Naturally Brewed Soy Sauce in 500 mL water
Fresh Raspberry	Sweet, fruit aroma/flavor associated with fresh raspberries	Raspberries from local grocery store, halved
Cantaloupe	Fruit aroma/flavor associated with fresh cantaloupe	Cantaloupe chunks
Fresh Banana	Fruit aroma/flavor associated with fresh/ripe bananas	One slice from local grocery store, halved
Hot Pepper	Aroma/flavor associated with fresh jalapeno peppers	One piece of fresh jalapeno pepper, crushed, from local grocery store
Fresh Strawberry	Fruit aroma/flavor associated with fresh strawberries	Fresh strawberry pieces
Floral	Aroma/flavor associated with fresh flowers	One piece of Choward's® Violet pastel, crushed
Lemon	Aroma/flavor associated with fresh lemons	One lemon slice
Green Wood	A "green" aroma/flavor typical of fresh wood	Grape stems crushed
Artificial Grape	Aroma/flavor associated with artificial grapes	One grape Jolly rancher®
Coconut	Aroma/flavor associated with fresh, slightly sweetened coconut	Shaved Baker's® Angel Flake Coconut, sweetened
Fresh Pineapple	Fruit aroma/flavor associated with fresh/ripe pineapples	Pineapple pieces
Fresh Apricot	Fruit aroma/flavor associated with fresh apricots	Not sold at stores during testing
Metallic	An aroma/flavor associated with metals	0.005% Ferrous Sulfate (0.025g/500ml)
Green Apple	Fruit aroma/flavor associated with green apples	Granny smith apple pieces
Fresh Grapefruit	Fruit aroma/flavor associated with fresh red grapefruit	One fresh grapefruit piece from local grocery store

Leather	Strong aroma/flavor associated with real leather	2 cubic inch piece of leather from Michaels® Arts & Crafts
Oak	Strong aroma/flavor associated with dried oak chips	LD Carlson Company® Oak chips
Green Bell Pepper	Aroma/flavor associated with fresh green peppers	One piece of fresh green bell pepper from local grocery store
Black Pepper	Aroma/flavor associated with fresh black peppercorns	4 black McCormick® peppercorns, crushed, in 500 mL Franzia® Crisp White boxed wine
Corned Beef	Aroma/flavor associated with fresh deli corned beef	One slice of deli corned beef (from local grocery store) broken up and stirred into 500 mL Franzia Crisp White boxed wine
Sauerkraut	Aroma/flavor associated with canned sauerkraut	15 mL canned Del Monte® Sauerkraut juice in 500 mL Franzia Crisp White boxed wine
Canned Pineapple	Aroma/flavor associated with canned pineapples	20 mL canned Del Monte Pineapple Slices juice in 500 mL Franzia Crisp White boxed wine
Canned Tomato	Aroma/flavor associated with canned tomatoes	50 mL canned Hunt's® Whole Tomato juice in 500 mL Franzia Crisp White boxed wine
Canned Peach	Aroma/flavor associated with canned peaches	22 mL canned Del Monte Peach juice in 500 mL Franzia Crisp White boxed wine

Basic Tastes

Descriptive Term	Definition	Reference
Sweetness	The taste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness	The taste stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitterness 2	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.014% caffeine in distilled water (.071g/500ml) **intensity=2**
Bitterness 6	The taste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml) **intensity=6**

Texture

Descriptive Term	Definition	Reference
Astringency 2	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.062% alum in distilled water (0.31g /500mL); **intensity=2**
Astringency 12	Chemical feeling factor on the tongue or other skin surfaces of the oral cavity described as rough/dry and associated with tannins/alum	0.25% alum in distilled water (1.25g /500mL); **intensity=12**

Aftertaste

Descriptive Term	Definition	Reference
Overall aftertaste	The overall intensity of the flavor aftertaste perceived a few seconds after swallowing.	
Sweetness aftertaste	The overall intensity of the aftertaste stimulated by sucrose and other sugars.	5.0% sucrose in distilled water (25g/500ml)
Sourness aftertaste	The intensity of the aftertaste stimulated by stimulated by acids, such as citric, malic, phosphoric, etc.	0.075% citric acid in distilled water (0.375g/500ml)
Bitter	Intensity of bitter aftertaste stimulated by substances such as quinine, caffeine, and hop bitters	0.057% caffeine in distilled water (.285g/500ml)

Appendix P: Sample SIMS Ballot-Calibration

<center>Welcome to the Sensory Center!

<center>Calibration Samples

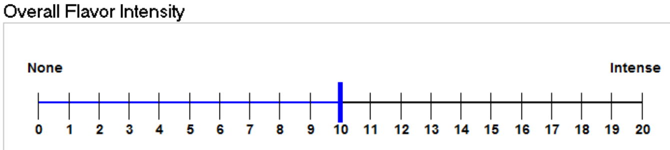
Before beginning, please take a moment to taste through your flavor intensity references and smell through your aroma intensity references.

You will be seeing TWO citric acids and ONE butanol today.

{ Page Break } { to page 2 }

Please rate sample 227 for its overall flavor intensity.

Overall Flavor Intensity



{ Page Break } { to page 3 }

The sample you just tasted has an intensity level of 3
on the flavor intensity scale.

If you did not get this correct, please take a moment to review your flavor intensity scale.

Appendix Q: Sample SIMS Ballot-Testing

<center>Welcome to the White Wine Study!

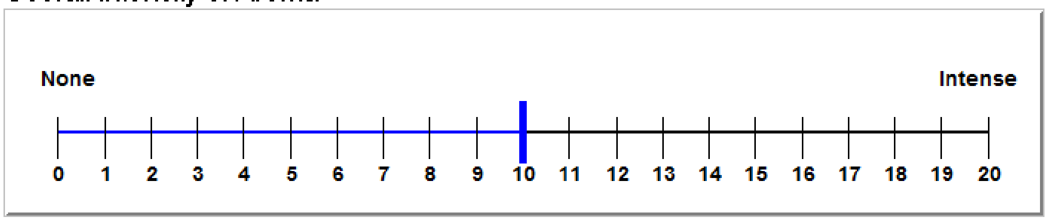
Please take your time and review your Lexicon and references before beginning.

{ Page Break } { to page 2 }

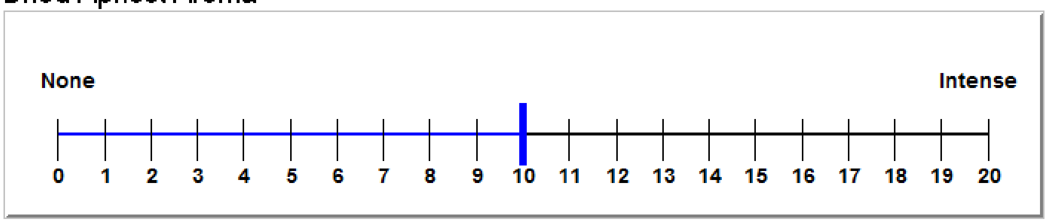
Aroma

Please lift the lid of the sample cup and rate the following:

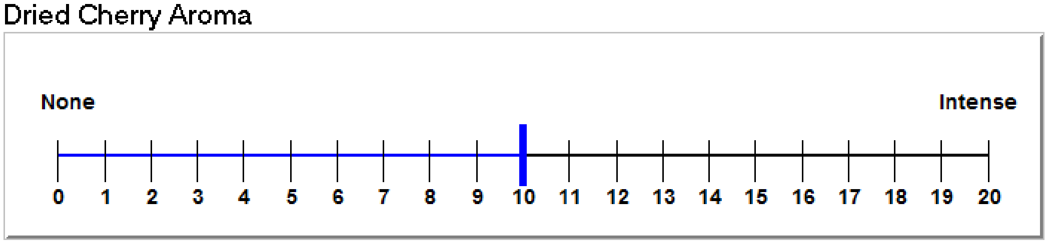
Overall Intensity of Aroma



Dried Apricot Aroma



Dried Cherry Aroma



Appendix R: Sample SAS code-Frontenac gris wine Objective A

The following was done to assign harvest dates to sample numbers

```
data xxx.frontgris4dates;
set xxx.frontgriswine16;
if Sample=1 then harvest="9/24/15";
if Sample=2 then harvest="9/24/15";
if Sample=3 then harvest="10/1/15";
if Sample=4 then harvest="10/1/15";
if Sample=5 then harvest="10/9/15";
if Sample=6 then harvest="10/9/15";
if Sample=1 then bottle="A";
if Sample=2 then bottle="B";
if Sample=3 then bottle="A";
if Sample=4 then bottle="B";
if Sample=5 then bottle="A";
if Sample=6 then bottle="B";
run;
```

The following was done to check frequencies

```
proc freq data = xxx.frontgris4dates;
run;
```

The following was done to sort data by harvest date

```
proc sort data = xxx.frontgris4dates;

by harvest;

run;
```

The following was done to find mean data by harvest date

```
proc means data =xxx.frontgris4dates;
by harvest;
var

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
Fresh_Peach_A Fresh_Apricot_A Fresh_Raspberry_A Fresh_Grapefruit_A
Strawberry_Jam_A Fresh_Green_A Leather_A G_Bell_Pepper_A Bl_Pepper_A
Corned_Beef_A Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Oak_A Sweetness Astringency Sourness Bitterness
Overall_Intensity_of_Flavor Dried_Apricot_F Metallic_F Dried_Cherry_F
Mushroom_F Soy_Sauce_F Citrus_Fruit_F Dried_Fruit_F Green_Apple_F
Banana_F Fresh_Peach_F Fresh_Apricot_F Fresh_Raspberry_F
Fresh_Grapefruit_F Strawberry_Jam_F Leather_F Oak_F G_Bell_Pepper_F
Bl_Pepper_F Corned_Beef_F Sauerkraut_F Canned_Pineapple_F
Canned_Tomato_F Canned_Peach_F Fresh_Green_F Astringency_AT
Overall_AT Sweetness_AT Sourness_AT Bitterness_AT
```

```
;
output out = meansfgwine4 mean =

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
Fresh_Peach_A Fresh_Apricot_A Fresh_Raspberry_A Fresh_Grapefruit_A
Strawberry_Jam_A Fresh_Green_A Leather_A G_Bell_Pepper_A Bl_Pepper_A
Corned_Beef_A Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Oak_A Sweetness Astringency Sourness Bitterness
Overall_Intensity_of_Flavor Dried_Apricot_F Metallic_F Dried_Cherry_F
Mushroom_F Soy_Sauce_F Citrus_Fruit_F Dried_Fruit_F Green_Apple_F
Banana_F Fresh_Peach_F Fresh_Apricot_F Fresh_Raspberry_F
Fresh_Grapefruit_F Strawberry_Jam_F Leather_F Oak_F G_Bell_Pepper_F
Bl_Pepper_F Corned_Beef_F Sauerkraut_F Canned_Pineapple_F
Canned_Tomato_F Canned_Peach_F Fresh_Green_F Astringency_AT
Overall_AT Sweetness_AT Sourness_AT Bitterness_AT
```

The following was done to find standard deviations of data by harvest date

```
stderr =
sOverall_Intensity_of_Aroma sDried_Apricot_A sDried_Cherry_A
sMushroom_A sSoy_Sauce_A sCitrus_Fruit_A sDried_Fruit_A
sGreen_Apple_A sBanana_A sFresh_Peach_A sFresh_Apricot_A
sFresh_Raspberry_A sFresh_Grapefruit_A sStrawberry_Jam_A sFresh_Green_A
sLeather_A sG_Bell_Pepper_A sBl_Pepper_A sCorned_Beef_A sSauerkraut_A
sCanned_Peach_A sCanned_Tomato_A sCanned_Pineapple_A sOak_A
sSweetness sAstringency sSourness sBitterness
sOverall_Intensity_of_Flavor sDried_Apricot_F sMetallic_F
sDried_Cherry_F sMushroom_F sSoy_Sauce_F sCitrus_Fruit_F sDried_Fruit_F
sGreen_Apple_F sBanana_F sFresh_Peach_F sFresh_Apricot_F
sFresh_Raspberry_F sFresh_Grapefruit_F sStrawberry_Jam_F sLeather_F
sOak_F sG_Bell_Pepper_F sBl_Pepper_F sCorned_Beef_F sSauerkraut_F
sCanned_Pineapple_F sCanned_Tomato_F sCanned_Peach_F sFresh_Green_F
sAstringency_AT sOverall_AT sSweetness_AT sSourness_AT sBitterness_AT
;
run;
```

The following was done to find F and p-values of the means across judge, harvest date, replicate, and bottle

```
Proc glm data = xxx.frontgris4dates outstat=fgwinestats4;
class Judge harvest Rep bottle;
model

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
Fresh_Peach_A Fresh_Apricot_A Fresh_Raspberry_A Fresh_Grapefruit_A
Strawberry_Jam_A Fresh_Green_A Leather_A G_Bell_Pepper_A Bl_Pepper_A
Corned_Beef_A Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Oak_A Sweetness Astringency Sourness Bitterness
Overall_Intensity_of_Flavor Dried_Apricot_F Metallic_F Dried_Cherry_F
Mushroom_F Soy_Sauce_F Citrus_Fruit_F Dried_Fruit_F Green_Apple_F
```

```
Banana_F Fresh_Peach_F Fresh_Apricot_F Fresh_Raspberry_F
Fresh_Grapefruit_F Strawberry_Jam_F Leather_F Oak_F G_Bell_Pepper_F
Bl_Pepper_F Corned_Beef_F Sauerkraut_F Canned_Pineapple_F
Canned_Tomato_F Canned_Peach_F Fresh_Green_F Astringency_AT
Overall_AT Sweetness_AT Sourness_AT Bitterness_AT

=Judge harvest Rep  / solution;
means harvest/snk alpha=0.1;
run;

quit;
```

Appendix S: SAS code-Frontenac gris wine Objective B

The following was done to assign sample numbers to wineries

```
data xxx.frontgriswine17;
set frontgriswine17  ;

 run;


data xxx.frontgriswine17;
set frontgriswine17;
if sample='sldr_crk_13' then Sample=1;
if sample='frsdrsd' then Sample=2;
if sample='tckr_wlk_1' then Sample=3;
if sample='rnd_lk' then Sample=4;
if sample='grp_ml' then Sample=5;
if sample=tckr_wlk_3 then Sample=6;
if sample=sldr_crk_14 then Sample=7;
if sample=cls_crk then Sample=8;
if sample=vns_rsh then Sample=9;
if sample=ind_isl then Sample=10;
if sample=svrgn_est then Sample=11;
if sample=st_crx then Sample=12;
if sample=prly_lk then Sample=13;
if sample=cyt_moon then Sample=14;
if sample=wn_hvn then Sample=15;
if sample=burr then Sample=16;
if sample=rchwd then Sample=17;
if sample=crw_rvr then Sample=18;
if sample=snta_mra then Sample=19;
run;
```

The following was done to check frequencies

```
proc freq data = xxx.frontgriswine17;
 run;
```

The following was done to sort data by wine sample

```
proc sort data = xxx.frontgriswine17;

by Sample;

run;
```

The following was done to find mean data by wine sample

```
proc means data =xxx.frontgriswine17;
by Sample;
var

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
```

```
Fresh_Apricot_A Fresh_Pineapple_A Coconut_A Floral_A
Hot_Pepper_A Fresh_Straw_A Art_Grape_A Green_Wood_A Lemon_A
Fresh_Raspberry_A Fresh_Grapefruit_A Strawberry_Jam_A Rasp_Jam_A
Fresh_Green_A Leather_A Bl_Pepper_A Corned_Beef_A
Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Honey_A Oak_A Cantaloupe_A Gr_Pep_A Sweetness
Astringency Sourness Bitterness Overall_Intensity_of_Flavor
Dried_Apricot_F Metallic_F Dried_Cherry_F Mushroom_F Soy_Sauce_F
Citrus_Fruit_F Dried_Fruit_F Green_Apple_F Banana_F
Fresh_Apricot_F Fresh_Raspberry_F Coconut_F Fresh_Pineapple_F
Floral_F Hot_Pepper_F Fresh_Straw_F Art_Grape_F Green_Wood_F
Lemon_F Fresh_Grapefruit_F Strawberry_Jam_F Raspberry_Jam_F
Fresh_Green_F Leather_F Oak_F Honey_F Bl_Pepper_F Corned_Beef_F
Sauerkraut_F Canned_Pineapple_F Canned_Tomato_F Canned_Peach_F
_Cantaloupe_F Gr_Pep_F Astringency_AT Overall_AT Sweetness_AT
Sourness_AT Bitterness_AT
;
output out = meansfgwine17 mean =

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
Fresh_Apricot_A Fresh_Pineapple_A Coconut_A Floral_A
Hot_Pepper_A Fresh_Straw_A Art_Grape_A Green_Wood_A Lemon_A
Fresh_Raspberry_A Fresh_Grapefruit_A Strawberry_Jam_A Rasp_Jam_A
Fresh_Green_A Leather_A Bl_Pepper_A Corned_Beef_A
Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Honey_A Oak_A Cantaloupe_A Gr_Pep_A Sweetness
Astringency Sourness Bitterness Overall_Intensity_of_Flavor
Dried_Apricot_F Metallic_F Dried_Cherry_F Mushroom_F Soy_Sauce_F
Citrus_Fruit_F Dried_Fruit_F Green_Apple_F Banana_F
Fresh_Apricot_F Fresh_Raspberry_F Coconut_F Fresh_Pineapple_F
Floral_F Hot_Pepper_F Fresh_Straw_F Art_Grape_F Green_Wood_F
Lemon_F Fresh_Grapefruit_F Strawberry_Jam_F Raspberry_Jam_F
Fresh_Green_F Leather_F Oak_F Honey_F Bl_Pepper_F Corned_Beef_F
Sauerkraut_F Canned_Pineapple_F Canned_Tomato_F Canned_Peach_F
_Cantaloupe_F Gr_Pep_F Astringency_AT Overall_AT Sweetness_AT
Sourness_AT Bitterness_AT
```

The following was done to find standard deviations of data by wine sample

```
stderr =
sOverall_Intensity_of_Aroma sDried_Apricot_A sDried_Cherry_A
sMushroom_A sSoy_Sauce_A sCitrus_Fruit_A sDried_Fruit_A
sGreen_Apple_A sBanana_A sFresh_Apricot_A sFresh_Pineapple_A
sCoconut_A sFloral_A sHot_Pepper_A sFresh_Straw_A
sArt_Grape_A sGreen_Wood_A sLemon_A sFresh_Raspberry_A
sFresh_Grapefruit_A sStrawberry_Jam_A sRasp_Jam_A
sFresh_Green_A sLeather_A sBl_Pepper_A sCorned_Beef_A
sSauerkraut_A sCanned_Peach_A sCanned_Tomato_A sCanned_Pineapple_A
sHoney_A sOak_A sCantaloupe_A sGr_Pep_A sSweetness sAstringency
sSourness sBitterness sOverall_Intensity_of_Flavor sDried_Apricot_F
sMetallic_F sDried_Cherry_F sMushroom_F sSoy_Sauce_F sCitrus_Fruit_F
```

```
sDried_Fruit_F sGreen_Apple_F sBanana_F sFresh_Apricot_F
sFresh_Raspberry_F sCoconut_F sFresh_Pineapple_F sFloral_F
sHot_Pepper_F sFresh_Straw_F sArt_Grape_F sGreen_Wood_F sLemon_F
sFresh_Grapefruit_F sStrawberry_Jam_F sRaspberry_Jam_F sFresh_Green_F
sLeather_F sOak_F sHoney_F sBl_Pepper_F sCorned_Beef_F sSauerkraut_F
sCanned_Pineapple_F sCanned_Tomato_F sCanned_Peach_F s_Cantaloupe_F
sGr_Pep_F sAstringency_AT sOverall_AT sSweetness_AT sSourness_AT
sBitterness_AT

;
run;
```

The following was done to find F and p-values of the means across judge, wine sample, replicate, and order

```
Proc glm data = xxx.frontgriswine17 outstat=fgwinestats17;
class Judge Sample Rep Order;
model

Overall_Intensity_of_Aroma Dried_Apricot_A Dried_Cherry_A Mushroom_A
Soy_Sauce_A Citrus_Fruit_A Dried_Fruit_A Green_Apple_A Banana_A
Fresh_Apricot_A Fresh_Pineapple_A Coconut_A Floral_A
Hot_Pepper_A Fresh_Straw_A Art_Grape_A Green_Wood_A Lemon_A
Fresh_Raspberry_A Fresh_Grapefruit_A Strawberry_Jam_A Rasp_Jam_A
Fresh_Green_A Leather_A Bl_Pepper_A Corned_Beef_A
Sauerkraut_A Canned_Peach_A Canned_Tomato_A
Canned_Pineapple_A Honey_A Oak_A Cantaloupe_A Gr_Pep_A Sweetness
Astringency Sourness Bitterness Overall_Intensity_of_Flavor
Dried_Apricot_F Metallic_F Dried_Cherry_F Mushroom_F Soy_Sauce_F
Citrus_Fruit_F Dried_Fruit_F Green_Apple_F Banana_F
Fresh_Apricot_F Fresh_Raspberry_F Coconut_F Fresh_Pineapple_F
Floral_F Hot_Pepper_F Fresh_Straw_F Art_Grape_F Green_Wood_F
Lemon_F Fresh_Grapefruit_F Strawberry_Jam_F Raspberry_Jam_F
Fresh_Green_F Leather_F Oak_F Honey_F Bl_Pepper_F Corned_Beef_F
Sauerkraut_F Canned_Pineapple_F Canned_Tomato_F Canned_Peach_F
_Cantaloupe_F Gr_Pep_F Astringency_AT Overall_AT Sweetness_AT
Sourness_AT Bitterness_AT

=Judge Sample Rep Order;

means Sample Rep Order / snk;
run;

quit;
```

Appendix T: R code-Frontenac gris wine Objective B

The following was done to import data and define x as working data

```
wine <- read.csv("C:/Users/brady270/Desktop/combined data 6.20.17.csv",header=T)
head(wine)
summary(wine)
ncol(wine)
nrow(wine)
x <- wine[,c((7:43),(45:79),(81:83))]
ncol(x)
head(x)
as.factor(wine$Judge)
```

The following was done to observe histograms of data

```
#aroma
hist(wine$Overall.Intensity.of.Aroma)
hist(x$Dried.Apricot.A)
hist(x$Dried.Cherry.A)
hist(x$Mushroom.A)
hist(x$Soy.Sauce.A)
hist(x$Citrus.Fruit.A)
hist(x$Dried.Fruit.A)
hist(x$Green.Apple.A)
hist(x$Banana.A)
hist(x$Fresh.Apricot.A)
hist(x$Fresh.Pineapple.A)
hist(x$Coconut.A)
hist(x$Floral.A)
hist(x$Hot.Pepper.A)
hist(x$Fresh.Straw.A)
hist(x$Art.Grape.A)
hist(x$Green.Wood.A)
hist(x$Lemon.A)
hist(x$Fresh.Raspberry.A)
hist(x$Fresh.Grapefruit.A)
hist(x$Strawberry.Jam.A)
hist(x$Rasp.Jam.A)
hist(x$Fresh.Green.A)
hist(x$Leather.A)
hist(x$Bl.Pepper.A)
hist(x$Corned.Beef.A)
hist(x$Sauerkraut.A)
```

```
hist(x$Canned.Peach.A)
hist(x$Canned.Tomato.A)
hist(x$Canned.Pineapple.A)
hist(x$Honey.A)
hist(x$Oak.A)
hist(x$Cantaloupe.A)
hist(x$Gr.Pep.A)

#taste
hist(x$Sweetness)
hist(x$Astringency)
hist(x$Sourness)
hist(x$Bitterness)

#flavor
hist(wine$Overall.Intensity.of.Flavor)
hist(x$Dried.Apricot.F)
hist(x$Metallic.F)
hist(x$Dried.Cherry.F)
hist(x$Mushroom.F)
hist(x$Soy.Sauce.F)
hist(x$Citrus.Fruit.F)
hist(x$Dried.Fruit.F)
hist(x$Green.Apple.F)
hist(x$Banana.F)
hist(x$Fresh.Apricot.F)
hist(x$Fresh.Raspberry.F)
hist(x$Coconut.F)
hist(x$Fresh.Pineapple.F)
hist(x$Floral.F)
hist(x$Hot.Pepper.F)
hist(x$Fresh.Straw.F)
hist(x$Art.Grape.F)
hist(x$Green.Wood.F)
hist(x$Lemon.F)
hist(x$Fresh.Grapefruit.F)
hist(x$Strawberry.Jam.F)
hist(x$Raspberry.Jam.F)
hist(x$Fresh.Green.F)
hist(x$Leather.F)
hist(x$Oak.F)
hist(x$Honey.F)
hist(x$Bl.Pepper.F)
hist(x$Corned.Beef.F)
hist(x$Sauerkraut.F)
hist(x$Canned.Pineapple.F)
hist(x$Canned.Tomato.F)
hist(x$Canned.Peach.F)
```

```
hist(x$Cantaloupe.F)
hist(x$Gr.Pep.F)

#AT
hist(x$Astringency.AT)
hist(wine$Overall.AT)
hist(x$Sweetness.AT)
hist(x$Sourness.AT)
hist(x$Bitterness.AT)
```

The following was done to find common attributes of Frontenac gris

```
winesample<-split(wine,wine$Sample)
length(winesample)
winemat<-t(sapply(winesample,function(y) colMeans(y[,6:83]>=1)))
head(winemat)
colMeans(winemat)
```

The following was done to set up data for PARAFAC analysis

```
install.packages("multiway")
library(multiway)


X <- array(NA, dim = c(10, 75, 19))
ilev <- levels(factor(wine$Judge))
ilev
wlev <- levels(wine$Sample)
wlev
for(i in 1:10){
  for(j in 1:19){
    xsub <- subset(x, wine$Judge == ilev[i] & wine$Sample == wlev[j])
    X[i,,j] <- colMeans(xsub)
  }
}
dimnames(X) <- list(ilev, names(x), wlev)
dimnames(X)

dim(X)
```

The following was done to change array into winery x attribute x judge

```
X <- aperm(X, perm = c(3,2,1))
```

The following was done to get averages across judges

```
Xavg <- apply(X, 1:2, mean)
```

The following was done to center each attribute across wineries for each judge

```
Xc <- ncenter(X, mode = 1)
```

The following was done to scale each attribute across wineries and judges

```
Xs <- nscale(Xc, mode = 2, ssnew = prod(dim(Xc)[c(1,3)]))
```

The following was done to choose the number of factors to use (2 factors were chosen based on this)

```
pflist <- vector("list", 10)
for(k in 1:10){
  cat("# of Factors:",k,"\n")
  set.seed(1)
  pflist[[k]] <- parafac(Xs, nfac = k, nstart = 25)
}
SSE <- sapply(pflist, function(x) x$SSE)
Rsq <- sapply(pflist, function(x) x$Rsq)
plot(1:10, SSE)
plot(1:10, 1 - Rsq)

# get ccd
ccd <- rep(0, 10)
for(k in 1:10){
  ccd[k] <- corcondia(Xs, pflist[[k]])
}
Ccd

#provides strong evidence for the R = 2 factor solution in this case.
```

The following was done to fit PARAFAC

```
set.seed(1)
pfac <- parafac(Xs, nfac=2, nstart=100, const = c(0,0,0))
pfac

pfac <- resign(resign(pfac), mode = "B")
pfac$A
pfac$B
```

The following was done to plot figures of PARAFAC results

```
par(mfrow=c(1,2))
```

```
dev.new(width=10, height=5)
plot(pfac$A, xlab="Dimension 1", ylab="Dimension 2", main = "Mode A (Wine) weights")
abline(h = 0, lty=3)
abline(v = 0, lty=3)
text(pfac$A, dimnames(X)[[1]])

dev.new(width=10, height=5)
plot(pfac$B, xlab="Dimension 1", ylab="Dimension 2", main = "Mode B (Attribute) weights")
abline(h = 0, lty=3)
abline(v = 0, lty=3)
text(pfac$B, dimnames(X)[[2]], cex=0.5)
```

Appendix U: Frontenac gris winery data-Objective B

winery	zip code	vintage	sweetness	yeast	residual sugar	alcohol percent
Winehaven Winery	55013	2013	off-dry	71B	0.75% or less	12.1%-14%
Saint Croix Vineyards	55082	2015	semi-sweet	71B, Lalvin C	0.76%-1.5%	10.1%-12%
Carlos Creek Winery	56308, 56378, 56229, 56170, 55446, 56347, 56401, 55051	2015	semi-sweet	Lalvin C,SVG,R2	2.6%-6.0%	10.1%-12%
Crow River Winery	55350	2015	dry	B11	0.75% or less	12.1%-14%
Sovereign Estate	55987	2015	dry	Wild Ferment	0.75% or less	10.1%-12%
Burr Vineyards	56315	2015	dry	Cote des blanc	0.75% or less	14.1%-16%
Fireside Winery	52301	2015	semi-sweet	QA23	2.6%-6.0%	10.1%-12%
Vines & Rushes Winery	53569	2015	semi-sweet	Epernay 2	2.6%-6.0%	12.1%-14%
Soldier Creek Winery	50501	2013	semi-sweet	R-HST	1.6%-2.5%	12.1%-14%
Soldier Creek Winery	50501	2014	semi-sweet	R-HST	2.6%-6.0%	10.1%-12%
Tucker's Walk Vineyard and Farm Winery	57030	2014	semi-sweet	DV10	1.6%-2.5%	12.1%-14%
Tucker's Walk Vineyard and Farm Winery	57030	2015	semi-sweet	DV10	1.6%-2.5%	12.1%-14%
Coyote Moon Vineyards	13624	2014	dry	71B	0.76%-1.5%	12.1%-14%
Grape Mill Vineyard & Winery	56721, 55372	2015	semi-sweet	71B	1.6%-2.5%	12.1%-14%
Richwood Winery	56521, 56222	2012	semi-sweet	M1	1.6%-2.5%	12.1%-14%
Santa Maria Winery	51401	2016	semi-sweet	V1118	2.6%-6.0%	10.1%-12%
Parley Lake Winery	55387	2015	n/a	n/a	n/a	12.1%-14%
Indian Island Winery	56048	n/a	semi-sweet	n/a	n/a	n/a
Round Lake Vineyard and Winery	56167	2015	n/a	n/a	n/a	10.1%-12%

Appendix V: Summary means (n = 10) data Objective B Part 1

Sample	burr	carlos creek	crow river	coyote moon	fireside	grape mill	indian island	parley lake	richwood	round lake
Dried Apricot Aroma	1.9	2.1	2.1	2.3	2.3	2.0	2.0	1.8	2.2	2.4
Dried Cherry Aroma	2.1	1.5	1.3	2.4	2.4	1.9	2.0	2.1	2.0	2.3
Citrus Fruit Aroma	3.1	2.3	2.2	1.9	2.1	2.0	1.9	2.5	2.6	2.2
Dried Fruit Aroma	2.6	2.5	2.3	2.6	2.4	2.8	2.9	2.4	2.4	3.1
Fresh Strawberry Aroma	2.0	2.0	1.6	2.1	3.0	1.8	2.2	1.8	2.2	1.8
Green Wood Aroma	2.1	2.3	2.1	2.4	1.3	2.3	1.7	2.6	2.4	1.8
Canned Peach Aroma	2.2	2.4	2.2	2.3	3.3	2.6	2.6	2.2	3.0	2.3
Sweetness	2.6	5.4	4.2	1.1	6.8	3.9	4.9	2.4	1.2	3.9
Astringency	3.1	1.2	2.4	2.9	1.8	2.2	2.0	2.8	3.1	2.7
Sourness	5.4	2.4	3.9	5.7	2.1	3.6	3.0	4.7	4.8	4.0
Bitterness	3.1	1.6	1.9	2.7	1.4	2.0	1.7	2.6	3.2	2.2
Dried Apricot Flavor	2.4	2.2	2.4	1.7	2.9	2.5	2.2	2.2	1.7	2.6
Dried Cherry Flavor	2.3	2.5	2.5	1.6	2.9	2.3	2.6	2.0	1.5	2.3
Citrus Fruit Flavor	3.3	2.5	2.3	3.1	2.0	2.3	1.7	3.0	2.8	2.1
Dried Fruit Flavor	2.3	3.2	2.8	2.2	3.5	2.7	3.3	2.0	2.3	2.9
Fresh Strawberry Flavor	2.3	2.7	2.8	2.1	3.0	2.1	2.3	2.1	1.6	2.0
Green Wood Flavor	2.6	2.0	1.8	2.1	1.1	2.2	1.4	2.6	2.8	2.0
Fresh Green Flavor	2.4	1.5	1.5	2.1	1.2	2.3	1.5	2.2	2.7	1.9
Canned Pineapple Flavor	1.9	2.6	2.5	1.6	2.3	2.2	2.2	1.8	1.4	2.1

Part 2

Sample	soldier creek 2013	soldier creek 2014	santa maria	saint croix	sovereign estate	tucker walk 1	tucker walk 3	vines and rushes	wine-haven
Dried Apricot Aroma	2.0	1.8	3.4	2.4	2.3	2.3	2.6	2.3	2.2
Dried Cherry Aroma	2.2	1.3	2.8	1.9	2.2	1.9	2.3	1.6	1.9
Citrus Fruit Aroma	2.8	1.7	1.5	2.1	1.8	3.0	2.8	1.7	2.4
Dried Fruit Aroma	2.2	2.3	3.7	2.8	2.7	2.7	2.7	2.5	2.2
Fresh Strawberry Aroma	2.2	1.5	2.0	2.1	2.1	2.3	2.0	1.4	2.9
Green Wood Aroma	2.3	2.1	1.8	2.0	1.9	1.8	2.3	2.6	1.4
Canned Peach Aroma	2.6	2.2	2.7	2.5	1.8	2.2	2.4	1.9	2.5
Sweetness	2.3	3.2	7.0	2.6	0.8	3.1	3.1	3.3	0.9
Astringency	2.5	2.0	1.4	2.2	2.8	2.4	3.0	2.2	2.8
Sourness	3.9	3.5	1.8	3.8	5.4	5.0	4.6	4.3	4.0
Bitterness	2.7	1.7	0.8	2.6	3.5	2.1	2.1	2.1	3.7
Dried Apricot Flavor	2.0	2.1	2.9	2.2	1.7	2.7	2.2	2.5	1.2
Dried Cherry Flavor	1.5	2.0	3.0	2.1	1.6	2.0	2.1	2.0	0.9
Citrus Fruit Flavor	2.0	2.5	1.8	2.8	3.2	3.2	3.1	2.7	2.3
Dried Fruit Flavor	2.3	2.4	4.0	2.4	1.9	2.7	2.6	2.6	1.4
Fresh Strawberry Flavor	1.4	1.9	2.9	2.2	1.6	2.4	2.6	1.8	1.0
Green Wood Flavor	2.9	2.1	1.2	2.6	2.8	2.0	1.9	2.3	3.0
Fresh Green Flavor	2.6	1.8	1.0	2.1	2.6	2.0	2.0	2.2	2.7
Canned Pineapple Flavor	1.3	1.8	2.4	2.0	1.1	2.2	2.5	1.8	1.1