SENSORY CHARACTERIZATION OF FRONTENAC AND MARQUETTE WINE GRAPE CULTIVARS BY DESCRIPTIVE ANALYSIS

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Dedication

This thesis is dedicated to my family: my mother, father, sister, aunt, and grandparents for supporting me through the long journey I have taken to get to this point.

Most of all, I dedicate this to my husband, Brandon. Thank you for being everything to me.

"You are the butter to my bread, the breath to my life."
"Life without you is like unsalted food".
- Paul Child

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Chapter 1 : Introduction

Interest in producing wine grapes that will grow in more northern and inland climates such as South Dakota and Minnesota has existed since the early 1900s (Luby, 1991), however, breeding work in the last thirty years has been especially productive, and has resulted in the development of a number of cold-hardy wine grape cultivars (Luby & Hemstad, 2000). Frontenac and Marquette red wine grapes are two such cold-hardy varietals released by the University of Minnesota grape breeding program.

Frontenac grapes are small to medium in size with blue-purple skin and pigmented flesh ("Frontenac Viticulture," 2012). Wine made from them is described as having a cherry aroma and flavors of berry, black currant, and plum. Previous research on this cultivar includes identification and characterization of aroma compounds (Mansfield, Schirle-Keller, & Reineccius, 2011) (Mansfield, 2008), and descriptive analysis of the aroma (Mansfield & Vickers, 2009). The grape berries of Marquette are smaller, darker and ripen slightly earlier than Frontenac (Hemstad & Luby, 2008) Marquette wine is unique among non-*V. vinifera* wines in that it contains considerable tannins, lending complexity to the wines and complementing the aromas and flavors of cherry, berry, black pepper, and spice (Hemstad & Luby, 2008).

The current study was designed to define 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. Paired with information about the chemical maturity of the grapes, this

knowledge may improve determination of the optimal maturity of wine grapes and help improve the overall quality of these wines.

Chapter 2 : Literature Review

2.1 Cold-hardy grape origins and varietals

Almost all of the wine names that the average consumer would recognize such as Cabernet Sauvignon, Merlot, Pinot Noir, and Shiraz are made from varieties of the *Vitis vinifera* wine grape species. These grapes were originally imported from Europe in the early days of this country and according to the USDA Plants Database profile of *Vitis vinifera* L. wine grape (http://plants.usda.gov/core/profile?symbol=VIVI5) are now grown in many west coast states (Oregon, Washington, and California), east coast states (Pennsylvania, New York, Massachusetts, Virginia, and Florida) and southern states (Texas, Alabama) in addition to Idaho and Utah.

Grape breeding at The University of Minnesota that began in 1908 by developing cold-hardy table grape and juice grape cultivars transitioned in the 1970s to the development of cold-hardy wine grape cultivars (Luby & Hemstad, 2000). These are generally hybrids made from some combination of the *V. vinifera*, *V. labrusca* (fox grape), and *V. riparia* species.

2.1.1 *Vitis riparia* as a breeding stock for cold-hardy grapes

Vitis riparia is a species of grape native to North America that is extremely cold hardy, and can be found from the eastern United States west into Colorado and north into Canada (Luby & Hemstad, 2000). It has the ability to resist cold down to -40°C and is resistant to powdery mildew, downy mildew, and phyloxera. Although the grape berries of *V. riparia* are undesirable for wine production (Hemstad & Luby, 2008) primarily due to high acidity, it has been successfully used in the breeding of cold-hardy wine grape

cultivars, including Maréchal Foch (Mansfield & Vickers, 2009), Frontenac, and most recently, Marquette (Hemstad & Luby, 2008).

2.1.2 Frontenac

The University of Minnesota grape breeding program released Frontenac (originally called MN 1047) in 1996. It is a red wine grape produced from the cross of the cultivar Landot 4511 and the native grape *Vitis riparia* (Mansfield & Vickers, 2009). Frontenac has been a successful producer of wine grapes in central Minnesota, where winter temperatures can reach -33°C ("Frontenac Viticulture," 2012). In 2007, Frontenac was the most-planted grape cultivar in Minnesota (Tordsen, Mansfield, & Smiley, 2007), however, it quickly lost ground to Marquette and as of 2012 accounted for approximately 22% of grapes planted (Tuck & Gartner, 2011).

2.1.3 Marquette

Marquette is a red wine grape that was released by the University of Minnesota in 2006, and is a cousin of Frontenac and grandson of Pinot noir (Hemstad & Luby, 2008). It originated by crossing MN 1094 with Ravat 262, and its breeding ancestry includes *V. riparia*, *V. vinifera*, and several other species of *Vitis*. Its disease resistance and ability to survive in climates with very cold winters is comparable to that of Frontenac.

Marquette's potential was quickly recognized by the Minnesota wine industry and in 2011 represented 53% of planted cold-hardy vines in Minnesota, comprising over 42,000 vines (Tuck & Gartner, 2011).

2.2 Contributions to wine aroma and flavor

Wine flavors and aromas originate with the wine grapes, the yeast, and any additional mediums encountered during the process such as barrels. The manipulation of these 'ingredients' affect the aroma and flavor of the final wine. The handling of the grapes up until harvest is perhaps the most complicated of these aspects to control and includes climate, canopy management, cluster management, and watering methods. The decision when to harvest, the process of extraction and maceration, (including oxidation and hydrolysis (Mansfield, 2008)), the fermentation process, and any aging of the wine (Ebeler, 2001) are all contributors to the final character of the wine.

2.2.1 Grapes

Grapes are the largest contributor to the distinct flavors and aromas that characterize varietal typicity (the degree to which the wine tastes like the varietal). The vast majority of sugars present in mature grapes are fructose and glucose (Kliewer, 1967), and the primary acids present in grapes are tartaric and malic, with tartaric acid being predominant (Lamikanra, Inyang, & Leong, 1995). Other compounds contributed by grapes include secondary metabolites such as anthocyanins (which contribute to astringency) and volatile compounds that characterize the 'fruity' aspects of wine.

2.2.2 Fermentation

Fermentation of the grapes occurs when yeast converts sugars into alcohol and carbon dioxide. The characteristics produced by the initial (or only) fermentation of wine are driven by the yeast used in production. In fact, this ingredient plays such a large role in the final wine flavor that use of the same yeast on different fruit substrates (for example: currants and grapes) has been found to produce very similar wines (Nykanen, 1985).

2.2.3 Malolactic fermentation

Cold–hardy grapes are fundamentally high acid producers due to their *V. riparia* lineage and often undergo a secondary fermentation, or malolactic fermentation (MLF), to reduce the overall acidity of the wine. This fermentation can either be done during or after primary alcoholic fermentation by *Saccharomyces cerevisiae*. and is catalyzed by lactic acid bacteria (Liu, 2002). This process converts malic acid to lactic acid, and not only decreases wine acidity, and can also produce flavors such as 'buttery'. (Ebeler, 2001)

2.2.4 Aging of wines

One of the primary reactions that change wine flavor during aging is the conversion of ethanol, glycerol, and acetic acid to acetaldehyde. Therefore, un-aged wines tend to have a higher alcohol percentage, a higher acid level, and can be described as more fruity than the same wine that has been aged (Muoz, Peinado, Medina, & Moreno, 2008). They will also tend to have fewer woody, vanilla, and nutty characteristics since they have not been aged in wood vessels (Ebeler, 2001).

2.3 Grape berry development and maturity

Grape berries develop in two stages separated by a lag phase. During the first stage the berry develops from the flower, then expands in volume through rapid cell division, and tannins and acids begin to form (Kennedy, 2002). At the end of this first stage the number of cells is fixed and any subsequent increase in berry size is due to enlargement of the cells (Harris, Kriedemann, & Possingham, 1968).

The second stage of development is categorized by the start of ripening, or véraison, in which the berry begins to soften, change color from green to purple (in the case of red

wine grapes) and sweeten due to a rapid influx of sucrose and the conversion of sucrose to glucose and fructose (Kennedy, 2002). Levels of acid decline both as the grapes grow larger (decrease in the percentage) and as some of them are utilized during the respiration process (Watson, 2003)

Bisson (Bisson, 2001) suggested that there are four sub-stages to véraison. During the first stage, water and sugars accumulate in the grape berry via transportation through the phloem. In the berry, sucrose is hydrolyzed to fructose and glucose, and flavor and aroma compounds are synthesized. The second stage of véraison is characterized by the halt of water and sugar transport through the phloem. In the third stage, the brix continues to rise, but this increase in sugar level is no longer due to the production of sugars (and subsequent transportation of sugars into the grape berry), but instead due to the desiccation of the grape berries through evaporation. The fourth stage is described as raisining, resulting in the extreme dehydration of the grape berries, formation of brown color pigments, and loss of flavor quality (Serratosa, Lopez-Toledano, Merida, & Medina, 2008). At some point during the second and third stage, production of desirable aroma flavor compounds is halted, and deterioration of these compounds occurs sometime during the third and fourth stage.

Because of the rate at which ripening occurs, a few days can mean the difference between a perfectly ripe grape crop and one past its prime. An overripe crop is characterized by a higher ratio of fructose to glucose (resulting in sweeter berries) (Kliewer, 1967), a lower acid content, and dehydration of the grape berries (Carroll, 1978).

2.3.1 Maturity and wine quality

Grapes that are underripe or even slightly overripe can cause a significant decrease in the perceived quality of the wine made. Carroll and others (Carroll, 1978) sorted Carlos muscadine grapes into four ripeness classes (1 being the least ripe and 4 being the most ripe) by using an optical berry sorting unit to evaluate the influence of grape ripeness on wine quality. Wines were made from each of the four ripeness levels, and sensory analysis was performed on the resulting wines by a panel of 8-12 judges. Judges rated the quality of the wines on a 20 point scale. The wines made from classes 2 and 3 (determined to be at the optimum ripeness levels) were determined to be of higher quality than those of class 1 (under ripe) or class 4 (slightly overripe). Class 1 wines were described as too tart, lacking balance, and low in aroma and flavor, while class 4 wines were described as 'flat', having a bitter aftertaste, and too yellow. Therefore, it is very important to harvest grapes at the peak of ripeness.

2.4 Determining grape maturity by chemical analysis

Flavor compounds rapidly develop in the final stages of ripening of the grape berries, as do secondary metabolites such as glycosides that do not become volatile until after the wine is produced (Francis, Kassara, Noble, & Williams, 1998). These compounds are not easily measured, and are impossible to measure in the field, so the vineyard manager must rely on chemical measurements such as pH, sugar level, and ratios of sugar and acid to determine the optimal harvest time.

2.4.1 Brix and Total Soluble Solids

Brix is a measurement of the percent (w/w) of sucrose in an aqueous solution and is reported in degrees or °Brix. In the case of grape juice, which contains very little sucrose

at harvest due to the conversion of sucrose to glucose and fructose, brix can be used to estimate the total soluble solids (TSS) in the grape juice, which can be used as a rough measurement of the amount of sugar in the grape juice. Levels of soluble solids in grape berries are within 1% of actual sugar content at or close to maturity (Jackson, Lombard, & Kabinett, 1993). This measurement is easily taken in the field by use of a handheld refractometer and should be done by randomly sampling a few berries, measuring their °Brix and calculating an average measurement (Plocher & Parke, 2008). This measurement can be misleading when used as a sole determination of ripeness of wine grapes, however, since the acid levels are also important.

2.4.2 pH and titratable acidity

The measurement of acid in the grape berries can also be a useful measurement of ripeness. Two measurements of acidity are used by enologists: pH, or the concentration of hydrogen ions present, or titratable acidity or total acidity (TA), which is a measurement of all of the acids present in the grapes (though primarily malic and tartaric acids), and is given in equivalent units of tartaric acid. pH can be measured in the field by use of a pH pen, though TA must be measured by titrating the juice against sodium hydroxide. Again, neither of these measurements alone can provide an adequate determination of ripeness.

2.4.3 Sugar to acid ratio

Sugar to acid ratio measurements are an attempt to use a single parameter to quantify fruit ripeness in species (such as grapes) that show an increase in sugar content and a decrease in acidity as the fruit ripens. A number of studies have evaluated the use of this ratio to determine quality in wines.

Ough and Alley (Ough & Alley, 1970) evaluated the effect of Thomson Seedless grape maturity on wine quality by harvesting five levels of maturity each year for three years and making them into wines. A panel of six expert tasters ranked each maturity level by perceived quality. These rankings were plotted against the Brix/acid ratio of the grapes, and used to determine that the optimum maturity for this grape varietal was located somewhere between 27 and 35 Brix/acid ratio. This is a fairly large spread, though they indicated that for that variety of grapes grown at that particular location they could narrow the range to 30-32.

Suresh and Ethiraj (Suresh & Ethiraj, 1987) evaluated the effect of grape maturity on wine quality of three new varietals (Arka Kanchan, Arka Shyam, and Bangalore Blue) and the well-established Thomson Seedless by harvesting wine grapes at three stages of maturity (early, intermediate, and late based on undisclosed measurements from previous years) and making wines for sensory evaluation. Six judges ranked the wines on perceived quality after one year. They concluded that the Arka Kanchan and Bangalore Blue grapes with low Brix to acid ratios (about 19.5) from the low maturity grapes produced better quality wines. The Arka Shyam grapes that produced the highest quality wines were the intermediate maturity grapes with Brix to acid ratios of 24.5 and 30.9 depending on the year. The Thomson Seedless grapes that produced the highest quality wines were the low maturity grapes from the first year (Brix to acid ratio of 25.7) and intermediate maturity grapes for the second year (Brix to acid ratio of 28.7). This study exemplifies the challenges of choosing an ideal brix to acid ratio to make wine from since the quality varies even within varietals by year. (Interesting note: the Kramer Ranking

method used to analyze the date in this study was later found to be invalid (O'Mahony, 1986).)

2.5 Determining grape maturity by sensory evaluation

Sensory evaluation is perhaps the most subjective way to determine the maturity of the grape, however, in addition to standard chemical measurements, the flavor and aroma of grapes can provide valuable information about the maturity and wine potential that is not measureable any other way.

2.5.1 Descriptive analysis of grapes

Descriptive analysis has been used to characterize wine grapes such as Semillon (Lohitnavy, Bastian, & Collins, 2010), and Cabernet Franc (Le Moigne, Maury, Bertrand, & Jourjon, 2008), and to compare fresh and frozen Shiraz grapes(Olarte Mantilla et al., 2013).

One of the methods most frequently used to quantify grape berry sensory attributes is Berry Sensory Assessment (BSA) or some modified version of BSA. BSA is a technique developed by Jacques Rousseau of the Institut Cooperatif du Vin in Montpellier, France in an attempt to design a sensory methodology that was accessible to grapegrowers and winemakers. The original methodology has since been modified to replace the four point scale with a line scale, and add additional attributes. These methods all evaluate sensory aspects of the grape berry pulp, skin, and seeds, and have been found to be a useful tool for assessing the link between grape berries and wine quality (Olarte Mantilla, Collins, Iland, Johnson, & Bastian, 2012).

2.5.2 Descriptive analysis of wines

Descriptive analysis has been used to describe the characteristics of many wines. These varietals include: Cabernet Sauvignon (Heymann & Noble, 1987) (Preston et al., 2008) (Robinson et al., 2011), Canadian ice wines produced from Riesling and Vidal (Cliff, Yuksel, Girard, & King, 2002), Chardonel (Mirarefi, Menke, & Lee, 2006), Listan blanco, Verdello, and Gual (Afonso, Darias, Armas, And, & M. Eugenio Diaz, 1998), Macabeo, Xarel.lo, and Parrellada (De La Presa-Owens & Noble, 1995), Semillon (Blackman & Saliba, 2009), Shiraz (Abbott, Coombe, & Williams, 1991), Pinot noir (Guinard & Cliff, 1987), Riesling (Douglas, Cliff, & Reynolds, 2001), Vidal blanc (Chisholm, Guiher, & Zaczkiewicz, 1995), and Zinfandel (Noble & Shannon, 1987). Descriptive analysis was previously used to characterize the aroma of table wines made from Frontenac (Mansfield & Vickers, 2009), with the primary focus on aromas common to Frontenac table wines produced commercially at the time of testing. Eleven trained descriptive analysis panelists evaluated six Frontenac wines produced in Minnesota and generated a list of descriptors to describe the aroma. Group consensus pared the list to attributes that existed in at least four of the six wines and to terms that were determined to be non-redundant. The final list contained thirteen descriptors: blackberry, black currant, cherry, jammy, cooked vegetable, fresh green, cedar, spice, black pepper, floral, geranium, earthy, and tamari. These attributes were accompanied by a reference and definition and were useful for both describing the aromas of the wines and distinguishing differences between the wine aromas.

2.6 Purpose and Hypotheses

The purpose of this study was to define 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. :

The hypotheses were as follows:

- As grapes ripen:
  - Sweetness would increase
  - Sourness would decrease
  - Astringency would decrease
  - Aroma and flavor intensity would increase

Chapter 3 : Grape Berry Descriptive Analysis

3.1 Materials and Methods

3.1.1 Panelists:

Fourteen panelists, 9 females and 5 males, (ages 21-60) with previous training and experience in descriptive analysis panels participated in training and testing in February 2013 and 2014. Panelists were selected based on their age (being of legal age to consume alcohol), their tasting ability (previously shown to be PROP tasters), previous training (on citric acid taste and butanol aroma scales), having no medical reason to not consume alcohol, and their availability. Panelists were compensated $10/hour for training and $13/hour for testing. All recruiting and experimental procedures were approved by the University of Minnesota's Institutional Review Board.

3.1.2 Grape Samples:

Frontenac and Marquette grapes grown in four location replications of the NE 1020 trial at Brookings, South Dakota were sampled at three stages of maturity in 2012 and at three (Frontenac) or four (Marquette) stages of maturity in 2013. These stages were indicated by soluble solids content (Brix) measured on an average of 10 unfrozen berries per location at room temperature (Table 3.1 and Table 3.2)

Grape berries were picked, rinsed 3 times with reverse osmosis water, blotted, frozen in -80°C and transferred to -20°C for holding until shipment. Samples were shipped to the University of Minnesota in an ice chest with dry ice and then immediately stored in a deep freeze (-20°C) until the week before testing. They were then stored at -10°C until up to 8 hours before testing when they were removed from the freezer, portioned into 60 ml

(2 ounce) sample cups (translucent soufflé cup, item number 10135, ProPak, Hunt Valley, Maryland) with two berries in each, and placed in the refrigerator. They were removed from the freezer or refrigerator 1-2 hours before the panelist received the samples, and left to equilibrate at room temperature until serving.

Table 3.1: Grape samples from 2012 and 2013. Location refers to the specific group of vines in the vineyard, consistent from year to year. Brix refers to the average Brix of 10 separate unfrozen berries at room temperature*.

Frontenac			
Year	**Harvest Date**	**Location**	**Brix**
2012	8/20	1	20.6°
	8/20	2	19.7°
	8/20	3	21.3°
	8/20	4	22.1°
	8/24	1	24.0°
	8/24	2	24.7°
	8/24	3	24.6°
	8/24	4	23.7°
	9/12	1	27.2°
	9/12	2	25.5°
	9/12	3	25.4°
	9/12	4	27.4°
2013	9/5	1	20.8°
	9/5	2	19.0°
	9/5	3	21.1°
	9/5	4	20.3°
	9/12	1	23.3°
	9/12	2	21.8°
	9/12	3	22.2°
	9/12	4	22.9°
	9/17	1	25.4°
	9/17	2	20.8°
	9/17	3	23.8°
	9/17	4	22.1°
	9/22	1	24.7°
	9/22	2	22.9°
	9/22	3	24.1°
	9/22	4	25.3°

Marquette			
Year	**Harvest Date**	**Location**	**Brix**
2012	8/21	1	23.4°
	8/21	2	22.6°
	8/21	3	23.8°
	8/21	4	21.3°
	8/24	1	23.3°
	8/24	2	23.7°
	8/24	3	24.1°
	8/24	4	24.0°
	9/12	1	30.2°
	9/12	2	28.9°
	9/12	3	28.5°
	9/12	4	28°
2013	9/3	1	21.1°
	9/3	2	19.7°
	9/3	3	19.8°
	9/3	4	19.9°
	9/10	1	22.3°
	9/10	2	20.6°
	9/10	3	24.0°
	9/10	4	23.2°
	9/18	1	26.6°
	9/18	2	24.9°
	9/18	3	25.6°
	9/18	4	25.4°

* Brix was measured immediately after harvest but before the initial berry freezing by Dr. Anne Fennel and her team at South Dakota State University.

3.2 Descriptive Analysis Training and Testing:

Frontenac grape berries were evaluated first before moving on to Marquette grape berries. Panelists participated in three training sessions and two testing sessions for each varietal, each lasting about an hour. Panelists completed 4-5 sessions per week and were allowed to complete more than one session per day with at least one hour between sessions, though most chose not to.

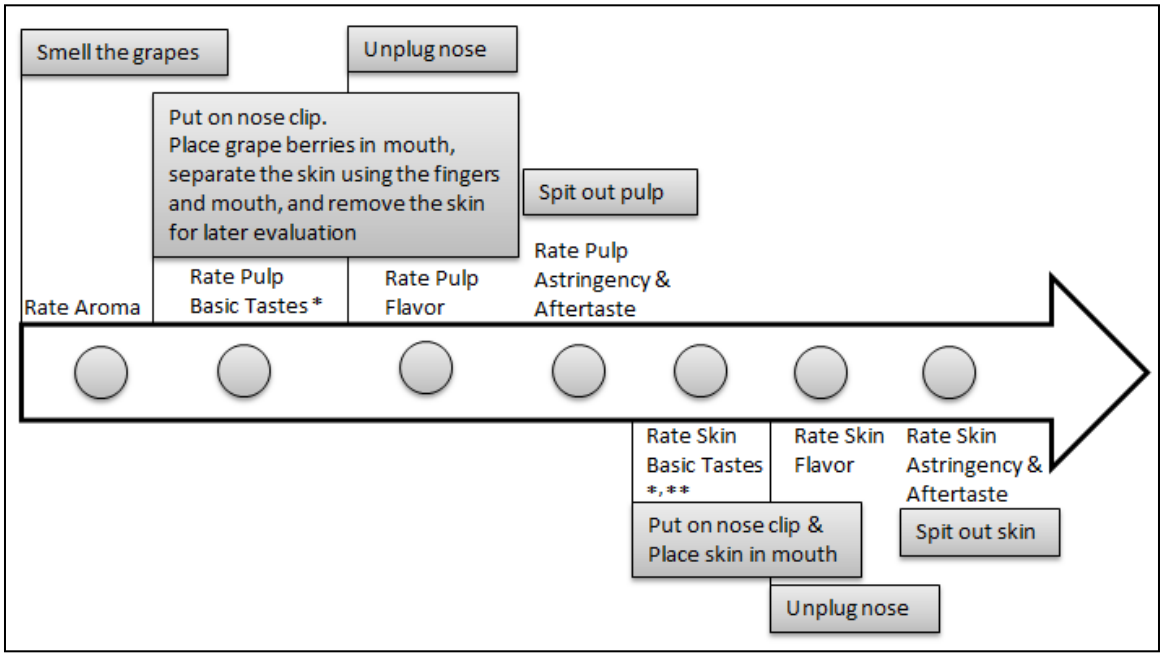
3.2.1 Year One Frontenac Grapes Training:

During the first training session, panelists were presented with a simple lexicon that contained seven attributes: sweetness, sourness, bitterness, astringency, herbaceous, jammy, and fresh fruit. Panelists discussed and practiced proper techniques for tasting the grape pulp and grape skins, modified the list of attributes, and discussed potential standard references for those attributes. Panelists decided that two grape berries would be evaluated at a time in order to provide sufficient volume of sample to evaluate. These were to be evaluated in the mouth at the same time. First, panelists removed the lids of the sample cups, and evaluated the aroma of the grape berries. Then they put on a nose clip, placed the grape berry in the mouth, separated the skin using the fingers and mouth, and removed the skin for later evaluation. Then panelists rated the basic tastes (sweetness, sourness, and bitterness) and then removed the nose clip to evaluate the flavor of the pulp. Panelists then spit out the pulp and rated the aftertastes. These steps were repeated with the skin: place nose clip, place grape skins in the mouth, rate basic tastes, remove nose clip and rate flavors, and spit out the skin before rating aftertastes ().

The second training session consisted of panelists individually tasting 6 grape berry samples in separate sensory booths and rating both the pulp and the skin of those samples for each of the attributes using the new references and attributes that had been discussed the previous day. This was essentially a mock-testing situation, details of which are provided below.

The third training session consisted of panelists reviewing the data produced the previous day, discussion of the effectiveness of the new references, and practicing tasting and rating samples. Discussion was held on whether to rate the skin after the initial "burst" of pulp/juice that was left in the skins or not. Panelists decided to wait until after the initial "burst" subsided to rate attributes. Panelists also decide to wait until the peak of the sweetness/sourness/overall intensity attributes of both the skin and pulp to rate that attribute rather than to rate the initial impression (Figure 3.1).

Figure 3.1: Grape Berry Tasting Procedure. Adapted with permisson (Cook 2011).



* Wait until the peak of the sweetness/sourness/overall intensity attributes of both pulp and skin to rate, not initial impression
** Wait until the initial "burst" of pulp/juice that is left in the skins has subsided to rate skin attributes

3.2.2 Year One Frontenac Grapes Testing:

Panelists participated in two testing sessions in which they tasted all 12 Frontenac grape samples twice and rated the intensity of the grape berry aroma attributes and the intensity of the taste, flavor, and aftertaste attributes for both pulp and skin (Table 3.2). Intensity ratings of taste and flavor were made using a citric acid scale, and ratings of odors were made using a butanol scale. (See Appendix 8.1 for citric acid and butanol scale information).

Panelists were seated in individual sensory booths and were provided with sensory references developed during training (Table 3.2) and a condensed set of butanol aroma and citric acid anchors: 3, 5, 7, and 10. Panelists were also provided with a blinded citric acid and butanol anchor and provided with feedback as to the intensity of the anchor after

entering the intensity they perceived. This allowed them to self-calibrate before each session.

Panelists evaluated each sample by rating the intensity of the attributes on 12 cm line scales with 20 markings from ‘0’ at the left end and ‘20’ at the right end using the data collection software SIMS2000 (Sensory Computer Systems). Panelists were allowed to take breaks during the session if they became fatigued. Panelists were also allowed to complete more than one session per day with at least one hour in between sessions, though most chose not to.

3.2.3 Year Two Frontenac Grapes Testing:

All procedures were completed the same as in 2013, except that there were 4 more samples from an additional harvest date (for a total of 16 samples) and a shift in butanol and citric acid anchors to numbers 2, 4, 6, and 9. Panelists requested this change due to the low intensity of attributes.

The Frontenac grapes reference formula for ‘fresh green’ was modified from strawberry tops (or calyx) to a mixture of green beans and asparagus to match the refinements made while working on the development of the Frontenac wine lexicon the previous year (see Table 3.2for changes to lexicon).

There was a change in the panelists on the panel. Five people did not return to the panel, and two new people were added to the panel. This put the panel at eleven panelists: 6 females and 5 males (ages 21-60).

Table 3.2: Lexicon of attributes and reference standard formulas for Frontenac grapes. Changes made to the lexicon in the second year of the study are noted in the Year Two column.

Attribute	Reference Standard	Year Two
	Aroma and Flavor	
Overall Intensity		
Fresh Fruit	Two pieces of each diced apple, pear, strawberry, plum; halved blueberry and raspberry **intensity=10**	Intensity removed
Dried Fruit	Raisins (Sun-Maid, Kingsburg, California)	
Citrus Fruit	Lemon peel, lime peel, orange peel	
Fermented Fruit	1-4 day old "Fresh Fruit" stored in the refrigerator	
Jammy	Black currant preserves (Duerr's, Manchester, England)	
Fresh Green	Green strawberry tops, whole, no fruit attached	Updated to fresh green bean & asparagus
Green Wood	Green grape stems, cut into 1 inch segments	
Earthy/Musty	Potting soil, 1 T, **intensity=6** (Miracle-Gro, Scotts Miracle-Gro Company, Marysville, Ohio)	
Hay	Hay	
Floral	Crushed violet candy, ½ teaspoon (Chowards, Bellport New York)	
Metallic	0.005% Ferrous Sulfate, 7-Hydrate (0.025g/500 ml) (Mallinckrodt Baker, Dublin, Ireland)	
Artificial Grape	Grape candy (Jolly Ranchers, Hershey Company, Hershey Pennsylvania)	
	Taste and Mouthfeel	
Sweetness	5.0% sucrose in distilled water (25g/500 ml) (C&H Sugar, Contra Costa County, California)	
Sourness	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness	0.014% caffeine in distilled water (.071g/500 ml) **intensity=2** (Sigma Aldrich, St. Louis, Missouri) 0.057% caffeine in distilled water (.285g/500 ml) **intensity=6**	Intensity 2 added

Attribute	Reference Standard	Year Two
Astringency	0.062% alum in distilled water (0.31g /500 ml); **intensity=2** 0.25% alum in distilled water (1.25g /500 ml); **intensity=12**	Intensity 2 added
	Aftertastes	
Overall aftertaste		
Sweetness aftertaste	5.0% sucrose in distilled water (25g/500 ml)	
Sourness aftertaste	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness aftertaste	0.057% caffeine in distilled water (.285g/500 ml)	

3.2.4 Year One Marquette Grapes Training:

During the first Marquette Grapes training session, panelists were presented with the Frontenac Grapes Lexicon and 6 samples of Marquette grape berries. Panelists were asked to taste the berry samples in pairs of two (with different Brix levels in the each pair) and asked to give feedback on attribute character and intensity. No new descriptors were added, though it was noted that the overall intensity of the flavor and aroma of this "new set of samples" was much higher than the previous set of samples (from Frontenac). Panelists noted that they were much sweeter and more "jammy".

The second training session was identical to the second training session for Frontenac grapes, and consisted of panelists individually tasting 6 grape berry samples in a mock-testing situation.

The third training session consisted of panelists reviewing the data produced the previous day, a discussion of the effectiveness of new references, and practicing tasting and rating samples.

3.2.5 Year One Marquette Grapes Testing:

Panelists participated in two testing sessions in which they tasted all 12 Marquette Grapes samples and rated the intensity of attributes for both the pulp and skin. For more details see section 3.2.2 Year One Frontenac Grapes Testing.

3.2.6 Year Two Marquette Grapes Testing:

All procedures were completed the same as in 2013, except for the previously mentioned shift in butanol and citric acid anchors and change of panelists. Year Two contained only 12 samples, and an extra Marquette harvest was not available as it was with Frontenac. For more details see section 3.2.3, Year Two Frontenac Grapes Testing.

Table 3.3: Lexicon of attributes and reference standard formulas for Marquette grapes. Changes made to the lexicon in the second year of the study are noted in the Year Two column.

Attribute	Reference Standard	Year Two
	Aroma and Flavor	
Overall Intensity		
Fresh Fruit	Two pieces of each diced apple, pear, strawberry, plum, halved blueberry and raspberry **intensity=10**	
Dried Fruit	Raisins (Sun-Maid, Kingsburg, California)	
Citrus Fruit	Lemon peel, lime peel, orange peel	
Fermented Fruit	1-4 day old "Fresh Fruit" stored in the refrigerator	
Jammy	Black currant preserves (Duerr's, Manchester, England)	
Fresh Green	Green strawberry tops, whole, no fruit attached	Updated to fresh green bean & asparagus
Green Wood	Green grape stems, cut into 1 inch segments	
Earthy/Musty	Potting soil, 1 T, **intensity=6** (Miracle-Gro, Scotts Miracle-Gro Company, Marysville, Ohio)	
Hay	Hay	
Floral	Crushed violet candy, ½ teaspoon (Chowards, Bellport New York	
Metallic	0.005% Ferrous Sulfate, 7-Hydrate (0.025g/500 ml) (Mallinckrodt Baker, Dublin, Ireland)	
Artificial Grape	Grape candy (Jolly Ranchers, Hershey Company, Hershey Pennsylvania)	
	Taste and Mouthfeel	
Sweetness	5.0% sucrose in distilled water (25g/500 ml) (C&H Sugar, Contra Costa County, California)	
Sourness	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness	0.014% caffeine in distilled water (.071g/500 ml) **intensity=2** (Sigma Aldrich, St. Louis, Missouri) 0.057% caffeine in distilled water (.285g/500 ml) **intensity=6**	
Astringency	0.062% alum in distilled water (0.31g /500 ml); **intensity=2** 0.25% alum in distilled water (1.25g /500 ml); **intensity=12**	
	Aftertastes	
Overall aftertaste		
Sweetness	5.0% sucrose in distilled water (25g/500 ml)	

Attribute	Reference Standard	Year Two
aftertaste		
Sourness aftertaste	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness aftertaste	0.057% caffeine in distilled water (.285g/500 ml)	

3.3 Data Analysis:

Brix values were sorted into a new variable called Sugar Level with the categories low, medium, and high. For Frontenac, 'low' sugar level had Brix values < 22^0, 'medium' sugar level had Brix values of 22^0 to 24^0, and 'high' sugar level had Brix values > 24^0. For Marquette, 'low' sugar level had Brix values < 23^0, 'medium' sugar level had Brix values of 23^0 to 24.1^0, and 'high' sugar level had Brix values > 24.8^0 (Table 3.4).

Analyses of variance (ANOVA) were conducted on each grape variety separately using SAS® version 9.4. A univariate analysis of variance model (PROC GLM) with a post-hoc analysis of Student–Newman–Keuls (SNK) multiple comparisons tests were used to determine if the three sugar levels of grapes differed in each attribute. The 'solution' command was added so that the predicted intercept could be seen in the data output. The dependent variables in the ANOVA model were the attribute ratings and the predictors were panelist (nested within year), sugar level, year, sensory rep, and location. This analysis was run for each year separately first. Next, this analysis was run on the combined years. The model for the combined years did not include sensory rep.

I selected attributes with significant ($P < 0.1$) differences among sugar levels in both the model and the post-hoc analysis for inclusion in the results tables and plots. Complete tables can be found in Appendixes 8.9 and 8.10.

Table 3.4: Grape samples from 2012 and 2013 color coded by Sugar Level. Location refers to the specific group of vines in the vineyard, consistent from year to year. Brix refers to the average Brix of 10 separate unfrozen berries at room temperature*.

Frontenac				
Year	Harvest Date	Location	Brix	Sugar Level
2012	8/20	1	20.6°	Low
	8/20	2	19.7°	Low
	8/20	3	21.3°	Low
	8/20	4	22.1°	Med
	8/24	1	24.0°	High
	8/24	2	24.7°	High
	8/24	3	24.6°	High
	8/24	4	23.7°	Med
	9/12	1	27.2°	High
	9/12	2	25.5°	High
	9/12	3	25.4°	High
	9/12	4	27.4°	High
2013	9/5	1	20.8°	Low
	9/5	2	19.0°	Low
	9/5	3	21.1°	Low
	9/5	4	20.3°	Low
	9/12	1	23.3°	Med
	9/12	2	21.8°	Low
	9/12	3	22.2°	Med
	9/12	4	22.9°	Med
	9/17	1	25.4°	High
	9/17	2	20.8°	Low
	9/17	3	23.8°	Med
	9/17	4	22.1°	Med
	9/22	1	24.7°	High
	9/22	2	22.9°	Med
	9/22	3	24.1°	High
	9/22	4	25.3°	High

Marquette				
Year	Harvest Date	Location	Brix	Sugar Level
2012	8/21	1	23.4°	Med
	8/21	2	22.6°	Low
	8/21	3	23.8°	Med
	8/21	4	21.3°	Low
	8/24	1	23.3°	Med
	8/24	2	23.7°	Med
	8/24	3	24.1°	Med
	8/24	4	24.0°	Med
	9/12	1	30.2°	High
	9/12	2	28.9°	High
	9/12	3	28.5°	High
	9/12	4	28°	High
2013	9/3	1	21.1°	Low
	9/3	2	19.7°	Low
	9/3	3	19.8°	Low
	9/3	4	19.9°	Low
	9/10	1	22.3°	Low
	9/10	2	20.6°	Low
	9/10	3	24.0°	Med
	9/10	4	23.2°	Med
	9/18	1	26.6°	High
	9/18	2	24.9°	High
	9/18	3	25.6°	High
	9/18	4	25.4°	High

* Brix was measured immediately after harvest but before the initial berry freezing by Dr. Anne Fennel and her team at South Dakota State University.

3.4 Frontenac Grapes Results:

3.4.1 Frontenac Grapes Year One Results

Panelists rated the overall intensity of flavor of pulp higher for the low sugar level and medium sugar level grapes than for the high sugar level grapes (Figure 3.3, Figure 3.4, and Table 3.5). The overall intensity of the skin of the medium sugar level grapes was lower than that of the high sugar level grapes. The sweetness of the pulp and the skin of the high level grapes were higher than the sweetness of the pulp and skin of the low and medium sugar level grapes (Figure 3.2). The sweetness aftertaste of the pulp was lower in the pulp of the low sugar level grapes than in the pulp of the medium and high sugar level grapes. The pulp and skin sourness and the sourness aftertastes of the pulp were rated higher in the low and medium sugar level grapes than in the high sugar level grapes, as was the citrus flavor and the earthy flavor of the pulp. By contrast, the citrus flavor of the skin was rated higher in the medium and high sugar level grapes than the low sugar level grapes. The earthy flavor was rated higher in the medium sugar level grapes than in the high sugar level grapes, as was the pulp fermented fruit flavor. The fresh green flavor of the skin of medium and high sugar level grapes was higher than that of the low sugar level grapes. The pulp bitterness was rated lower in the high sugar level grapes than in the low sugar level grapes. The skin floral flavor was rated higher in the high sugar level grapes than in the medium sugar level grapes.

Table 3.5: Frontenac Grapes results from Year One. All included attributes contain significant differences among sugar levels (gray is $0.05 < p < 0.1$; white is $p < 0.05$). *

Attribute	Sugar Level				
	Low	**Medium**	**High**	**F- statistic**	**p-value**
Pulp Overall Intensity Flavor	6.3 [a]	6.4 [a]	6.0 [b]	8.7	< 0.001
Skin Overall Intensity Flavor	3.0 [ab]	3.2 [a]	2.9 [b]	3.3	0.04
Pulp Sweetness	3.4 [b]	3.5 [b]	4.1 [a]	12.5	< 0.001
Pulp Sweetness Aftertaste	1.3 [b]	1.5 [a]	1.6 [a]	5.8	< 0.001
Skin Sweetness	1.2 [b]	1.4 [b]	1.7 [a]	13.0	< 0.001
Pulp Sourness	5.5 [a]	5.3 [a]	4.2 [b]	29.0	< 0.001
Pulp Sourness Aftertaste	2.1 [a]	2.1 [a]	1.7 [b]	7.1	< 0.001
Skin Sourness	1.8 [a]	1.9 [a]	1.5 [b]	5.7	< 0.001
Pulp Bitterness	1.4 [a]	1.2 [ab]	1.1 [b]	3.7	0.03
Skin Fresh Green Flavor	0.8 [b]	1.0 [a]	1.0 [a]	2.5	0.08
Pulp Citrus Flavor	1.4 [a]	1.4 [a]	0.9 [b]	10.5	< 0.001
Skin Citrus Flavor	0.4 [ab]	0.5 [a]	0.3 [b]	7.3	< 0.001
Pulp Fermented Fruit Flavor	2.0 [ab]	2.2 [a]	1.8 [b]	3.1	0.05
Skin Earthy Flavor	0.9 [ab]	1.1 [a]	0.8 [b]	2.4	0.09
Pulp Earthy Flavor	1.0 [a]	0.8 [b]	0.9 [ab]	3.1	0.05
Skin Floral Flavor	0.3 [ab]	0.2 [b]	0.4 [a]	3.5	0.03

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Figure 3.2: Mean panelist ratings (± standard error) of basic taste attributes of Frontenac grapes that show significant differences among sugar levels in Year One (2012). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

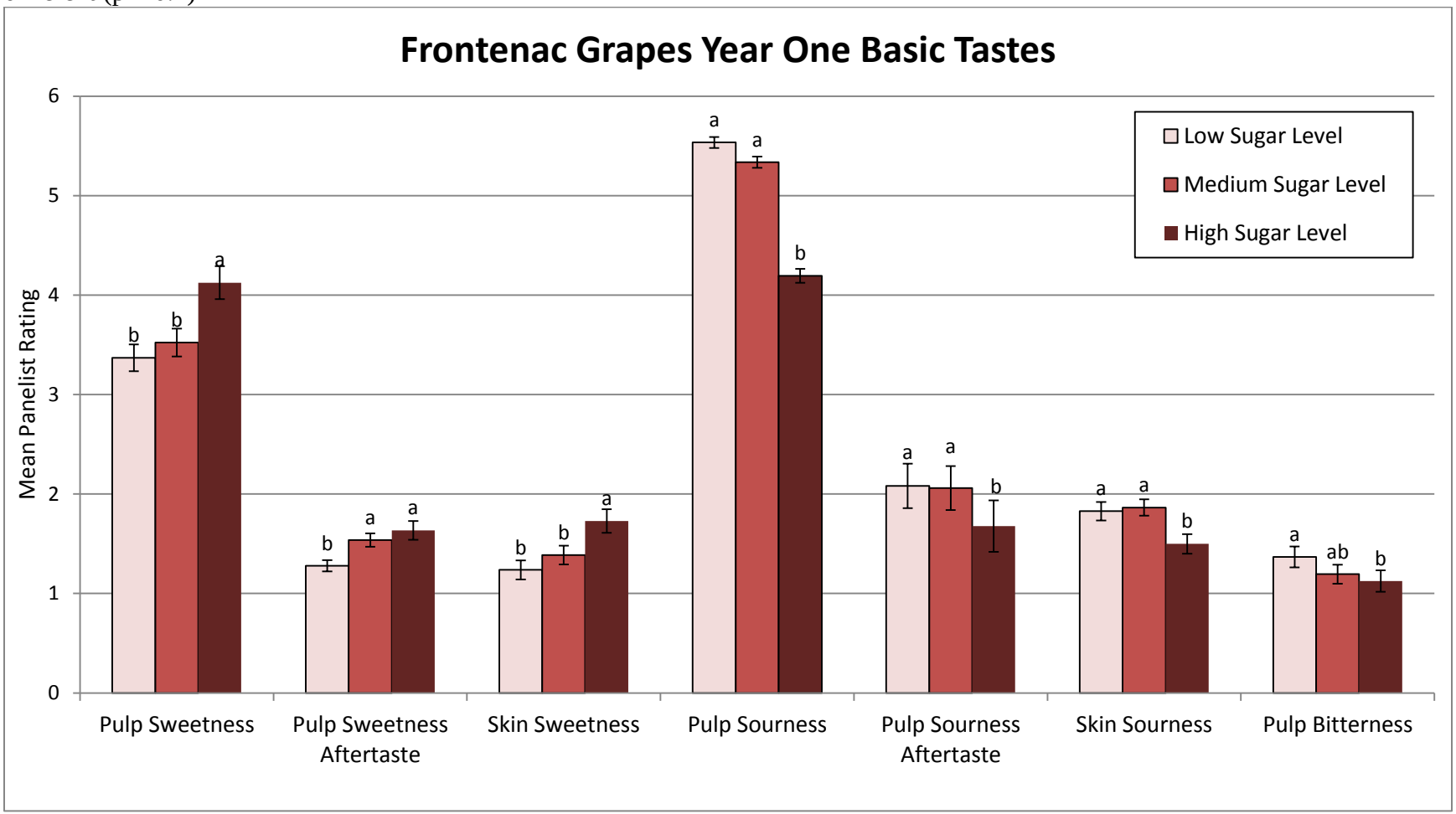


Figure 3.3: Mean panelist ratings (± standard error) of flavor attributes of Frontenac Grapes that show significant differences among sugar levels in Year One (2012). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

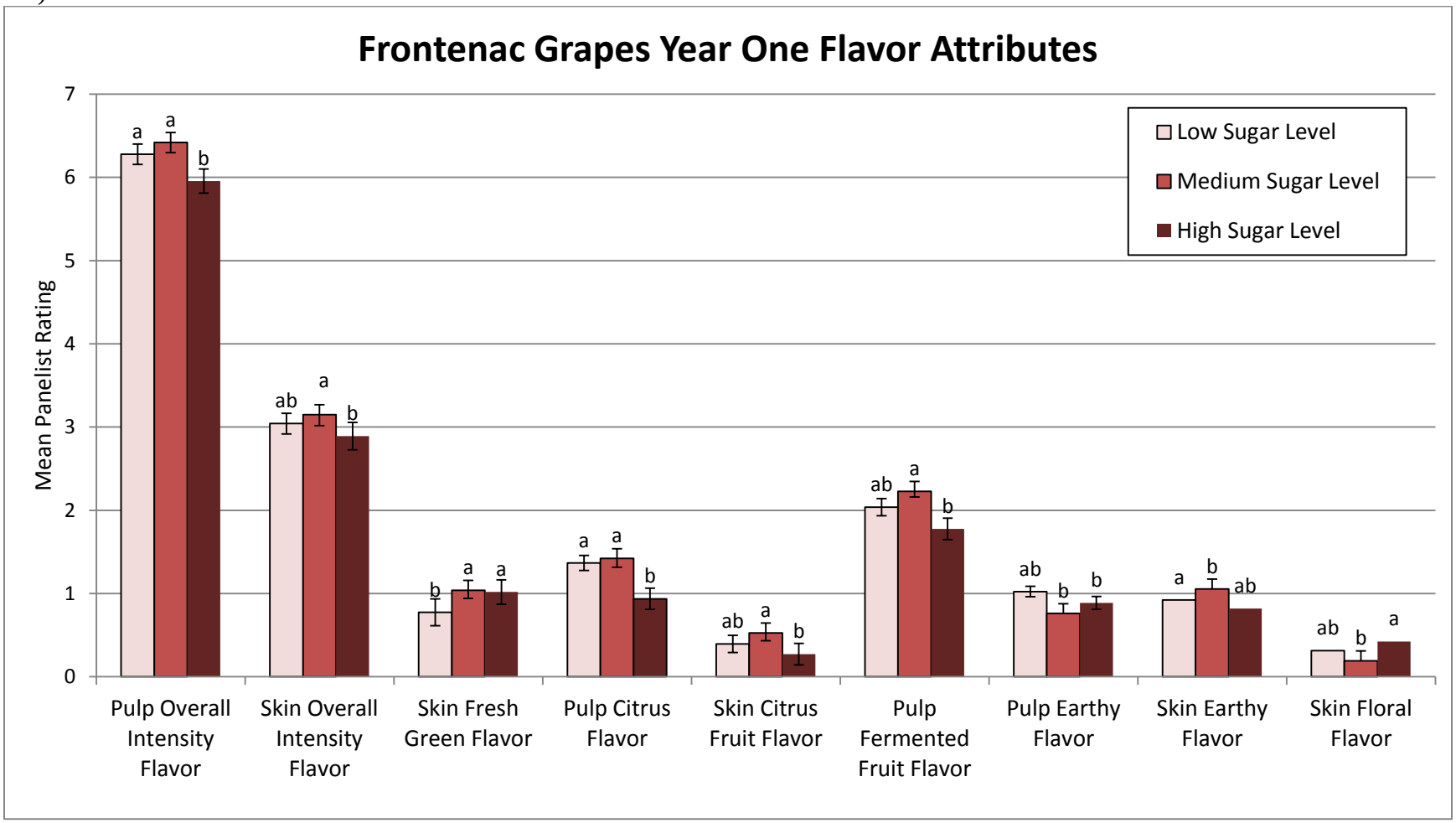
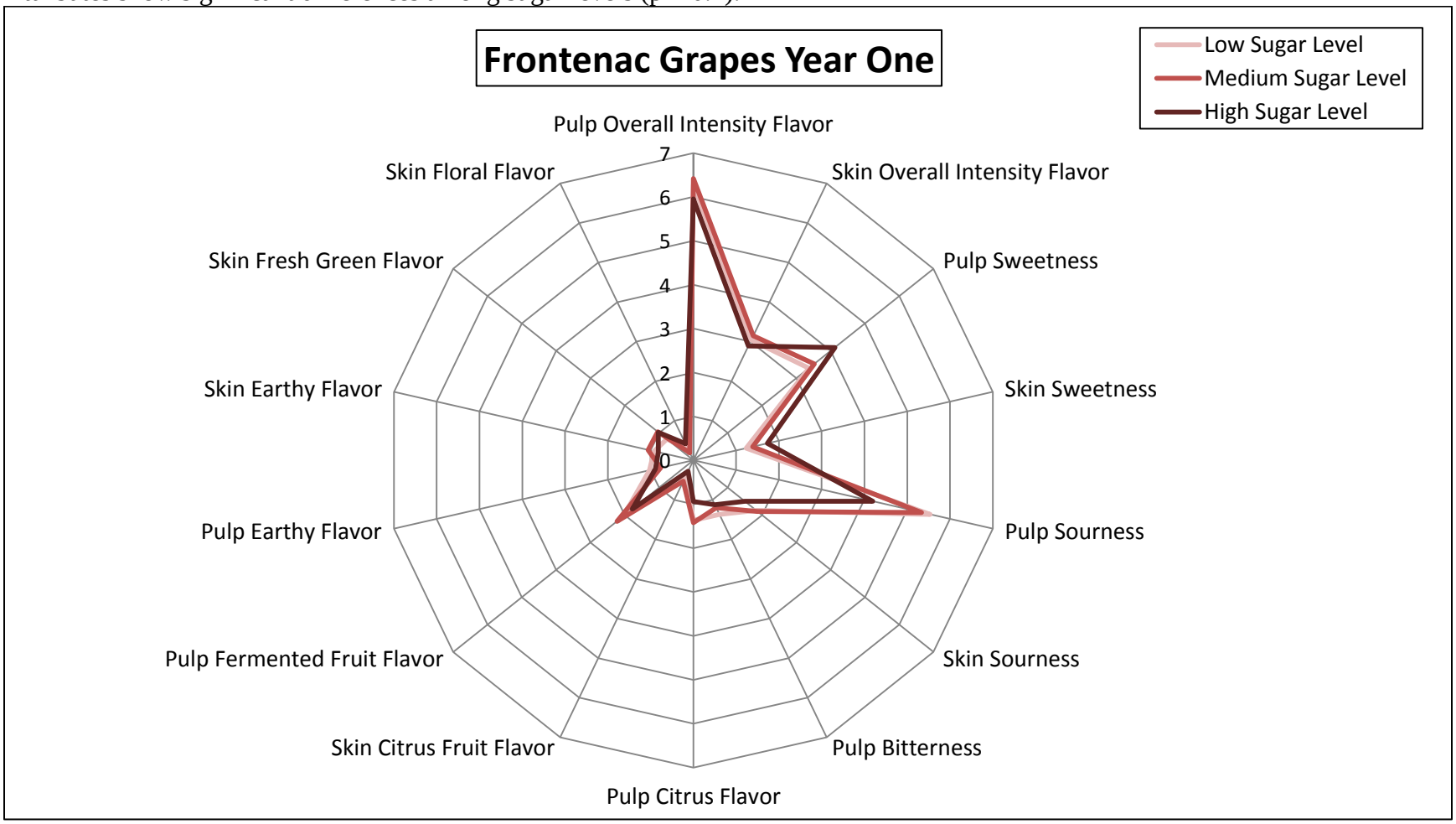


Figure 3.4: Spider plot of the mean panelist ratings (± standard error) of Frontenac Grapes attributes in Year One (2012). Attributes show significant differences among sugar levels ($p < 0.1$).*



*Pulp sweetness and sourness aftertaste also differed significantly among the sugar levels, but they have been omitted from this plot because they followed the same pattern as sweetness and sourness of the pulp

3.4.2 Frontenac Grapes Year Two Results

Panelists rated the overall intensity of flavor higher for the low sugar level grapes than for the medium and high sugar level grapes (Table 3.6, Figure 3.6, and Figure 3.7). The sweetness of the pulp was rated higher as the sugar level rose from low to medium to high, as was the jammy flavor of the pulp (Figure 3.5). Similar to the results of year one, the skin of the high sugar level grapes was higher than the sweetness of the skin of the low and medium sugar level grapes, as was the sweetness aftertaste of the pulp. Continuing this trend, the sweetness aftertaste of the skin was higher the pulp of the high sugar level grapes than in the pulp of the low sugar level grapes. Both the pulp sourness and the skin sourness aftertaste ratings decreased as the sugar level of the grapes rose from low to medium to high. The skin sourness and the pulp sourness aftertaste were rated higher in the low sugar level grapes than in the medium and high sugar level grapes, as was the pulp citrus flavor. The pulp bitterness aftertaste was the only bitterness attribute that showed significant differences among sugar levels and was slightly higher in the medium sugar level grapes than in the low and high sugar level grapes. The astringency of the pulp was rated higher in the low sugar level grapes than in the high sugar level grapes. The dried fruit flavor of the pulp and the fermented fruit flavor of the skin were both rated higher in the high sugar level grapes than in the low sugar level grapes, though these differences were very small in the case of the skin fermented fruit flavor (less than 0.2 points on a 20 point scale).The earthy aroma was rated lower in the medium sugar level grapes than in the high sugar level grapes.

Table 3.6: Frontenac Grapes results from Year Two. All included attributes contain significant differences among sugar levels (gray is $0.05 < p < 0.1$; white is $p < 0.05$).*

Attribute	Sugar Level				
	Low	**Medium**	**High**	**F- statistic**	**p-value**
Pulp Overall Intensity Flavor	6.1 [a]	5.6 [b]	5.7 [b]	4.2	0.02
Pulp Sweetness	2.6 [c]	3.3 [b]	3.8 [a]	26	< 0.001
Pulp Sweetness Aftertaste	0.9 [b]	1.0 [b]	1.4 [a]	11	< 0.001
Skin Sweetness	0.9 [b]	1.1 [b]	1.3 [a]	6.3	< 0.001
Skin Sweetness Aftertaste	0.5 [b]	0.6 [ab]	0.7 [a]	2.8	0.06
Pulp Sourness	5.5 [a]	4.8 [b]	4.2 [c]	17	< 0.001
Pulp Sourness Aftertaste	1.7 [a]	1.5 [b]	1.1 [b]	16	< 0.001
Skin Sourness	1.5 [a]	1.2 [b]	1.2 [b]	2.8	0.06
Skin Sourness Aftertaste	0.7 [a]	0.6 [b]	0.4 [c]	4.2	0.02
Pulp Bitterness Aftertaste	0.7 [b]	0.9 [a]	0.7 [b]	3.7	0.03
Pulp Astringency	2.9 [a]	2.8 [ab]	2.6 [b]	3.9	0.02
Pulp Citrus Flavor	2.1 [a]	1.6 [b]	1.3 [b]	8.8	< 0.001
Pulp Dried Fruit Flavor	0.8 [b]	0.9 [ab]	1.1 [a]	2.3	0.10
Pulp Jammy Flavor	1.8 [c]	2.1 [b]	2.3 [a]	6.6	< 0.01
Earthy Aroma	1.0 [ab]	0.8 [b]	1.1 [a]	2.6	0.08
Skin Fermented Fruit Flavor	0.34 [b]	0.46 [ab]	0.52 [a]	4.2	0.02

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Figure 3.5: Mean panelist ratings (± standard error) of basic taste attributes of Frontenac Grapes that show significant differences among sugar levels in Year Two (2013). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

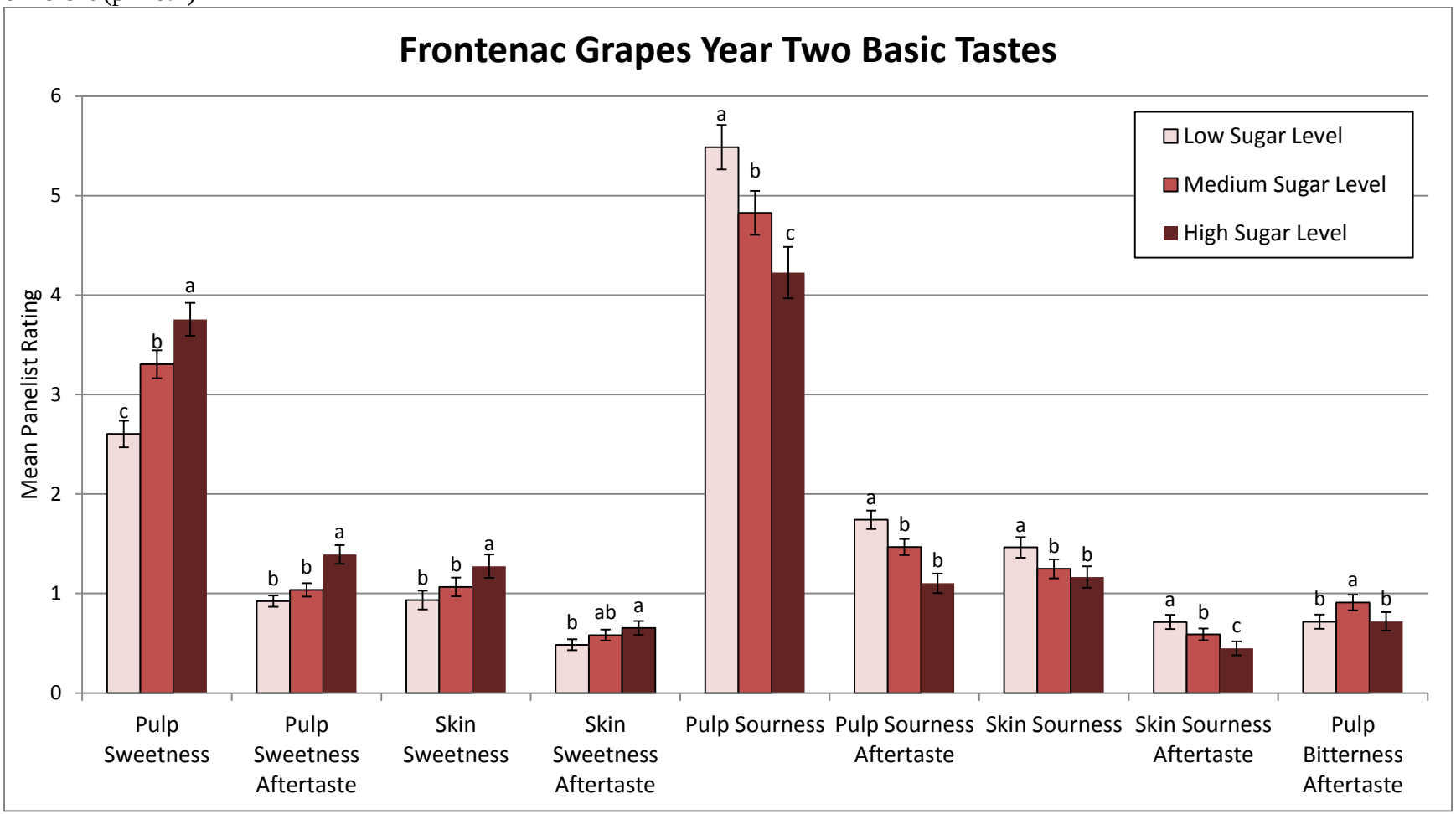


Figure 3.6: Mean panelist ratings (± standard error) of astringency, aroma, and flavor attributes of Frontenac Grapes that show significant differences among sugar levels in Year Two (2013). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

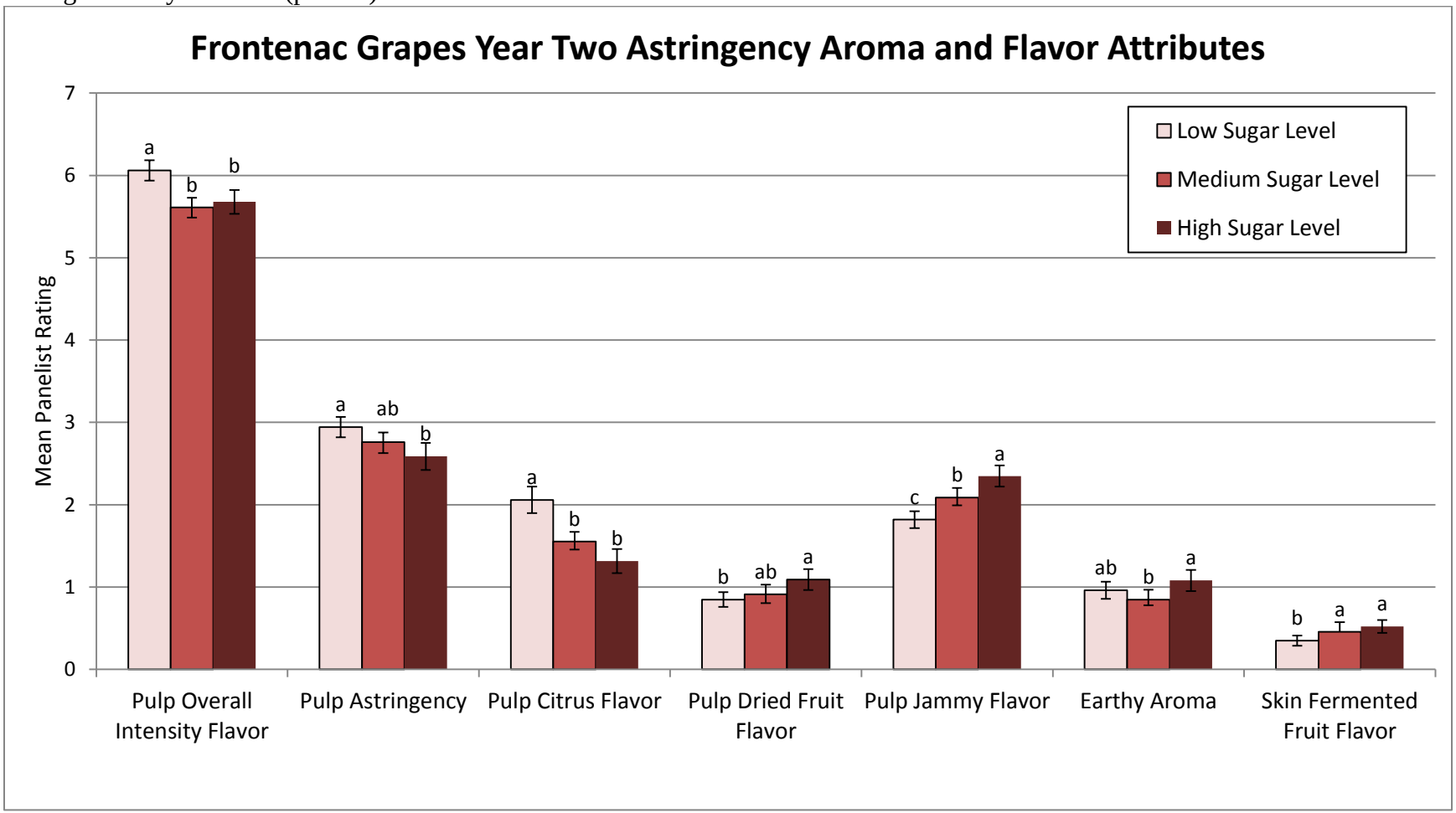
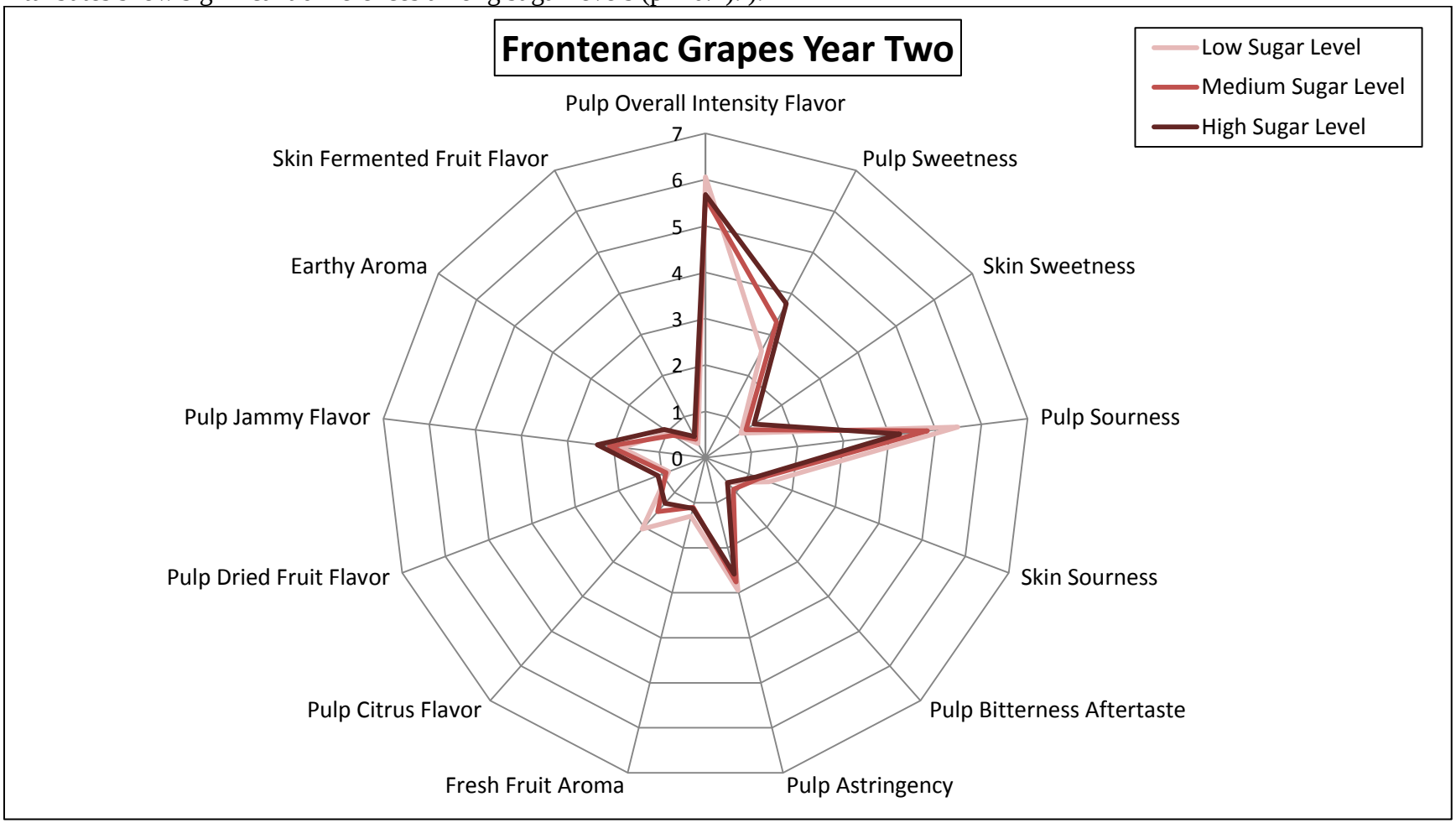


Figure 3.7: Spider plot of mean panelist ratings (± standard error) of the attributes for Frontenac Grapes in Year Two (2013). Attributes show significant differences among sugar levels ($p < 0.1$).).*



*Sweetness and sourness aftertaste also differed significantly among the sugar levels, but they have been omitted from this plot because they followed the same pattern as sweetness and sourness of the skin and pulp

3.4.3 Frontenac Grapes Combined Year One and Two Results

Panelists rated the overall intensity of flavor of the pulp of the low sugar level grapes higher than that of the medium and high sugar level grapes (Table 3.7, Figure 3.8, and Figure 3.9). The sweetness of the pulp, pulp aftertaste, skin, and skin aftertaste were rated increasingly more intense as the sugar level increased from low to medium to high. The jammy flavor of the pulp also increased as the sugar level increased. The pulp and skin sourness and the sourness aftertastes of the skin and pulp decreased as the sugar level rose, as did the citrus flavor of the skin and pulp. The floral flavor of the skin in medium sugar level grapes was rated lower than that of the low and high sugar level grapes.

Table 3.7: Combined Frontenac Grapes results from Year One and Year Two. All included attributes contain significant differences among sugar levels ($p < 0.05$).*

	Sugar Level				
Attribute	**Low**	**Medium**	**High**	**F- statistic**	**p-value**
Pulp Overall Intensity Flavor	6.1 [a]	5.9 [b]	5.9 [b]	5.4	< 0.01
Pulp Sweetness	2.9 [c]	3.4 [b]	4.0 [a]	33.5	< 0.001
Pulp Sweetness Aftertaste	1.1 [c]	1.2 [b]	1.6 [a]	13.4	< 0.001
Skin Sweetness	1.1 [b]	1.2 [b]	1.6 [a]	18.4	< 0.001
Skin Sweetness Aftertaste	0.5 [c]	0.6 [b]	0.7 [a]	4.4	0.01
Pulp Sourness	5.5 [a]	5.0 [b]	4.2 [c]	39.4	< 0.001
Pulp Sourness Aftertaste	1.9 [a]	1.6 [b]	1.5 [c]	17.9	< 0.001
Skin Sourness	1.6 [a]	1.4 [b]	1.4 [b]	7.1	< 0.001
Skin Sourness Aftertaste	0.8 [a]	0.7 [b]	0.6 [b]	5.8	< 0.001
Pulp Citrus Flavor	1.8 [a]	1.5 [b]	1.1 [c]	18.2	< 0.001
Skin Citrus Flavor	0.4 [a]	0.4 [a]	0.3 [b]	4.3	0.01
Pulp Jammy Flavor	2.0 [c]	2.2 [b]	2.4 [a]	5.5	< 0.001
Skin Floral Flavor	0.3 [a]	0.2 [b]	0.4 [a]	3.8	0.02

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Figure 3.8: Mean panelist ratings (± standard error) of attributes of Frontenac Grapes that show significant differences among sugar levels when Year One (2012) and Year Two (2013) were combined. Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

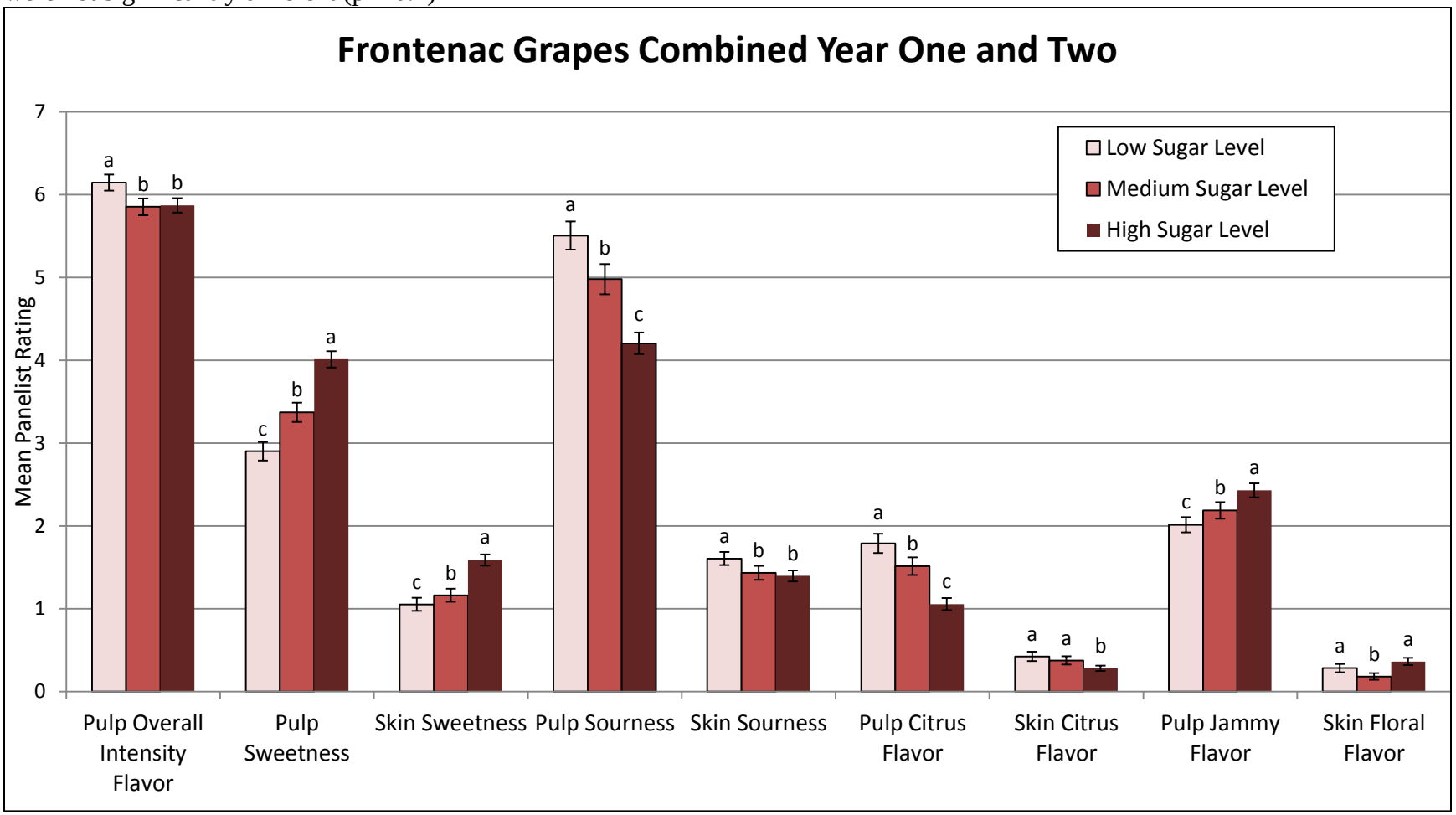
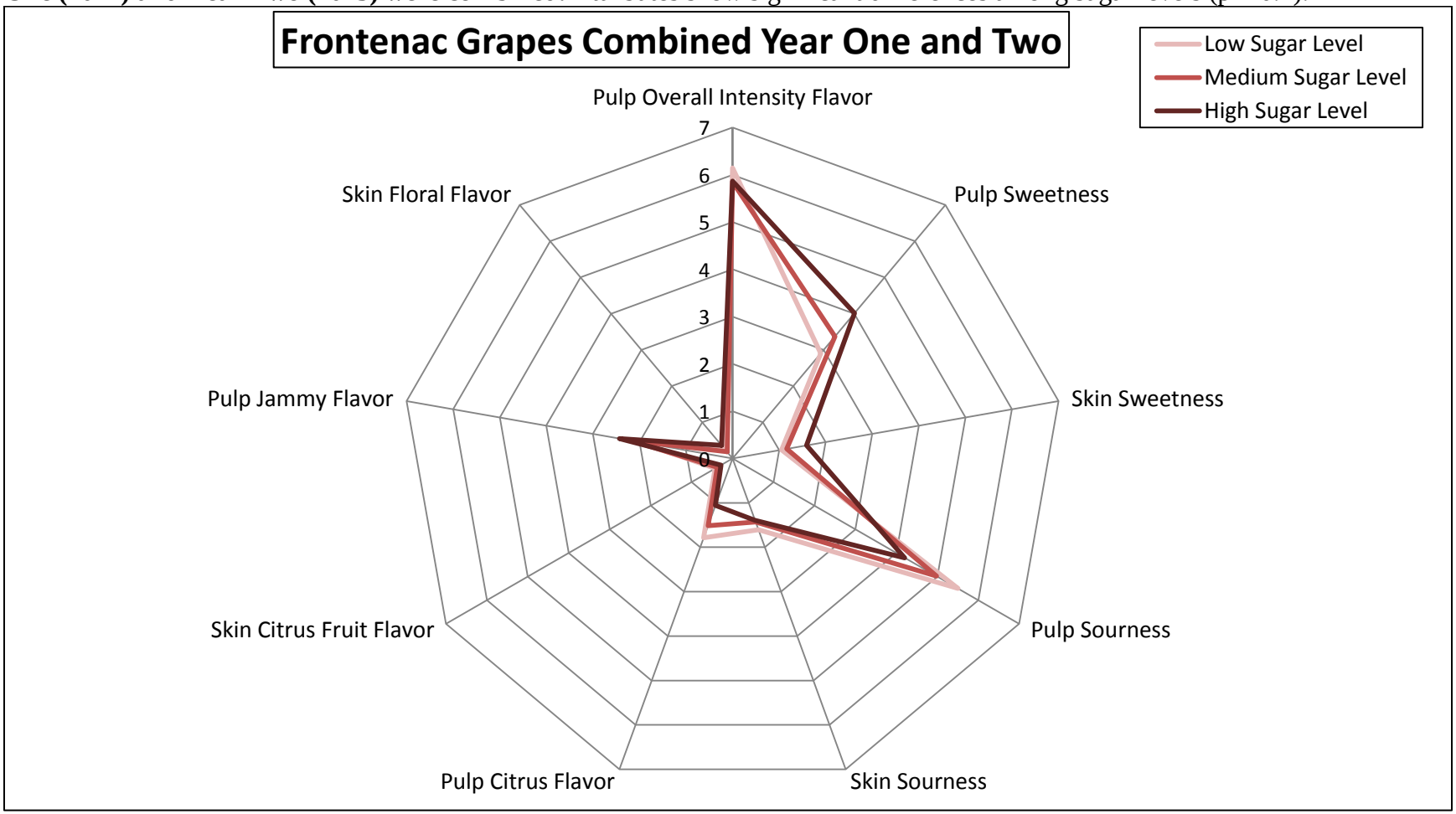


Figure 3.9: Spider plot of chart of mean panelist ratings (± standard error) of the attributes of Frontenac grapes when Year One (2012) and Year Two (2013) were combined. Attributes show significant differences among sugar levels ($p < 0.1$).



3.5 Marquette Grapes Results

3.5.1 Marquette Grapes Year One Results

Panelists rated the overall intensity of flavor of pulp higher for the low sugar level and medium sugar level grapes than for the high sugar level grapes (Table 3.8, Figure 3.11, and Figure 3.12). The overall intensity of the skin of the low sugar level grapes was lower than that of the high sugar level grapes. The sweetness of the pulp and the skin of the high sugar level grapes were higher than the sweetness of the pulp and skin of the low and medium sugar level grapes (Figure 3.10). The sweetness aftertaste of the pulp and skin were also higher in the pulp and skin of the high sugar level grapes than in the pulp of the low and medium sugar level grapes. The pulp and skin sourness and the sourness aftertastes of the pulp and skin were rated higher in the low and medium sugar level grapes than in the high sugar level grapes, as were the pulp bitterness and pulp astringency. The artificial grape aroma, jammy aroma, fresh fruit aroma, and pulp citrus flavor were also rated higher in the low and medium sugar level grapes than in the high sugar level grapes. By contrast, the jammy flavor of the pulp and skin were rated higher in the high sugar level grapes than in the medium and low sugar level grapes, as were the floral flavor of the pulp and skin and the green wood aroma. The dried fruit flavor of the pulp was rated higher in the medium and high sugar level grapes than in the low sugar level grapes. The earthy aroma was rated higher in the high sugar level grapes than in the low sugar level grapes.

Table 3.8: Marquette Grapes results from Year One (2012). All included attributes contain significant differences among sugar levels (gray is 0.05 < p < 0.1; white is p < 0.05).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Overall Intensity Flavor	5.8 [a]	5.8 [a]	5.3 [b]	12	< 0.001
Skin Overall Intensity Flavor	3.1 [b]	3.2 [ab]	3.4 [a]	3.4	0.04
Pulp Sweetness	3.3 [b]	3.1 [b]	4.3 [a]	51	< 0.001
Pulp Sweetness Aftertaste	1.2 [b]	1.2 [b]	1.7 [a]	16	< 0.001
Skin Sweetness	1.5 [b]	1.3 [b]	2.0 [a]	27	< 0.001
Skin Sweetness Aftertaste	0.6 [b]	0.5 [b]	0.8 [a]	14	< 0.001
Pulp Sourness	4.7 [a]	4.6 [a]	2.5 [b]	106	< 0.001
Pulp Sourness Aftertaste	1.9 [a]	1.8 [a]	1.0 [b]	30	< 0.001
Skin Sourness	1.9 [a]	2.0 [a]	1.3 [b]	26	< 0.001
Skin Sourness Aftertaste	0.8 [a]	0.9 [a]	0.6 [b]	5.2	0.01
Pulp Bitterness	1.3 [a]	1.3 [a]	1.0 [b]	4.5	0.01
Pulp Astringency	3.4 [a]	3.4 [a]	2.8 [b]	8.8	< 0.001
Artificial Grape Aroma	0.5 [a]	0.6 [a]	0.3 [b]	8.0	< 0.001
Jammy Aroma	1.4 [a]	1.6 [a]	1.1 [b]	5.5	< 0.001
Pulp Jammy Flavor	2.1 [b]	2.2 [b]	2.7 [a]	14	< 0.001
Skin Jammy Flavor	0.6 [b]	0.6 [b]	0.9 [a]	8.3	< 0.001
Fresh Fruit Aroma	2.0 [a]	1.9 [a]	1.6 [b]	4.5	0.01
Pulp Citrus Flavor	1.3 [a]	1.2 [a]	0.5 [b]	26	< 0.001
Pulp Floral Flavor	0.4 [b]	0.5 [b]	0.8 [a]	11	< 0.001
Skin Floral Flavor	0.1 [b]	0.2 [b]	0.3 [a]	3.5	0.03
Pulp Dried Fruit Flavor	0.6 [b]	0.9 [a]	0.8 [a]	2.6	0.07
Green Wood Aroma	2.6 [b]	2.4 [b]	2.9 [a]	6.3	< 0.01
Earthy Aroma	0.9 [b]	1.1 [ab]	1.3 [a]	4.0	0.02

*means within a row with the same letter superscript were not significantly different (p > 0.1)

Figure 3.10: Mean panelist ratings (± standard error) of taste and astringency attributes of Marquette Grapes that show significant differences among sugar levels in Year One (2012). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

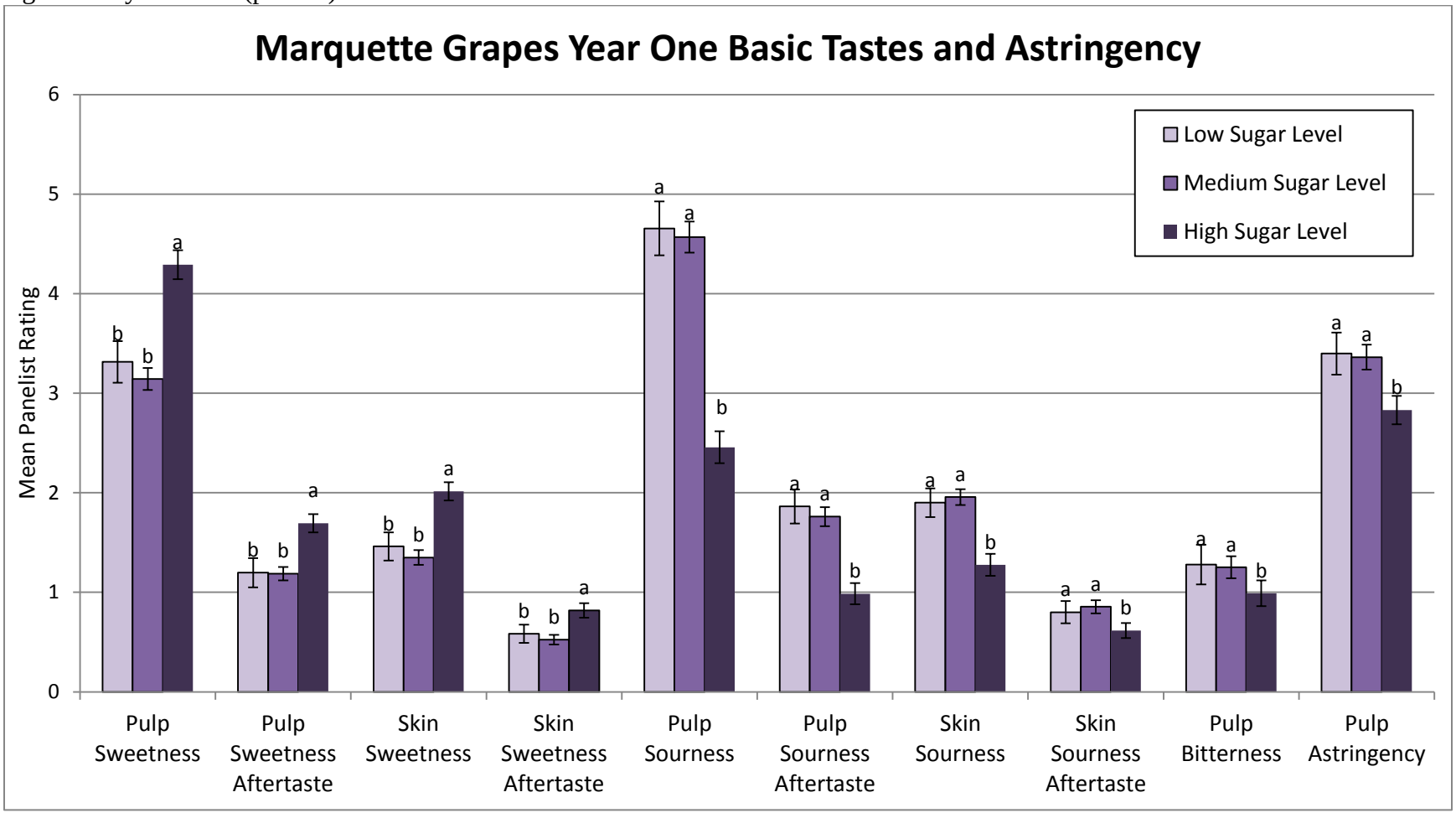


Figure 3.11: Mean panelist ratings (± standard error) of flavor and aroma attributes of Marquette Grapes that show significant differences among sugar levels in Year One (2012). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

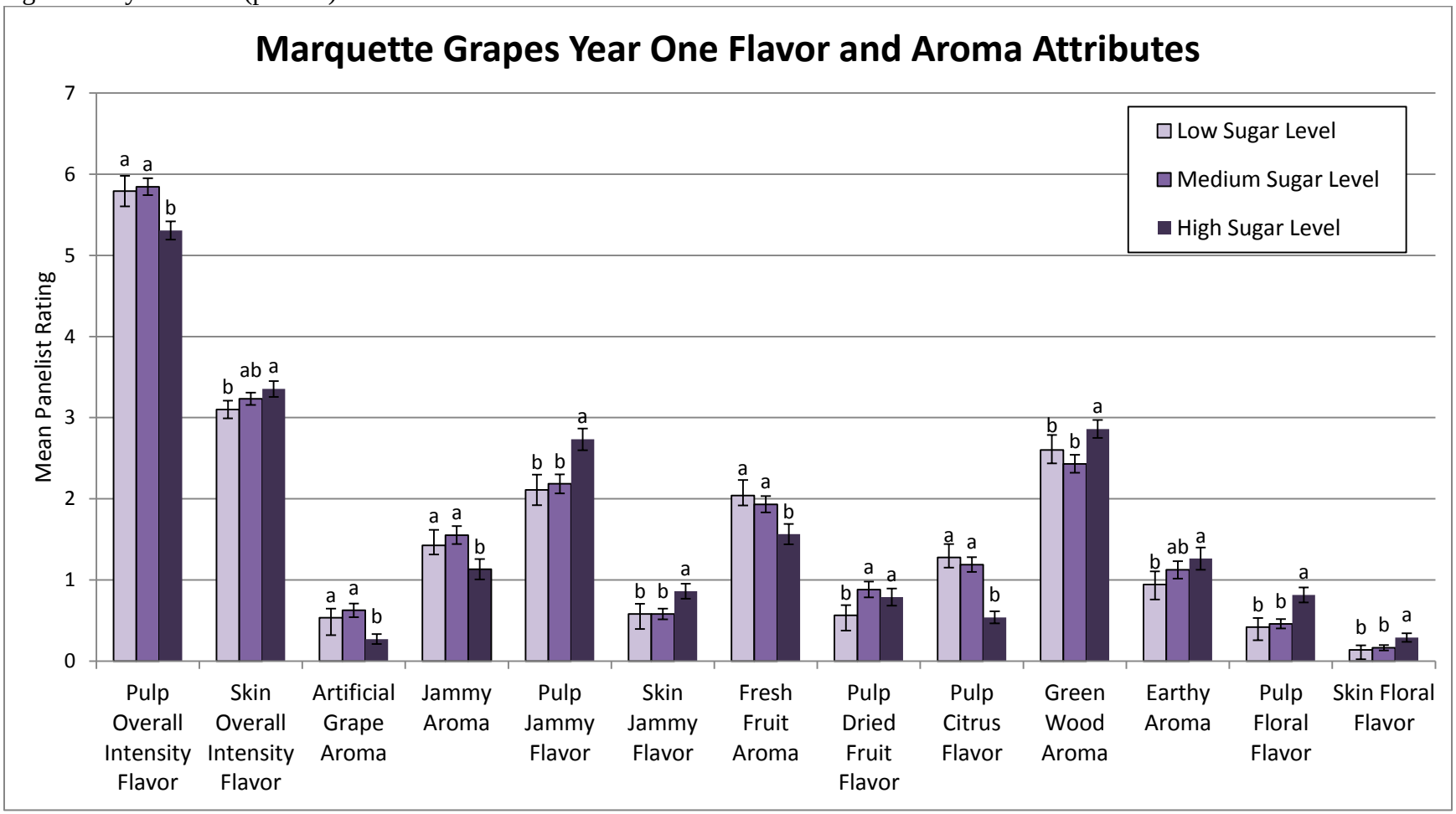
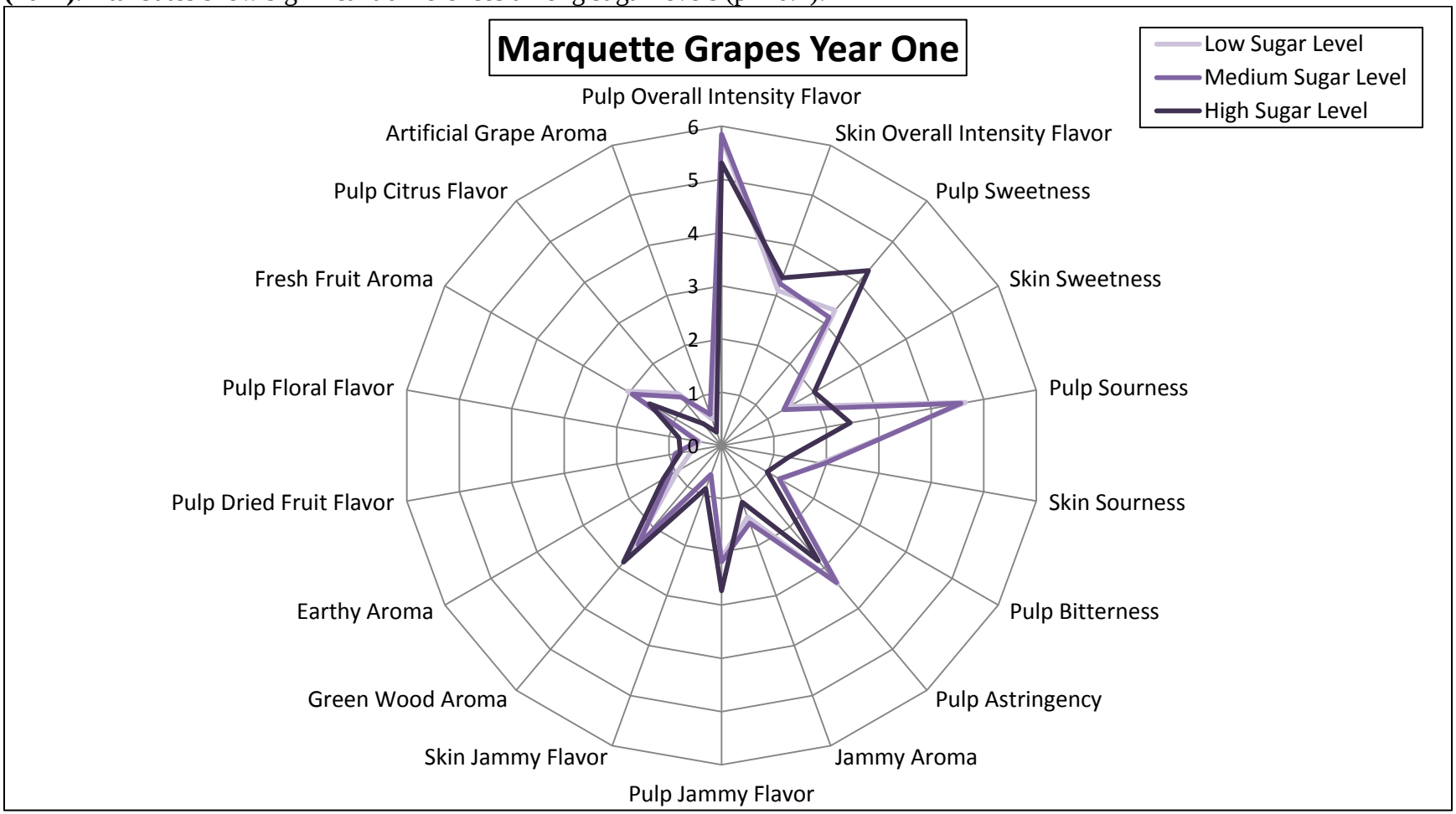


Figure 3.12: Spider plot of mean panelist ratings (± standard error) of the attributes for Marquette Grapes in Year One (2012). Attributes show significant differences among sugar levels ($p < 0.1$).*



*Sweetness and sourness aftertaste also differed significantly among the sugar levels, but they have been omitted from this plot because they followed the same pattern as sweetness and sourness of the skin and pulp

3.5.2 Marquette Grapes Year Two Results

Panelists rated the overall intensity of flavor of the pulp higher for the low and medium sugar level grapes than for the high sugar level grapes (Table 3.9, Figure 3.14, and Figure 3.15). The sweetness of the pulp and skin were rated higher in the medium and high sugar level grapes than in the low sugar level grapes, as was the sweetness aftertaste of the pulp (Figure 3.13). The sourness of the pulp and skin were rated progressively lower as the sugar level of the grapes rose from low to medium to high. The sourness aftertaste of the pulp was rated lower in the high sugar level grapes than in the medium sugar level grapes. The sourness aftertaste of the skin and the pulp citrus flavor were rated lower in the medium and high sugar level grapes than in the low sugar level grapes. The pulp bitterness aftertaste was rated higher in the low and medium sugar level grapes than in the high sugar level grapes. The green wood flavor of the skin was also rated higher in the low and medium sugar level grapes than in the high sugar level grapes. The astringency of the pulp was rated higher in the low sugar level grapes than in the high sugar level grapes. The citrus flavor of the skin was also rated higher in the low sugar level grapes than in the high sugar level grapes. The only aroma attribute that was rated significantly different between sugar levels was green wood aroma, and the low sugar level grapes were rated lower in that attribute than the medium and high sugar level grapes. The jammy flavor of the pulp was rated higher in the medium and high sugar level grapes than in the low sugar level grapes. The jammy flavor of the skin was rated higher in the high sugar level grapes than in the medium and low sugar level grapes, as was the fermented fruit flavor of the skin. The earthy flavor of the pulp was rated lower in the medium sugar level grapes than in the high sugar level grapes.

Table 3.9: Marquette Grapes results from Year Two (2013). All included attributes contain significant differences among sugar levels (gray is $0.05 < p < 0.1$; white is $p < 0.05$).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Overall Intensity Flavor	5.9 [a]	6.1 [a]	5.5 [b]	5.9	< 0.001
Pulp Sweetness	3.0 [b]	3.8 [a]	4.1 [a]	27	< 0.001
Pulp Sweetness Aftertaste	1.0 [b]	1.6 [a]	1.5 [a]	21	< 0.001
Skin Sweetness	1.1 [b]	1.4 [a]	1.4 [a]	5.3	0.01
Skin Sweetness Aftertaste	0.66 [b]	0.75 [ab]	0.83 [a]	3.3	0.04
Pulp Sourness	5.1 [a]	4.1 [b]	3.3 [c]	44	< 0.001
Pulp Sourness Aftertaste	1.4 [a]	1.3 [a]	0.8 [b]	15	< 0.001
Skin Sourness	1.4 [a]	1.2 [b]	0.8 [c]	13	< 0.001
Skin Sourness Aftertaste	0.7 [a]	0.5 [b]	0.4 [b]	10	< 0.001
Pulp Bitterness	1.2 [a]	1.1 [a]	0.9 [b]	6.4	< 0.01
Pulp Astringency	2.8 [a]	2.6 [ab]	2.4 [b]	5.0	0.01
Green Wood Aroma	1.8 [b]	2.1 [a]	2.0 [a]	2.5	0.09
Skin Green Wood Flavor	1.8 [a]	1.9 [a]	1.6 [b]	3.0	0.05
Pulp Citrus Flavor	1.9 [a]	1.3 [b]	1.0 [b]	24	< 0.001
Skin Citrus Flavor	0.5 [a]	0.4 [ab]	0.3 [b]	6.6	0.00
Pulp Jammy Flavor	2.1 [b]	2.7 [a]	2.7 [a]	13	< 0.001
Skin Jammy Flavor	0.5 [b]	0.4 [b]	0.7 [a]	4.4	0.01
Skin Fermented Fruit Flavor	0.4 [b]	0.4 [b]	0.6 [a]	4.3	0.01
Pulp Earthy Flavor	0.44 [ab]	0.36 [b]	0.61 [a]	2.5	0.09

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Figure 3.13: Mean panelist ratings (± standard error) of taste and astringency attributes of Marquette Grapes that show significant differences among sugar levels in Year Two (2013). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

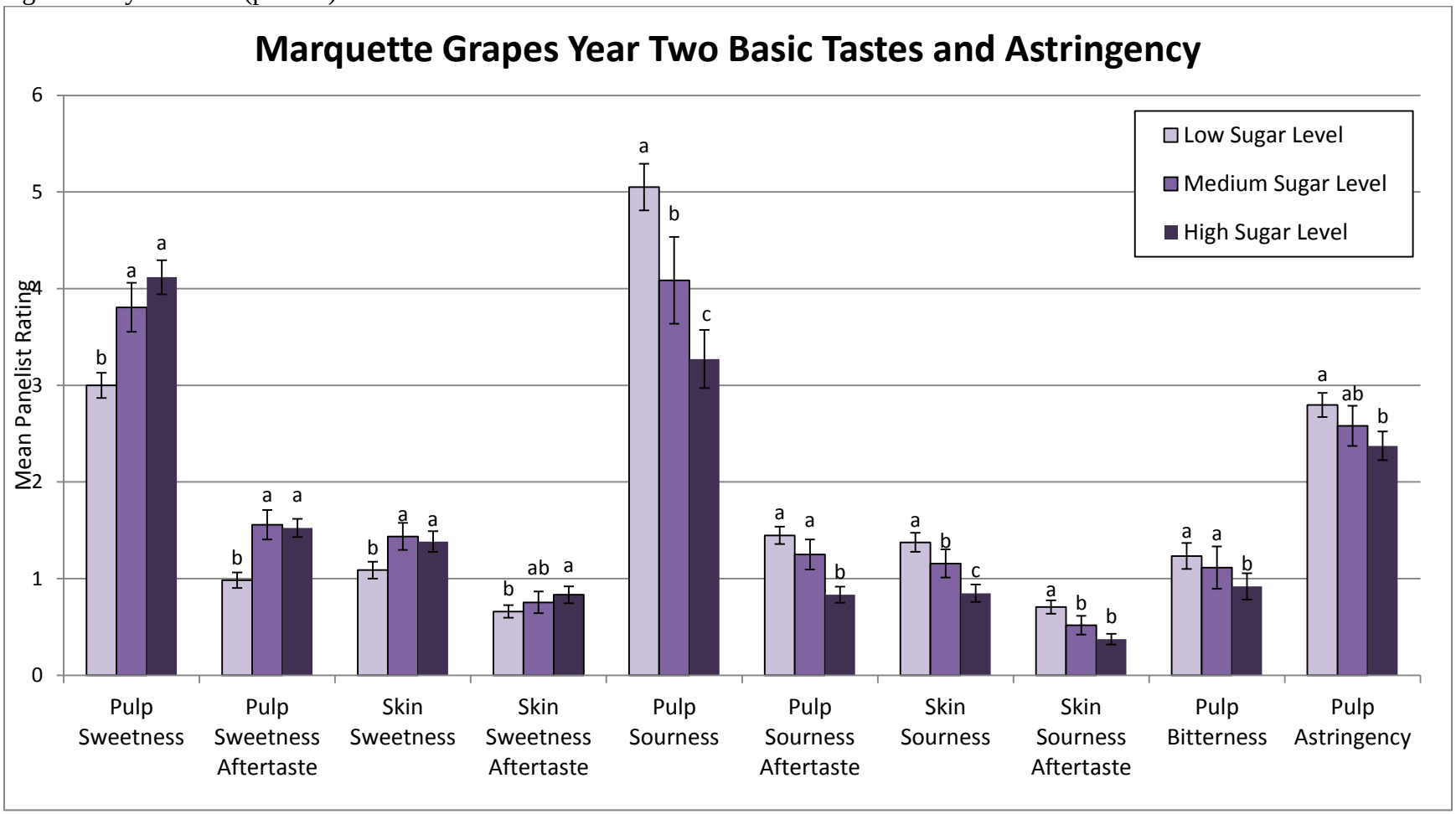


Figure 3.14: Mean panelist ratings (± standard error) of flavor and aroma attributes of Marquette Grapes that show significant differences among sugar levels in Year Two (2013). Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

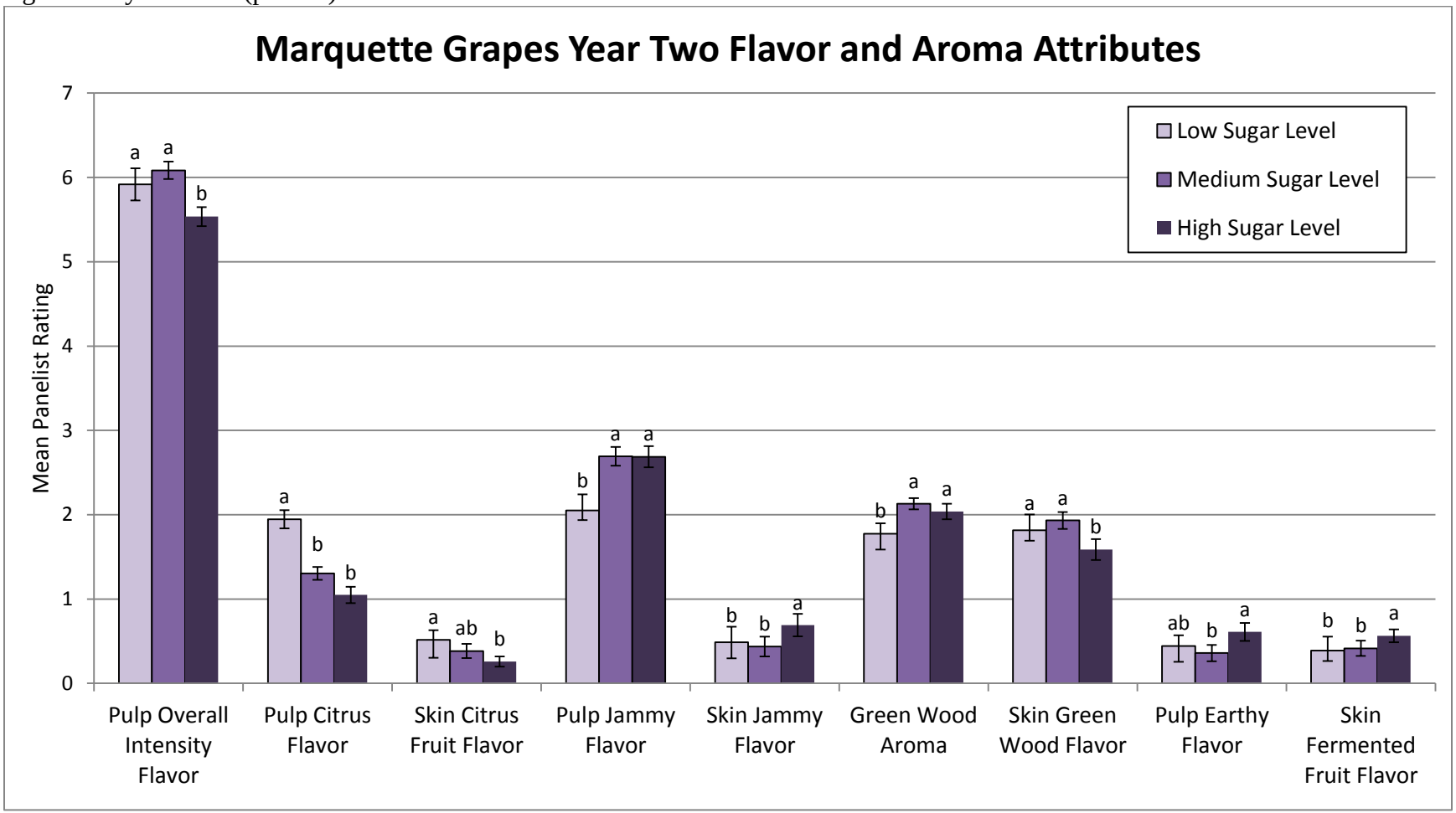
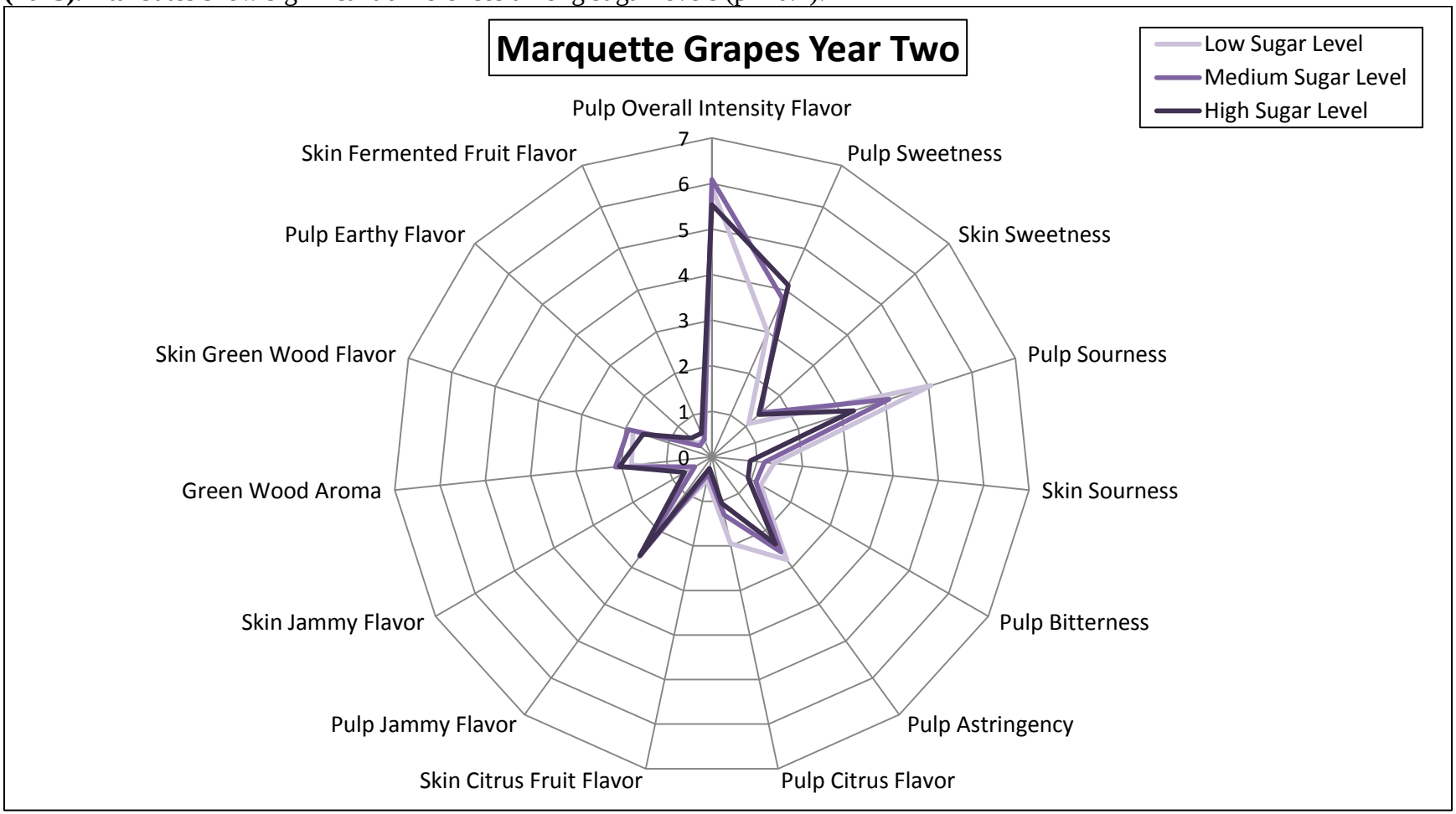


Figure 3.15: Spider plot of mean panelist ratings (± standard error) of the attributes for Marquette Grapes in Year Two (2013). Attributes show significant differences among sugar levels ($p < 0.1$).*



*Sweetness and sourness aftertaste also differed significantly among the sugar levels, but they have been omitted from this plot because they followed the same pattern as sweetness and sourness of the skin and pulp

3.5.3 Marquette Grapes Combined Year One and Two Results

Panelists rated the overall intensity of flavor of the pulp of the low and medium sugar level grapes higher than that of the high sugar level grapes (Table 4.10, Figure 4.14, and Figure 4.15). The sweetness of the pulp, pulp aftertaste, and skin were rated increasingly more intense as the sugar level increased from low to medium to high (Figure 4.13).The sweetness aftertaste of the skin was rated higher in the high sugar level grapes than in the medium and low sugar level grapes. The sourness of the pulp was rated increasingly more intense as the sugar level decreased from high to medium to low. The sourness of the skin was rated higher in the medium sugar level grapes than the low sugar level grapes; and the sourness of the skin of the low sugar level grapes was rated higher than the high sugar level grapes. The sourness aftertaste of the pulp and skin were rated higher in the low and medium sugar level grapes than in the high sugar level grapes, as was the citrus flavor of the skin. The astringency of the pulp was rated highest in the medium sugar level grapes, followed by the low sugar level grapes and then the high sugar level grapes. The bitterness of the pulp was rated higher in the low and medium sugar level grapes than in the high sugar level grapes. The fresh fruit aroma, jammy aroma, green wood flavor of the skin, artificial grape flavor of the pulp, and fresh green flavor of the pulp were all rated higher in the medium sugar level grapes than in the low and high sugar level grapes. The jammy flavor of the pulp increased as the sugar level increased, and the citrus flavor of the pulp was rated the opposite, with the ratings decreasing as the sugar level increased. The jammy flavor of the skin and the floral flavor of the pulp were both rated higher in the high sugar level grapes than in the low and medium sugar level grapes. The green wood aroma and the dried fruit flavor of the pulp were both rated

higher in the medium and high sugar level grapes than in the low sugar level grapes. The artificial grape aroma was rated highest in the medium sugar level grapes, followed by the low sugar level grapes and then the high sugar level grapes.

Table 3.10: Combined Marquette Grapes results from Year One and Year Two. All included attributes contain significant differences among sugar levels (gray is 0.05 < p < 0.1; white is p < 0.05).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Overall Intensity Flavor	5.9 [a]	5.9 [a]	5.4 [b]	18	< 0.001
Pulp Sweetness	3.1 [c]	3.3 [b]	4.2 [a]	62	< 0.001
Pulp Sweetness Aftertaste	1.0 [c]	1.3 [b]	1.6 [a]	29	< 0.001
Skin Sweetness	1.2 [c]	1.4 [b]	1.7 [a]	23	< 0.001
Skin Sweetness Aftertaste	0.6 [b]	0.6 [b]	0.8 [a]	14	< 0.001
Pulp Sourness	4.9 [a]	4.5 [b]	2.8 [c]	127	< 0.001
Pulp Sourness Aftertaste	1.6 [a]	1.7 [a]	0.9 [b]	40	< 0.001
Skin Sourness	1.5 [b]	1.8 [a]	1.1 [c]	36	< 0.001
Skin Sourness Aftertaste	0.7 [a]	0.8 [a]	0.5 [b]	12	< 0.001
Pulp Bitterness	1.2 [a]	1.2 [a]	1.0 [b]	10	< 0.001
Pulp Astringency	3.0 [b]	3.2 [a]	2.6 [c]	13	< 0.001
Fresh Fruit Aroma	1.6 [b]	1.8 [a]	1.5 [b]	3.3	0.04
Jammy Aroma	1.3 [b]	1.5 [a]	1.2 [b]	3.4	0.03
Pulp Jammy Flavor	2.1 [c]	2.3 [b]	2.7 [a]	23	< 0.001
Skin Jammy Flavor	0.5 [b]	0.6 [b]	0.8 [a]	13	< 0.001
Pulp Citrus Flavor	1.7 [a]	1.2 [b]	0.8 [c]	43	< 0.001
Skin Citrus Flavor	0.5 [a]	0.5 [a]	0.3 [b]	6.7	< 0.01
Green Wood Aroma	2.0 [b]	2.4 [a]	2.5 [a]	6.0	0.00
Skin Green Wood Flavor	1.9 [b]	2.1 [a]	1.8 [b]	4.1	0.02
Artificial Grape Aroma	0.5 [b]	0.6 [a]	0.3 [c]	7.6	0.00
Pulp Artificial Grape Flavor	1.7 [b]	1.9 [a]	1.7 [b]	3.3	0.04
Pulp Dried Fruit Flavor	0.7 [b]	0.9 [a]	0.8 [a]	2.9	0.06
Pulp Fresh Green Flavor	0.9 [b]	1.1 [a]	0.9 [b]	2.5	0.08
Pulp Floral Flavor	0.4 [b]	0.5 [b]	0.7 [a]	8.4	0.00

*means within a row with the same letter superscript were not significantly different (p > 0.1)

Figure 3.16: Mean panelist ratings (± standard error) of taste and astringency attributes of Marquette Grapes that show significant differences among sugar levels when Year One (2012) and Year Two (2013) were combined. Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

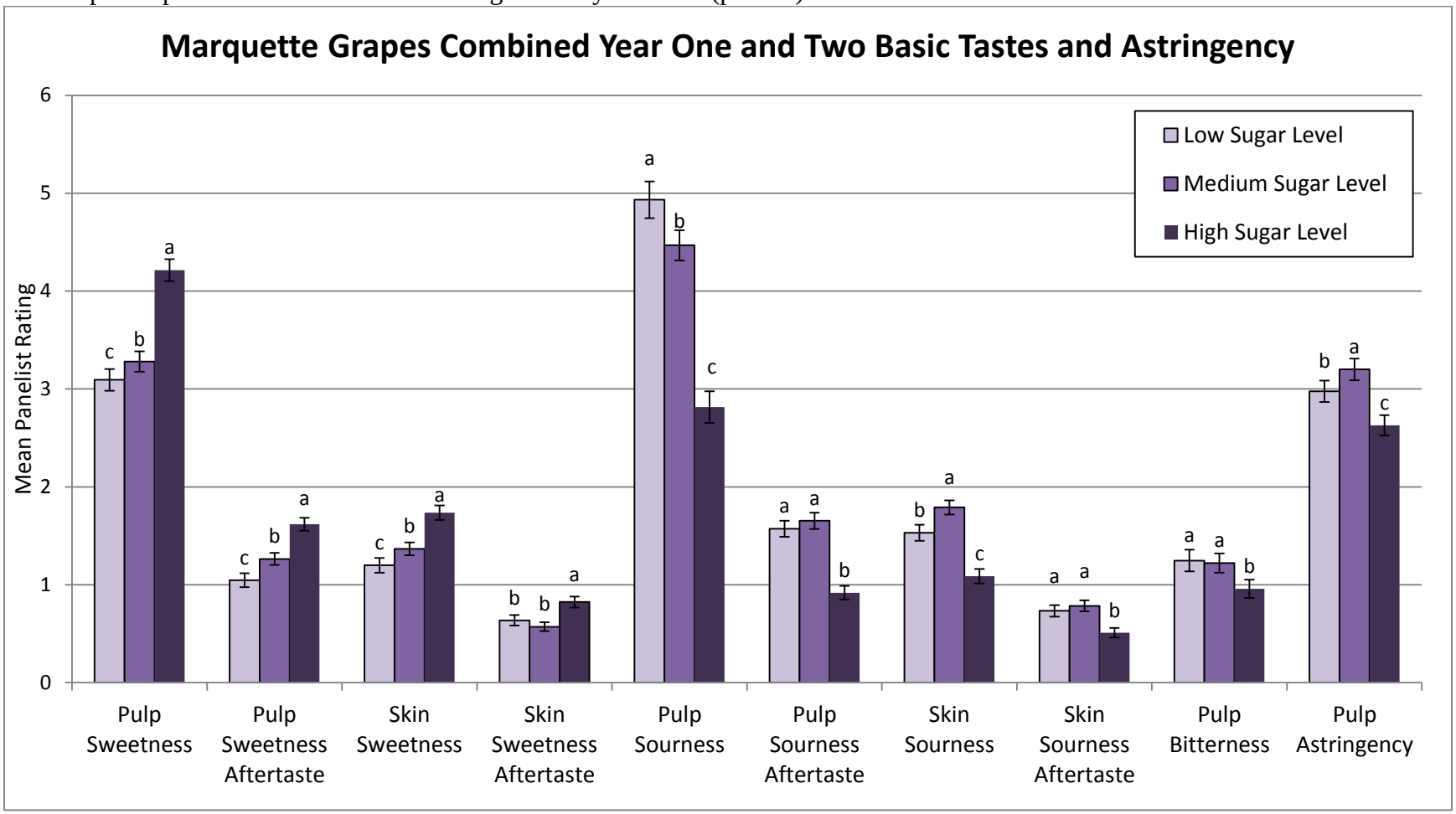


Figure 3.17: Mean panelist ratings (± standard error) of flavor and aroma attributes of Marquette Grapes that show significant differences among sugar levels when Year One (2012) and Year Two (2013) were combined. Means with the same letter superscript within attributes were not significantly different ($p > 0.1$)

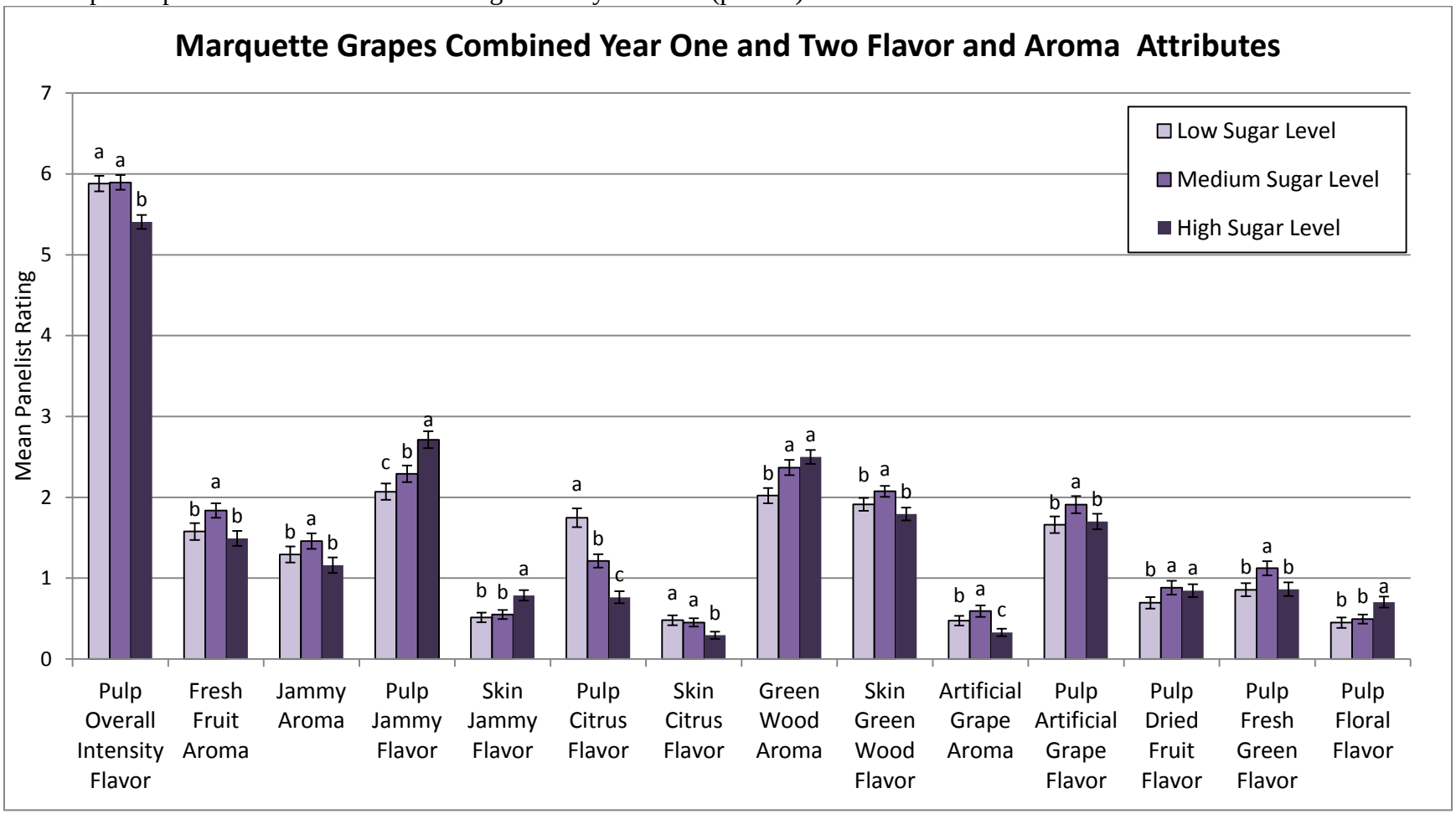
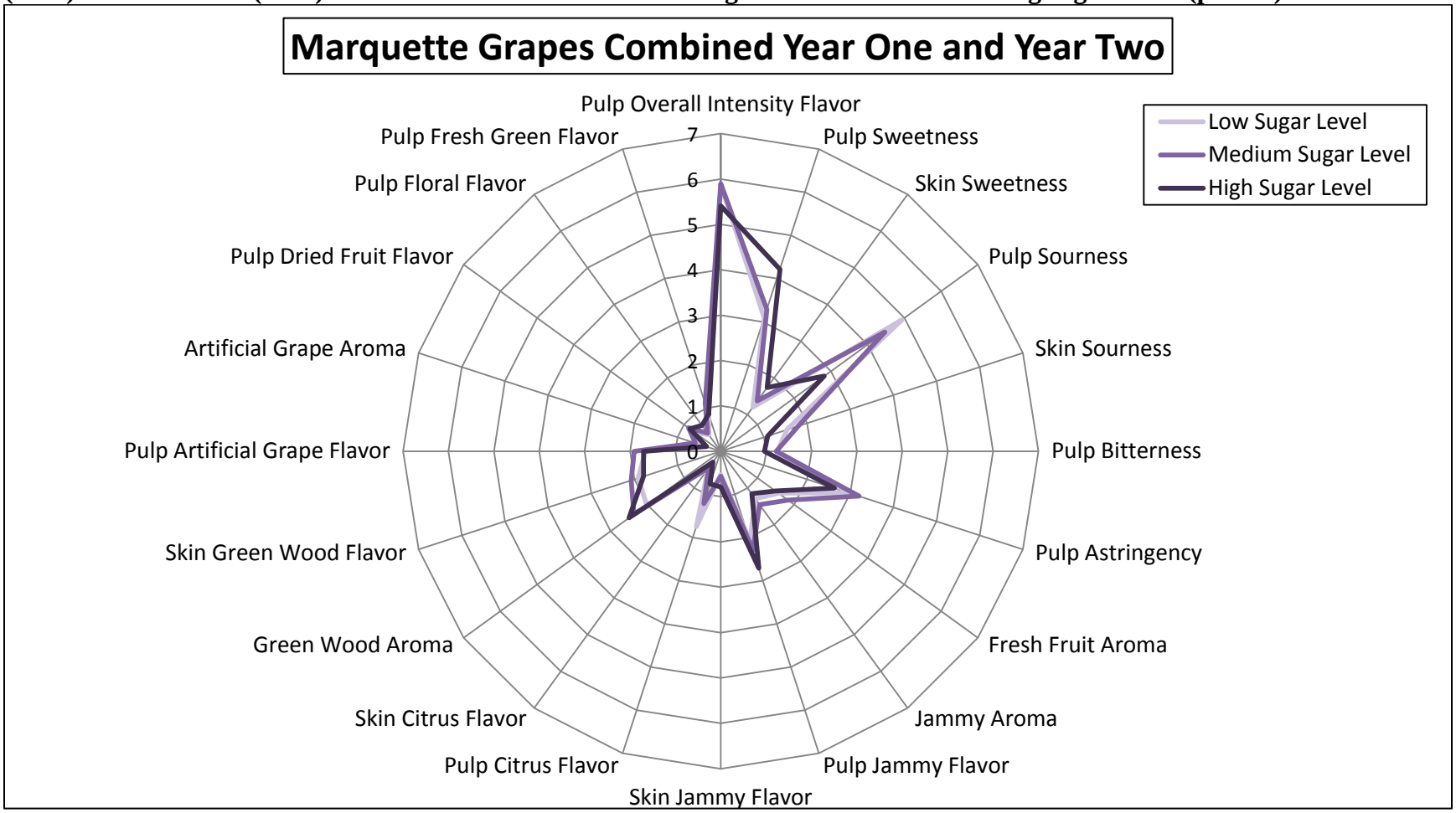


Figure 3.18: Spider plot of mean panelist ratings (± standard error) of the attributes for Marquette Grapes when Year One (2012) and Year Two (2013) were combined. Attributes show significant differences among sugar levels ($p < 0.1$).



*Sweetness and sourness aftertaste also differed significantly among the sugar levels, but they have been omitted from this plot because they followed the same pattern as sweetness and sourness of the skin and pulp

Chapter 4 : Wine Descriptive Analysis

4.1 Materials and Methods

4.1.1 Panelists:

As in the grape berry tests, fourteen panelists, 9 females and 5 males, (ages 21-60) with previous training and experience in descriptive analysis panels participated in training and testing in February and March 2013 and 2014. Panelists were selected based on their age (being of legal age to consume alcohol), their tasting ability (previously shown to be PROP tasters) previous training (on citric acid taste and butanol aroma scales), having no medical reason to not consume alcohol, and their availability. Panelists were compensated $10/hour for training and $13/hour for testing. All recruiting and experimental procedures were approved by the University of Minnesota's Institutional Review Board.

4.1.2 Wine Samples:

Frontenac and Marquette grapes grown in four location replications of the NE 1020 trial at Brookings, South Dakota were processed into wines in 2012 (year 1) and 2013 (year 2) (Table 4.1). Frontenac wines were made at Prairie Berry Winery (Hill City, South Dakota) and Marquette at Tucker's Walk Vineyard (Garretson, South Dakota) using a standard winemaking protocol developed by the University of Minnesota (Appendix 8.2). In 2012 wine was made from pooled location replicates from the final harvest of each varietal. In 2013 two wines were made from each varietal: one using an early harvest before optimal ripeness (Early Harvest), and the second using the last berry harvest (Late

Harvest). Again, location replicates were pooled. (See Table 4.1 or Table 4.4 for detailed information on grape berries).

Table 4.1 Harvest dates and chemical measurements for wine samples produced from grapes grown at the NE 1020 trial at Brookings, South Dakota.

Varietal	Date of Harvest	°Brix of juice before fermentation*	Sample Name Assigned	pH**	TA**	% Alcohol**	% Residual Sugar **
Frontenac	9/12/2012	26.0	Frontenac (2012)	3.15	11.90	15.7	0.50
Marquette***	9/12/2012	28.0	Marquette (2012)	3.53	7.63	15.2	0.20
Frontenac	9/17/2013	22.0	Frontenac Early (2013)	4.05	10.74	12.0	0.09
Frontenac***	9/22/2013	23.9	Frontenac Late (2013)	3.25	11.53	12.8	0.15
Marquette	9/10/2013	22.5	Marquette Early (2013)	3.87	10.31	12.2	0.10
Marquette	9/18/2013	23.6	Marquette Late (2013)	4.05	9.07	13.0	0.09

* Measurements obtained from the winery
** Measurements done by Jennie Savits at the Midwest Grape and Wine Industry Institute Iowa State University
*** This wine did not complete malolactic fermentation

4.2 Training and Testing:

Frontenac wines were evaluated first before moving on to Marquette wines. Panelists participated in 3-6 training sessions and one testing session for each varietal, each lasting about an hour. Panelists completed 4-5 training or testing sessions per week and were allowed to complete more than one session per day with at least one hour between sessions, though most chose not to.

4.2.1 Year One Frontenac Wine Training:

During the first training session panelists were presented with the wine sample of interest and three other wine samples used for training purposes only (Table 4.2) in addition to the lexicon generated by Anna Katharine Mansfield (Table 4.3) with a few modifications based on previous grape berry development and preliminary evaluation by researchers. Panelists were served 60 ml of each wine in wine glasses (model C66, Libbey, Toledo, Ohio) topped with upside-down soufflé cup lids (2 ounce, item number 10135, ProPak, Hunt Valley, Maryland) and blinded with three-digit codes. Panelists evaluated the wines by first smelling the sample and rating the aroma attributes. Then panelists put on a nose clip and rated the basic tastes (sweetness, sourness, and bitterness). Panelists then removed the nose clip to evaluate the flavors of the wine without swallowing the sample (though they were allowed to expectorate and resample if needed), and finally, swallowed a small sip of the wines to evaluate aftertastes. They discussed and generated new attributes when needed and discussed the creation of references for those attributes.

The second training session consisted of another group training session in which panelists reviewed the additions to the lexicon, evaluated the efficacy of the new references, and practiced tasting more samples.

The third training session consisted of panelists being served wine samples individually in separate sensory booths and rating each of the attributes in the lexicon (incorporating new references and attributes that had been discussed the previous day). This was essentially a mock-testing situation, the details of which are provided below.

The fourth training session consisted of panelists reviewing the data produced the previous day, discussing the effectiveness of the new references, and practicing tasting and rating samples. The fifth and sixth training sessions were similar to the third and fourth training sessions.

Table 4.2 Wines used for panel training purposes during Frontenac wine training and testing Year One (2012).

Wine	Producer
Frontenac (2012)*	Tucker's Walk Vineyard (Garretson, South Dakota)
Frozen Frontenac (2012)*, **	Tucker's Walk Vineyard (Garretson, South Dakota)
Rivertown Red (unknown year)	Northern Vineyards Winery (Stillwater, Minnesota)
Frontenac Late Harvest (2011)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Frontenac Rose (2011)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Frontenac (2000)	St. Croix Vineyards (Stillwater, Minnesota)

* produced using grapes grown in the research vineyard at South Dakota State University
** This sample was accidentally frozen and thawed during storage, but was found suitable for training purposes

Table 4.3 Table of attributes and reference standard formulas for red Frontenac table wines presented to panelists in first session. Adapted from "Characterization of the Aroma of Red Frontenac Table Wines by Descriptive Analysis", by A.K. Mansfield and Z.M. Vickers, 2009, American Journal of Enology and Viticulture.

Attribute	Reference standard formula for 500 mL red wine
Blackberry	30 frozen blackberries, thawed and crushed
Black currant	75 g black currant jam
Cherry	Unsweetened tart cherry juice (not in wine)
Jammy	50 g strawberry jam
Cooked vegetable	5 mL ea juice from canned asparagus and green beans
Fresh green	Fresh green beans and asparagus (not in wine)
Cedar	16.5 g cedar shavings soaked in wine 30 min and removed
Spice	Whole Jamaican allspice berries (not in wine)
Black pepper	5 black peppercorns, crushed, stirred for 5 min
Floral	Rose petals and/or violet pastilles (not in wine)
Geranium	50 mL wine with suspected geranium taint
Earthy	50 mL liquid from reconstituted dried mushrooms; potting

Attribute	Reference standard formula for 500 mL red wine
	soil (not in wine)
Tamari[a]	San-J brand organic tamari (not in wine)

[a]A fermented soy product similar to soy sauce, but made without wheat.

4.2.2 Year One Frontenac Wine Testing:

Panelists participated in one testing session in which they tasted the wine sample of interest in replicate (blinded and coded with three-digit codes) and rated the intensity of the aroma, taste, flavor, and aftertaste attributes (Table 4.4). Panelists were also provided with replicate samples of the frozen Frontenac wine used in training, though these data were not used in any way. Panelists evaluated each sample by rating the intensity of the attributes on 12-cm line scales with 20 markings from '0' at the left end and '20' at the right end using the data collection software SIMS2000. Intensity ratings of taste and flavor were made using a citric acid scale and ratings of odors were made using a butanol scale (see Appendix 8.1 for citric acid and butanol scale information).

Panelists were seated in individual sensory booths and were provided with sensory references developed during training (Table 4.4) and a condensed set of butanol aroma and citric acid anchors: 3, 5, 7, and 10. Panelists were also provided with a blinded citric acid and butanol anchor and provided with feedback as to the intensity of the anchor after entering the intensity they perceived. This allowed them to self-calibrate before each session.

Panelists were allowed to take breaks during the session if they became fatigued. Panelists were also allowed to complete more than one session per day with at least one hour in between sessions, though most chose not to.

Table 4.4: Lexicon of attributes and reference standard formulas for Frontenac wine. Changes made to the lexicon in the second year of the study are noted in the Year Two column.

Attribute	Reference Standard	Year Two
	Aroma and Flavor	
Overall Intensity		
Artificial Banana*	3 banana Runt candies dissolved in 500 mL wine**, out of wine: 1 candy broken in half	
Black Currant	Cassis gummy candy, halved (Katjes Berry Cassis Gummie Candy)	
Cooked Berry	Frozen berry mix (strawberry, blueberry, blackberry, raspberry) with ½ cup water boiled for 5 minutes	
Dark Fruit	50 g blackberry jam, 100 mL unsweetened tart cherry juice (R.W. Knudsen, Chico, California), 100 mL plum juice (Sunsweet, Yuba City, California), 100 mL pomegranate juice (POM Wonderful, Los Angeles, CA) -5 mL of the above liquid mixture + 2 cm^2 pieces **fresh plum** with skin	
Cooked Vegetable*	5 ml each from canned asparagus and green beans in 500 ml red wine**	
Fresh Green	Fresh green beans and asparagus	
Woody	Blend of 1 cm^2 flake cedar, 1 American oak chip (medium toast), and 1 French oak chip (medium toast) (each type of wood soaked in ½ cup hot filtered water for 30 minutes	
Hay	Hay	
Black Pepper*	Black peppercorns (McCormick, Hunt Valley Maryland), crushed in wine**	
Spice*	Allspice (McCormick, Hunt Valley Maryland), crushed in wine**	
Floral	Rose water- diluted (Nielsen-Massey)	Changed to Choward's violet candies
Ethanol	Ethanol on a cotton pad	
Chemical	Diluted isopropyl alcohol	
White Mushroom	Sliced white button mushrooms	
Dried Mushroom	Water from rehydrated mushrooms.	
Tamari	San-J brand organic tamari	
	Taste and Astingency	
Sweetness	5.0% sucrose in distilled water (25g/500 ml)	
Sourness	0.075% citric acid in distilled water (0.375g/500 ml)	

Attribute	Reference Standard Year Two
Bitterness 2	0.014% caffeine in distilled water (.071g/500 ml) **intensity=2** 0.057% caffeine in distilled water (.285g/500 ml) **intensity=6**
Astringency 2	0.062% alum in distilled water (0.31g /500 ml); **intensity=2** 1.25g alum in 500 mL water; **intensity=12**
	Aftertastes
Overall aftertaste	
Sweetness aftertaste	5.0% sucrose in distilled water (25g/500 ml)
Sourness aftertaste	0.075% citric acid in distilled water (0.375g/500 ml)
Bitterness aftertaste	0.057% caffeine in distilled water (.285g/500 ml)
Ethanol aftertaste	Ethanol on a cotton pad

* indicates that the reference was also provided in a sample cup without wine
** wine used for references: Bota Box RedVolution (DFV Wines, Manteca, California)

4.2.3 Year One Marquette Wine Training:

During the first Marquette wines training session, panelists were presented with the Frontenac wine Lexicon, the Marquette wine sample of interest and three other wine samples used for training purposes only (Table 4.5). Panelists evaluated these samples by first smelling the sample and rating the aroma attributes. Then panelists put on a nose clip and rated the basic tastes (sweetness, sourness, and bitterness). Panelists then removed the nose clip to evaluate the flavors of the wine without swallowing the sample (though they were allowed to expectorate and resample if needed), and finally, swallowed a small sip of the wines to evaluate aftertastes. They discussed and generated new attributes when needed and discussed the creation of references for those attributes. The second and third training sessions were identical to the second and third training sessions for Frontenac wines, but with the replacement of Marquette Wines (for more information see Year One Frontenac Wine Training section 5.2.1).

Table 4.5: Wines used for panel training purposes during Marquette wine training and testing Year One (2012).

Wine	Producer
Marquette (2012)*	Prairie Berry Winery (Hill City, South Dakota)
Marquette Saignee (2011)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Marquette Reserve (2008)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Marquette Winter (unknown year)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Marquette Reserve (2011)	Chankaska Creek Ranch and Winery (Kasota, Minnesota)

*produced using grapes grown in the research vineyard at South Dakota State University

4.2.4 Year One Marquette Wine Testing:

Panelists participated in two testing sessions in which they tasted two replicates of the Marquette wine sample and rated the intensity of attributes. (For more information see Frontenac Wine Testing section 5.2.2).

Table 4.6: Lexicon of attributes and reference standard formulas for Marquette wine. Changes made to the lexicon in the second year of the study are noted in the Year Two column.

Attribute	Reference Standard	Year Two
	Aroma and Flavor	
Overall Intensity		
Artificial Banana*	3 banana Runt candies dissolved in 500 mL wine**	
Black Currant	Cassis gummy candy, halved	
Cooked Berry	Frozen berry blend, cooked	
Dark Fruit	Tart cherry juice, plum juice, pomegranate juice, blackberry jam, fresh red plum	
Grapefruit	1 ounce Grapefruit juice (Ruby Red Ocean Spray)	
Cooked Vegetable*	5 ml each liquid from canned asparagus and low salt green beans in 500 ml red wine**	
Fresh Green	Fresh green beans and asparagus, crushed	
Woody	Blend of cedar, American oak chip (medium toast), and 1 French oak chip (medium toast).	
Hay	Hay	
Pepper*	Black peppercorns, crushed in wine**	Added white pepper to make a

Attribute	Reference Standard	Year Two
		blend
Spice*	Allspice, crushed in wine**	
Floral	Rose water- diluted	Changed to Choward's violet candy
Geranium	0.1g of geranium extract in 100 mL ethanol (95.5%). 0.1 mL of the above geranium extract and ethanol solution stirred into 500 mL red wine**	Added
Ethanol	Ethanol on a cotton pad	
Chemical	Diluted isopropyl alcohol	
Caramel	Homemade caramel	Added
White Mushroom	Sliced white button mushrooms	
Dried Mushroom	Water from rehydrated mushrooms.	
Tamari	San-J brand organic tamari	
Cheese/Butyric	Cube of asiago cheese (BelGioioso)	Added
	Taste and Mouthfeel	
Sweetness	5.0% sucrose in distilled water (25g/500 ml)	
Sourness	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness	0.014% caffeine in distilled water (.071g/500 ml) **intensity=2** 0.057% caffeine in distilled water (.285g/500 ml) **intensity=6**	
Astringency	0.062% alum in distilled water (0.31g /500 ml); **intensity=2** 1.25g alum in 500 mL water; **intensity=12**	
	Aftertastes	
Overall aftertaste		
Sweetness aftertaste	5.0% sucrose in distilled water (25g/500 ml)	
Sourness aftertaste	0.075% citric acid in distilled water (0.375g/500 ml)	
Bitterness aftertaste	0.057% caffeine in distilled water (.285g/500 ml)	
Ethanol aftertaste	See ethanol reference above	
Chemical aftertaste	See chemical reference above	
Cooked vegetable aftertaste	See cooked vegetable reference above	
Woody aftertaste	See woody reference above	

* indicates that the reference was also provided in a sample cup without wine

** wine used for references: Bota Box RedVolution (DFV Wines, Manteca, California)

4.2.5 Year Two Frontenac Wine Testing:

All procedures were completed the same as in 2013, except for the change in training samples due to availability and a shift in butanol and citric acid anchors to numbers 2, 4, 6, and 9. Panelists had requested this change due to the low intensity of aroma attributes in the grapes and decided to carry this into the wine. The floral reference was changed to use the same violet candies as in the Grapes lexicon. There was a change in the panelists on the panel. Five people did not return to the panel, and two new people were added to the panel. This put the panel at eleven panelists: 6 females and 5 males (ages 21-60). Panelists also evaluated the sample from the previous year. This sample had been stored in imperfect aging conditions (both in the refrigerator and at room temperature), however, it was decided that it would be interesting to see if the sample had changed during that time.

Table 4.7 Wines used for panel training purposes during Frontenac wine training and testing Year Two (2013).

Wine	Producer
Frontenac Early (2013)*	Tucker's Walk Vineyard (Garretson, South Dakota)
Frontenac Late (2013)*	Tucker's Walk Vineyard (Garretson, South Dakota)
Frontenac (2012)*	Tucker's Walk Vineyard (Garretson, South Dakota)
Frontenac Rhone (2012)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Frontenac GRE (2012)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Frontenac Opale (2012)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)

*produced using grapes grown in the research winery at South Dakota State University

4.2.6 Year Two Marquette Wine Testing:

All procedures were completed the same as in 2013, except for the change in training samples due to availability (Table 4.8) and the previously mentioned shift in butanol and citric acid anchors to numbers 2, 4, 6, and 9. There was a modification to the reference formula for pepper to incorporate white pepper as well as black pepper; caramel was added to the lexicon, as was cheese/butyric. There was a change in the panelists on the panel. Five people did not return to the panel, and two new people were added to the panel. This put the panel at eleven panelists: 6 females and 5 males (ages 21-60).

Again, panelists also evaluated the sample of interest from the previous year. This sample had been stored in imperfect aging conditions (both in the refrigerator and at room temperature), however, it was decided that it would be interesting to see if the sample had changed during that time.

Table 4.8 Wines used for panel training purposes during Marquette wine training and testing Year Two (2013).

Wine	Producer
Marquette Early (2013)*	Prairie Berry Winery (Hill City, South Dakota)
Marquette Late (2013)*	Prairie Berry Winery (Hill City, South Dakota)
Marquette (2012)*	Prairie Berry Winery (Hill City, South Dakota)
Marquette Maranda Acres (2009)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Marquette BRG (2012)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)
Marquette Crush (2012)	University of Minnesota Horticulture Research Center (HRC) (Chanhassen, Minnesota)

* produced using grapes grown in the research winery at South Dakota State University

4.3 Data Analysis:

4.3.1 Year One

Due to the nature of the study design (only one sample per varietal for the first year and two were available for the second year), Year One results are reported in conjunction with Year Two.

4.3.2 Year Two:

Analyses of variance (ANOVA) (SAS® PROC GLM) were conducted on each wine varietal separately to determine if the products differed in each attribute. The dependent attributes in the ANOVA model were the attribute ratings; panelist, sample and sensory replicate were predictors. I ran two contrast statements to separate out the early and late 2013wines from the 2012 wine. Only the results from the second contrast statement were used.

I selected attributes with significant ($P < 0.1$) differences between wines in the model for inclusion in the results tables and plots. Complete tables can be found in Appendixes 8.13 and 8.14.

4.3.3 Year One and Two Combined:

The Year One wine was essentially a late harvest wine. This presented the opportunity for additional comparison to the 2013 late harvest wine. I manually combined the data collected about the year one wine in both 2012 and in 2013, and the data collected about the 2013 late harvest wine into a single data file for further evaluation. In doing so I had to rename a few samples. Since the 2012 wine sample was evaluated in both Year One (2012) and Year Two (2013) I decided to call them ‘2012in2012’ (the 2012 sample

evaluated in 2012) and 2012in2013 (or the aged 2012 wine sample that panelists evaluated in 2013). No statistical analysis was done to compare the 2012in2012 and 2012in2013 samples, but attributes that appeared to be the most different among wine samples were plotted for evaluation. Complete tables of means can be found in Appendixes 8.13 and 8.14.

4.4 Frontenac Wine Results:

4.4.1 Year Two Frontenac Wine:

Panelists rated the overall intensity of aroma higher for the late harvest wine than for the early harvest wine (Figure 4.1, Figure 4.3, and Table 4.9). Sweetness and sweetness aftertaste were rated higher in the late harvest than in the early harvest wine, as were artificial banana aroma, artificial banana flavor, black currant flavor, cooked berry aroma and flavor, cooked vegetable aroma, floral aroma, and hay aroma (Figure 4.2). Conversely, panelists rated bitterness and bitterness aftertaste higher in the early harvest wine than in the late harvest wine. They also rated spice aroma, dried mushroom aroma and flavor, white mushroom flavor, tamari aroma and tamari flavor higher in the early harvest wine than in the late harvest wine.

Table 4.9: Frontenac Wine results from Year Two (2013). All included attributes contain significant differences among sugar levels (gray is 0.05 < p < 0.1; white is p < 0.05).

Attribute	Wine Harvest		F- statistic	P-value
	Early	Late		
Overall Intensity of Aroma	5.7	6.2	5.5	0.02
Sweetness	0.5	2.2	29	< 0.001
Sweetness Aftertaste	0.5	1.2	16	< 0.001
Bitterness	4.0	2.8	16	< 0.001
Bitterness Aftertaste	2.7	1.8	9.2	< 0.001
Artificial Banana Aroma	0.7	1.2	3.3	0.08
Artificial Banana Flavor	0.3	0.8	9.7	< 0.001

Attribute	Wine Harvest			
	Early	Late	F- statistic	P-value
Black Currant Flavor	1.5	1.9	3.0	0.09
Cooked Berry Aroma	0.9	1.4	3.5	0.07
Cooked Berry Flavor	0.7	1.8	15	< 0.001
Cooked Vegetable Aroma	0.8	1.7	6.8	0.01
Floral Aroma	0.3	0.7	3.1	0.09
Spice Aroma	0.9	0.5	3.0	0.09
Dried Mushroom Aroma	1.3	0.5	8.6	< 0.001
Dried Mushroom Flavor	1.7	0.4	21	< 0.001
White Mushroom Flavor	1.2	0.6	6.5	0.01
Tamari Aroma	1.9	0.6	21	< 0.001
Tamari Flavor	1.9	0.4	25	< 0.001
Hay Flavor	0.8	0.1	12	< 0.001

Figure 4.1 Spider plot of mean panelist ratings (± standard error) of the taste and overall intensity attributes for Frontenac Wines Year Two (2013) that were significantly different between wines.

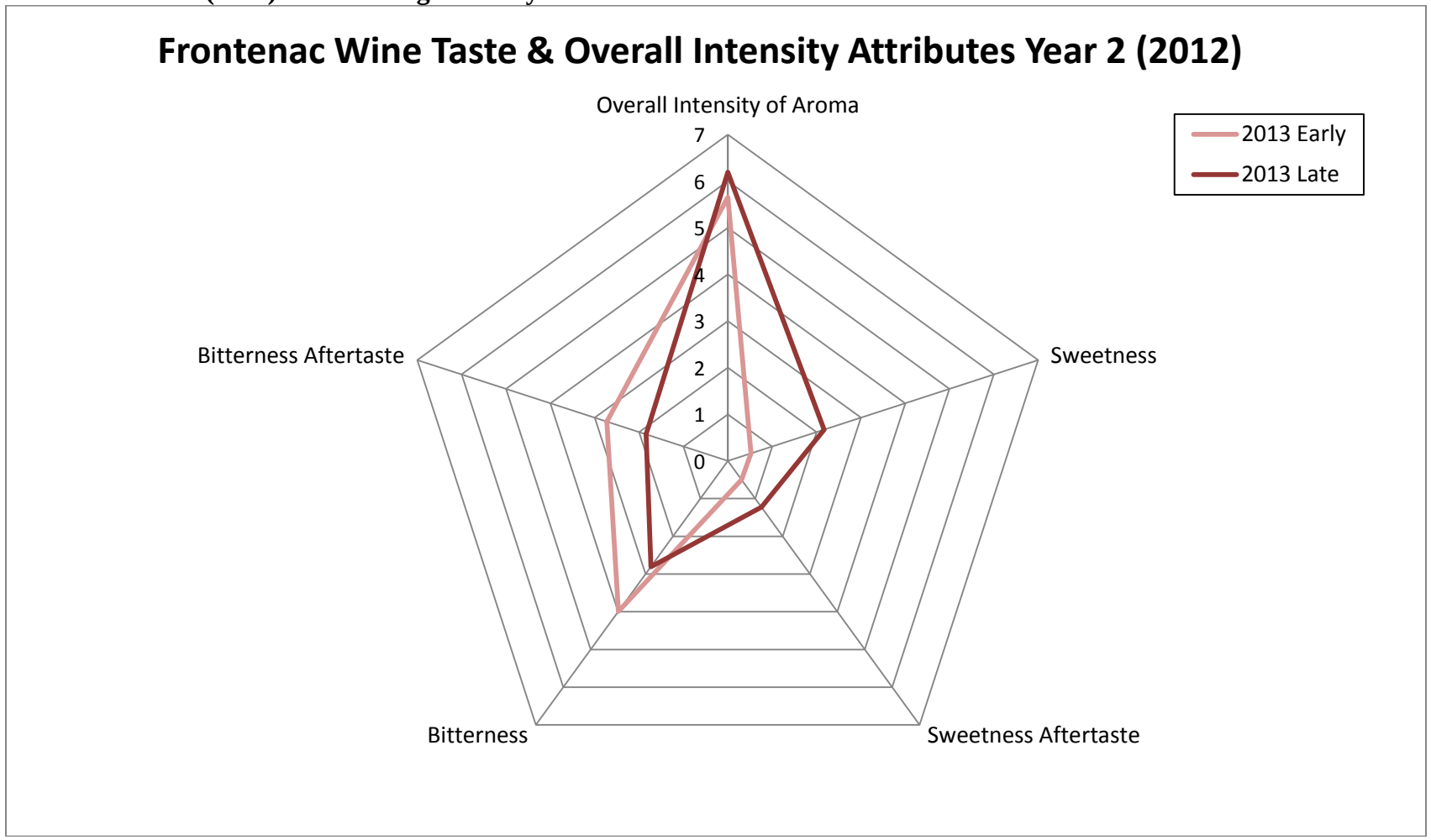


Figure 4.2 Spider plot of mean panelist ratings (± standard error) of the aroma and flavor attributes for Frontenac Wines Year Two (2013) that are significantly different between wines ($p < 0.1$).

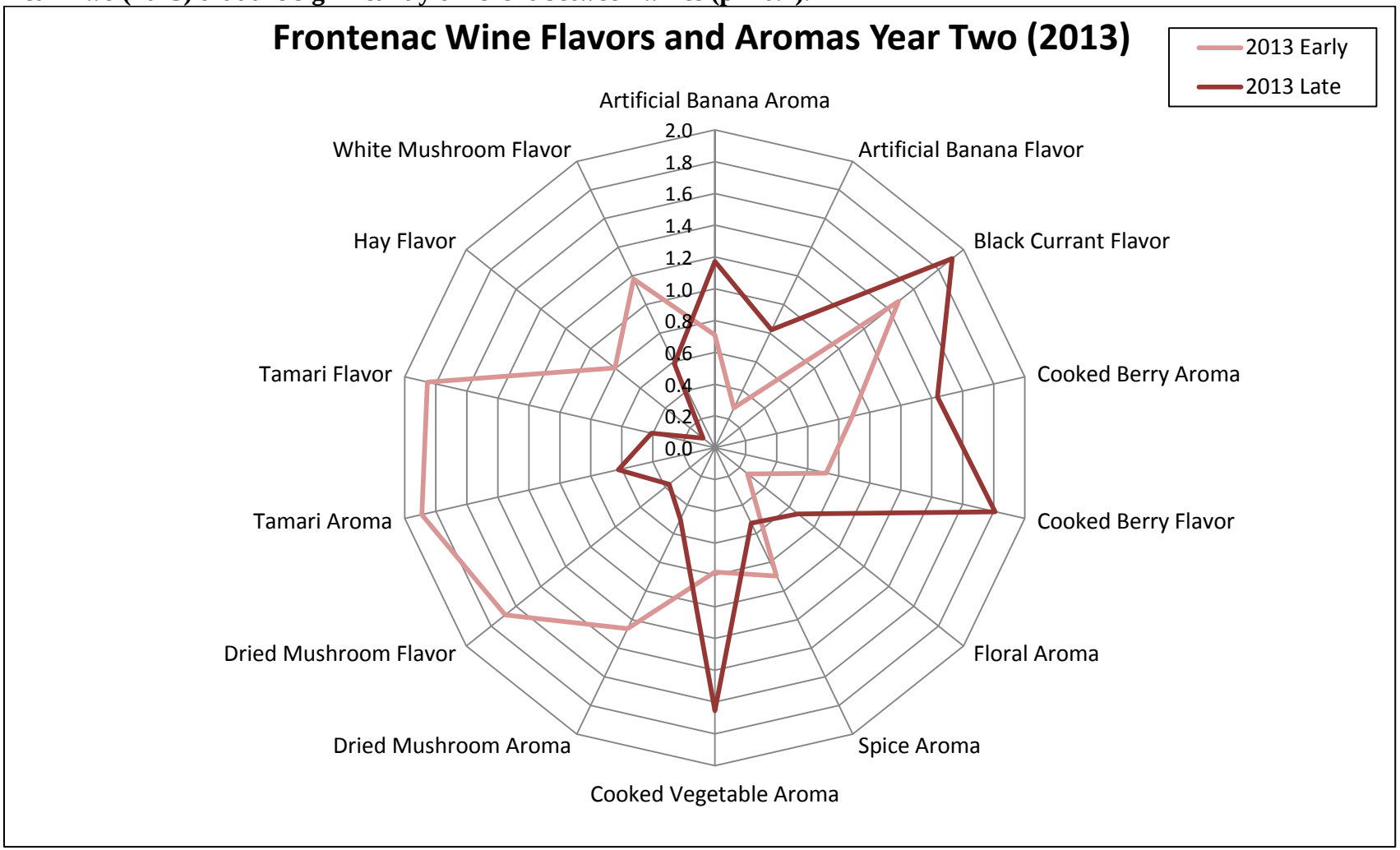
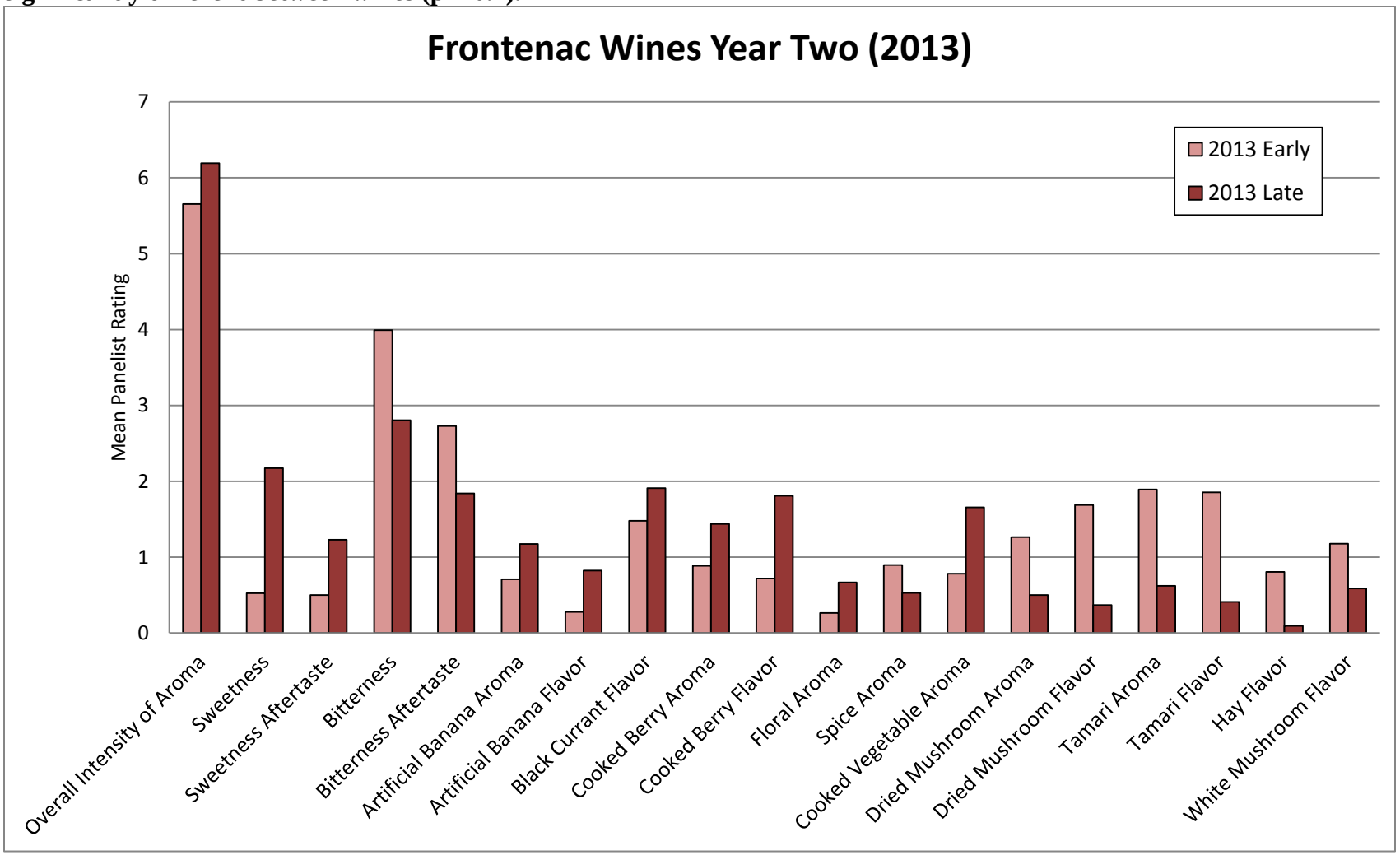


Figure 4.3: Mean panelist ratings (± standard error) of the attributes for Frontenac Wines Year Two (2013) that were significantly different between wines ($p < 0.1$).



4.4.2 Frontenac Wine Year One and Two Combined:

Panelists rated the floral aroma and flavor lower in the 2012 Frontenac wine when they rated it in Year Two than when they rated it in Year One (2012). They also rated the fresh green flavor and sourness of the 2012 sample lower in 2013 than in 2012. Panelists rated the bitterness, woody flavor, hay flavor, and dried mushroom aroma higher in the 2012 wine in 2013 than in 2012. Ethanol aroma, flavor, and aftertaste were rated lower in the 2012 wine when panelists rated it in 2013 than when they rated it in 2012. Panelists also rated the cooked berry flavor lower in both the 2012 wine evaluated in 2013 and in the late harvest 2013 wine sample. Geranium aroma was not defined until Year Two (2013), but that year panelists rated the 2012 wine sample higher than the 2013 late sample in that attribute. Panelists rated the spice flavor higher in the 2013 Late sample lower than in the 2012 sample, however they rated the 2012 sample higher in 2013 than in 2012.

Table 4.10: Mean and standard errors of select Frontenac Wine attributes from Year One (2012) and Year Two (2013). All wines could be considered to be produced from Late Harvest grape berries. The wine from 2012 was evaluated in both 2012 and 2013 after aging.

	Wine Sample			Standard error		
Attribute	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Floral Aroma	1.5	0.9	0.7	0.2	0.2	0.2
Floral Flavor	1.3	0.6	0.4	0.3	0.2	0.2
Sourness	4.8	3.1	3.8	0.3	0.4	0.5
Bitterness	2.8	3.1	2.8	0.3	0.3	0.3
Woody Flavor	0.9	1.5	1.1	0.2	0.2	0.2
Hay Flavor	0.0	0.4	0.1	0.0	0.2	0.1
Dried Mushroom Aroma	0.3	0.6	0.5	0.1	0.2	0.2
Ethanol Aroma	2.0	1.5	1.4	0.2	0.3	0.3
Ethanol Flavor	2.9	1.4	1.9	0.3	0.3	0.3
Ethanol Aftertaste	2.6	1.7	1.6	0.3	0.3	0.3
Geranium Aroma*		0.5	0.1		0.2	0.1
Spice Flavor	1.0	1.3	0.6	0.2	0.2	0.2

Attribute	Wine Sample			Standard error		
	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Cooked Berry Flavor	2.3	1.4	1.8	0.2	0.2	0.3
Fresh Green Flavor	0.8	0.3	0.4	0.2	0.1	0.2

*Geranium attributes were added to the lexicon in 2013 and were not rated in 2012

4.5 Marquette Wine Results:

4.5.1 Year Two Marquette Wine:

Panelists rated the overall intensity of aftertaste higher for the late harvest wine than for the early harvest wine (Figure 4.4, Figure 4.5, and Table 4.11). Sweetness and sweetness aftertaste were rated higher in the early harvest, as were astringency and white mushroom flavor. Conversely, panelists rated sourness aftertaste, bitterness, and bitterness aftertaste higher in the late harvest wine than in the early harvest wine; and they also rated dried mushroom aroma, dried mushroom flavor, cooked vegetable flavor, cooked vegetable aftertaste, pepper flavor, ethanol flavor, and ethanol aftertaste higher in the early harvest wine.

Table 4.11: Marquette Wine results from Year Two (2013). All included attributes contain significant differences among sugar levels (gray is 0.05 < p < 0.1; white is p < 0.05).

Attribute	Wine Harvest			
	Early	Late	F- statistic	P-value
Overall Aftertaste	3.3	4.1	14	< 0.001
Sweetness	1.6	0.9	8.0	< 0.01
Sweetness Aftertaste	1.1	0.7	4.0	0.05
Sourness Aftertaste	1.9	2.4	4.6	0.04
Bitterness	3.5	4.2	4.2	0.04
Bitterness Aftertaste	2.2	2.9	6.3	0.02
Astringency	2.9	3.9	6.2	0.02
Dried Mushroom Aroma	0.3	0.8	5.8	0.02
Dried Mushroom Flavor	0.4	0.9	6.6	0.01
White Mushroom Flavor	0.9	0.5	3.4	0.07
Cooked Vegetable Flavor	1.4	2.0	4.1	0.05
Cooked Vegetable Aftertaste	0.8	1.4	6.0	0.02
Pepper Flavor	0.7	1.1	2.8	0.10
Ethanol Flavor	1.4	2.0	5.9	0.02
Ethanol Aftertaste	1.6	2.0	3.2	0.08

Figure 4.4: Spider plot of mean panelist ratings (± standard error) of the aroma and flavor attributes for Marquette Wines Year Two (2013) that were significantly different between wines ($p < 0.1$).

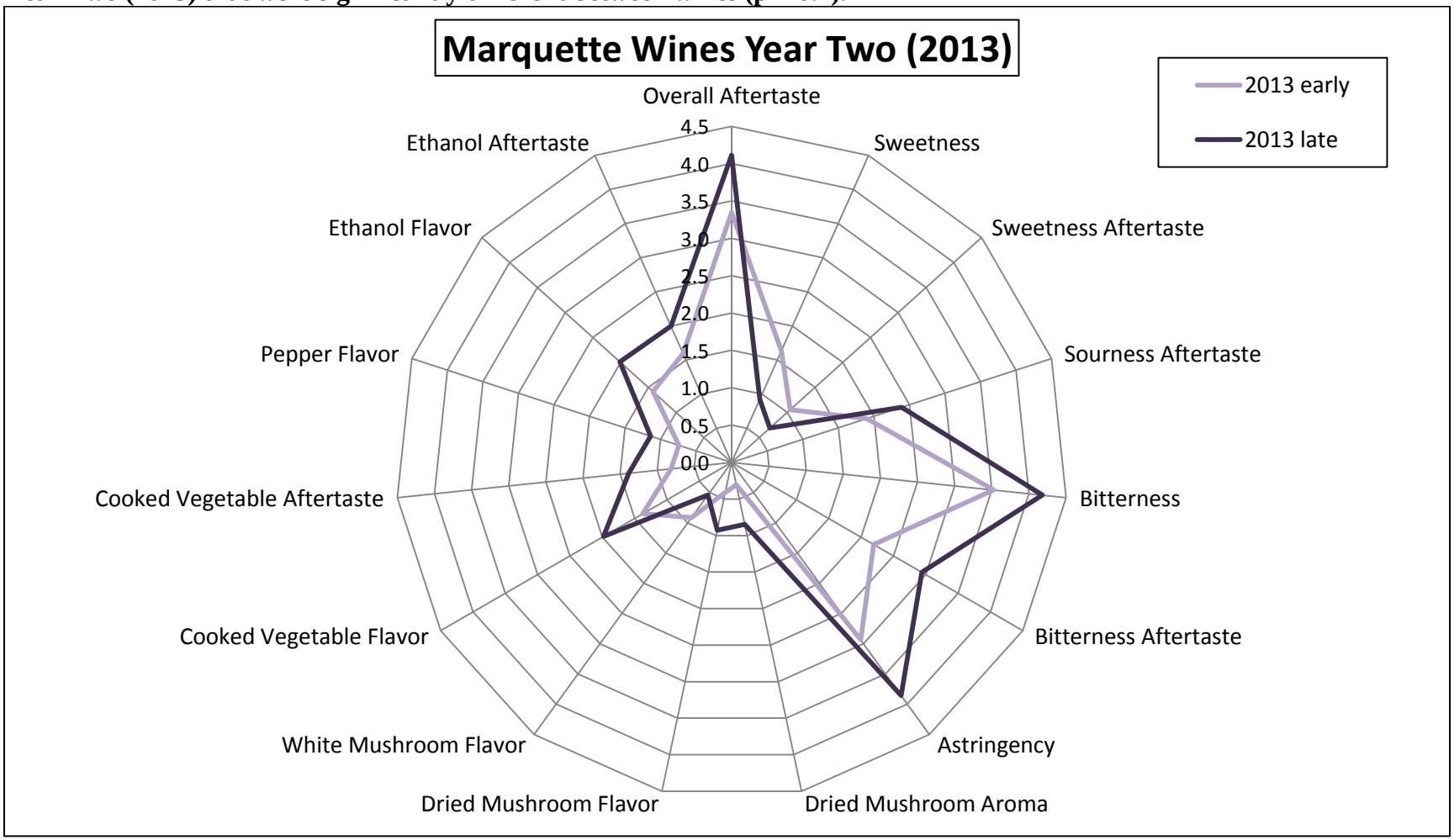
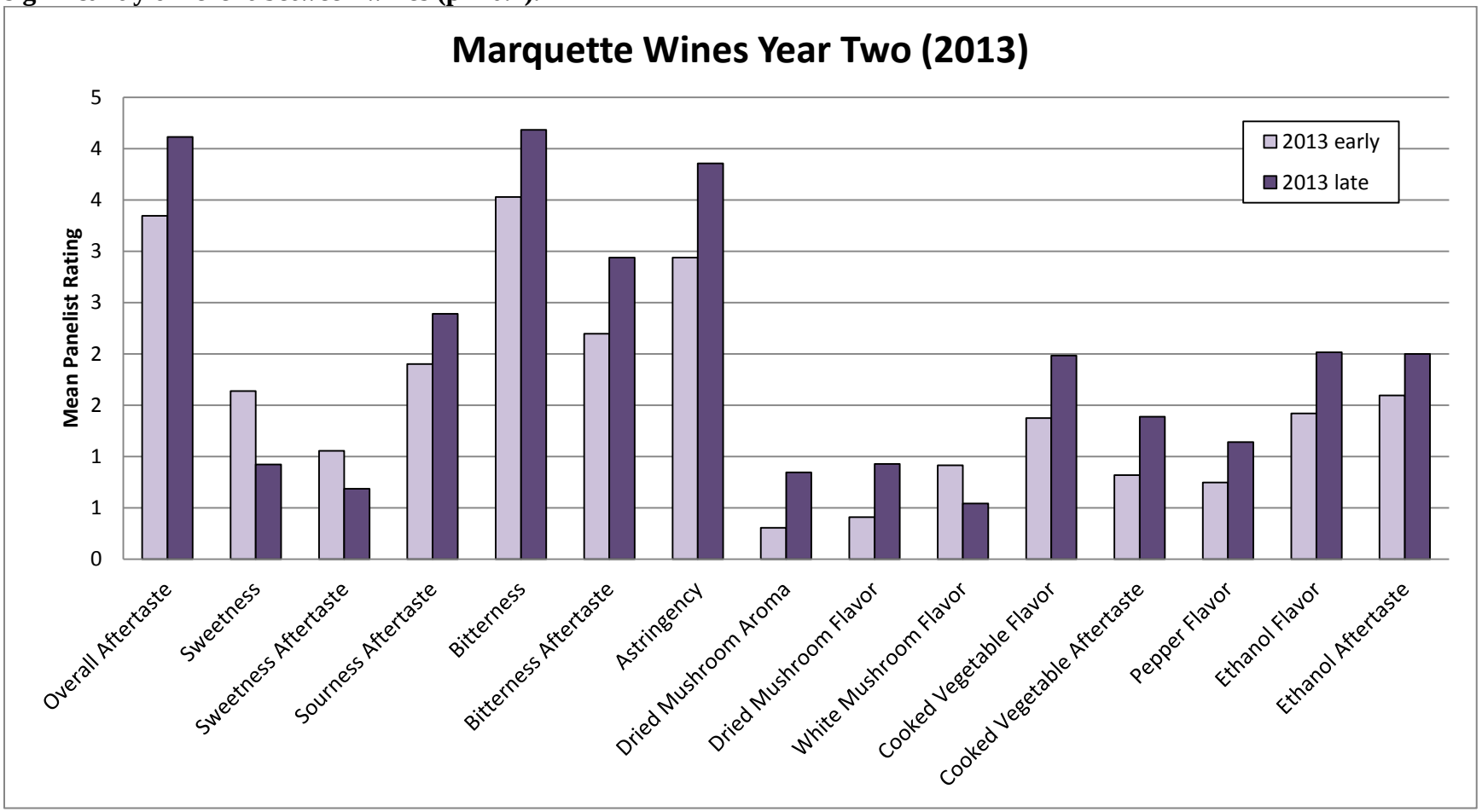


Figure 4.5: Mean panelist ratings (± standard error) of the attributes for Frontenac Wines Year Two (2013) that were significantly different between wines ($p < 0.1$).



4.5.2 Marquette Wine Year One and Two Combined:

Panelists rated the overall intensity of aroma lower in the 2012 Frontenac wine when they rated it in Year Two than when they rated it in Year One (2012). The cooked vegetable aroma was rated higher in the 2012in2012 wine than in the 2012in2013 and in Late 2013 wine. The opposite trend was noted with the cooked vegetable flavor and aftertaste, and panelists rated the late harvest 2013 higher in those attributes. Panelists rated the ethanol aroma of the 2012 sample lower when they rated it in year two as compared to year one. Panelists rated the sweetness of the 2012 sample higher when they rated it in year two. Panelists rated the bitterness of the 2013 late sample higher than the 2012 sample, though their rating for the 2012 sample did decrease from year one to year two. The cheese/butyric attributes were not defined until Year Two (2013), but that year panelists rated the 2012 wine sample higher than the 2013 late sample in both cheese/butyric aroma and flavor . The black currant flavor in the 2012 sample was rated higher in the 2012 wine in year one than in year two. The 2013 late harvest wine was rated higher than the 2012 sample either year.

Table 4.12: Mean and standard errors of select Marquette Wine attributes from Year One (2012) and Year Two (2013). All wines could be considered to be produced from Late Harvest grape berries. The wine from 2012 was evaluated in both 2012 and 2013 after aging.

	Wine Sample			Standard error		
Attribute	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Overall Intensity of Aroma	7.3	6.3	5.8	0.2	0.3	0.2
Cooked Vegetable Aroma	2.1	1.8	1.1	0.2	0.2	0.3
Cooked Vegetable Flavor	1.3	1.2	2.0	0.2	0.2	0.3
Cooked Vegetable Aftertaste	0.7	0.6	1.4	0.2	0.2	0.2

Attribute	Wine Sample			Standard error		
	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Ethanol Aroma	2.5	1.4	1.2	0.3	0.3	0.2
Cheese Butyric Aroma*		0.9	0.6		0.2	0.2
Cheese Butyric Flavor*		0.6	0.5		0.2	0.2
Sweetness	1.9	3.1	0.9	0.3	0.3	0.2
Bitterness	3.4	2.9	4.2	0.4	0.4	0.3
Black Currant Flavor	2.3	1.8	1.7	0.2	0.2	0.2
Cooked Berry Flavor	1.5	1.6	0.8	0.2	0.3	0.2

*Cheese/butyric attributes were added to the lexicon in 2013 and were not rated in 2012

Chapter 5 : Discussion

5.1 Grapes: Both Varietals

Grapes that have been frozen and then thawed may have different sensory characteristics than fresh berries. The freezing process ruptures cells due to the expansion of liquid, which upon thawing, allows the liquid and any dissolved or volatile compounds to be more readily accessible for sensory analysis. Pulp sweetness is perceived as higher and skin bitterness is perceived as lower in previously frozen grapes than in fresh grapes (Olarte Mantilla et al. 2013). Evaluating grapes that have been frozen may then be more representative of the sensory profile created by the extraction process that is undergone during the winemaking process than evaluating fresh grapes. Red wine is made by crushing the grapes and beginning fermentation of the resulting must in contact with the skins. Some winemakers add in macerating enzymes like pectinase and gluconase that are designed to further break down the cell walls of the grape berry skins and result in higher extraction of desirable compounds such as tannins, anthocyanins, and aroma compounds (Bakker, Bellworthy, Reader, & Watkins, 1999). Schmid (Schmid et al., 2007) suggested that similar results could be achieved by freezing the must which would be similar to the technique used in this study.

5.2: Frontenac Grapes

Panelists were probably not able to separate the flavor of the citrus references from the sourness of the fruits when making their ratings. This is supported by the fact that the citrus aromas were not rated significantly different among sugar levels in either year, even though the citrus flavors of both the skin (year one) and the pulp (year one and year

two) and were rated in the same manner as the sourness attributes, with higher values in the low sugar grapes than in the high sugar grapes (Table 5.1).

Table 5.1 Citrus and sourness attributes from Frontenac Grapes. Shaded rows indicate significant differences among samples (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).*

Year	Attribute	Sugar Level				
		Low	Medium	High	F- statistic	p-value
One (2012)	Citrus Fruit Aroma	0.3	0.4	0.3	0.4	0.70
One (2012)	Pulp Citrus Flavor	1.4 [a]	1.4 [a]	0.9 [b]	10.5	< 0.001
One (2012)	Skin Citrus Fruit Flavor	0.4 [ab]	0.5 [a]	0.3 [b]	7.3	< 0.001
One (2012)	Pulp Sourness	5.5 [a]	5.3 [a]	4.2 [b]	29.0	< 0.001
One (2012)	Skin Sourness	1.8 [a]	1.9 [a]	1.5 [b]	5.7	< 0.001
Two (2013)	Citrus Fruit Aroma	0.3	0.3	0.3	0.4	0.66
Two (2013)	Pulp Citrus Flavor	2.1 [a]	1.6 [b]	1.3 [b]	8.8	< 0.001
Two (2013)	Skin Citrus Flavor	0.4	0.3	0.3	2.7	0.07
Two (2013)	Pulp Sourness	5.5 [a]	4.8 [b]	4.2 [c]	17	< 0.001
Two (2013)	Skin Sourness	1.5 [a]	1.2 [b]	1.2 [b]	2.8	0.06

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

5.3: Marquette Grapes

Panelists may have confused the dried fruit and jammy flavors of the pulp with the increase in sweetness. This is supported by the fact that the ratings of dried fruit aroma were not significantly different among sugar levels of grapes (year one) even though the dried fruit flavor of the pulp was rated higher in the high sugar level grapes than the medium and low sugar level grapes (Figure 5.1 and Table 5.2). The sweetness attributes were also rated higher in the high sugar level grapes than in the medium and low sugar level grapes in year one. The jammy aroma was rated higher in the low sugar level grapes than in the medium and high sugar level grapes (year one), but the opposite trend was observed in the ratings of pulp jammy flavor and skin jammy flavor. Those attributes were rated higher in the high sugar level grapes than the medium and low sugar level grapes, as were the sweetness attributes (Figure 5.1 and Table 5.2). In year two, the jammy aroma was not rated significantly different among sugar levels but the pulp jammy flavor and skin jammy flavor were again rated higher in the high sugar level grapes than the medium and low sugar level grapes, as were the sweetness attributes (Table 5.3). The increase in sweetness in the high sugar level grapes may explain why panelists rated the jammy and dried fruit flavors higher in the high sugar level grapes but did not rate not the jammy and dried fruit aromas higher.

Table 5.2: Jammy, dried fruit, and sweetness attribute results from Marquette Grapes Year One (2012). Shaded rows indicate significant differences among samples (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Jammy Aroma	1.4 [a]	1.6 [a]	1.1 [b]	5.5	< 0.001
Pulp Jammy Flavor	2.1 [b]	2.2 [b]	2.7 [a]	14	< 0.001
Skin Jammy Flavor	0.6 [b]	0.6 [b]	0.9 [a]	8.3	< 0.001

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Dried Fruit Aroma	0.8	0.8	0.8	0.3	0.77
Pulp Dried Fruit Flavor	0.6 [b]	0.9 [a]	0.8 [a]	2.6	0.07
Skin Dried Fruit Flavor	0.8	0.9	0.9	0.6	0.57
Pulp Sweetness	3.3 [b]	3.1 [b]	4.3 [a]	51	< 0.001
Skin Sweetness	1.5 [b]	1.3 [b]	2.0 [a]	27	< 0.001

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Figure 5.1: Mean panelist ratings (± standard error) of jammy, dried fruit, and sweetness attributes from Marquette Grapes Year One (2012).

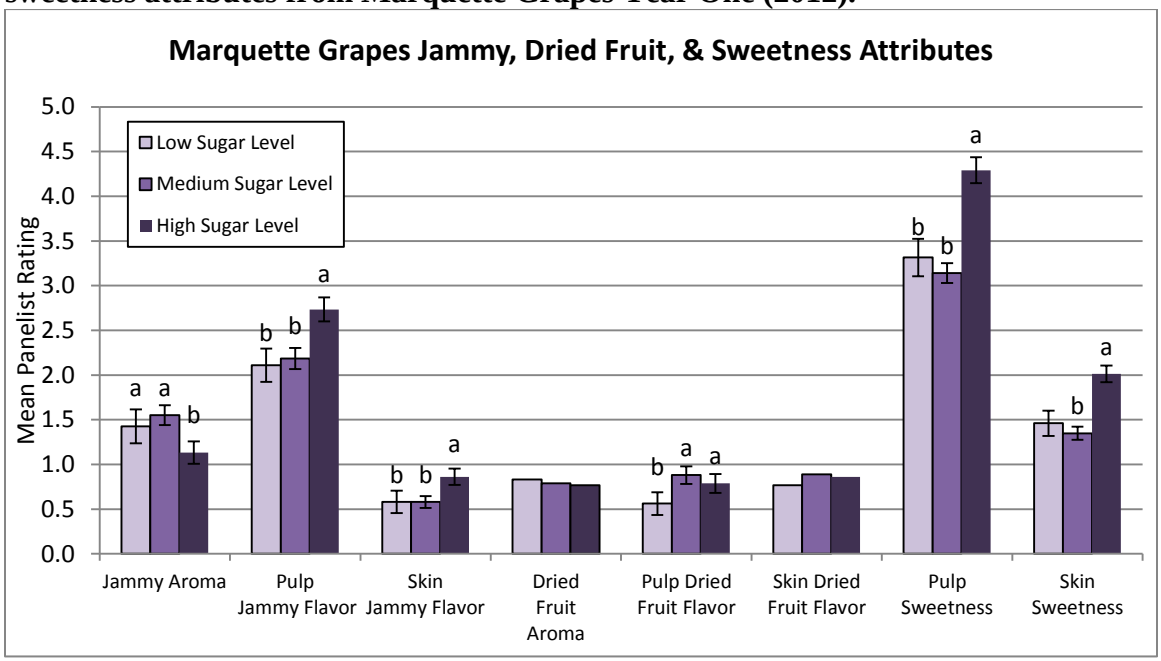


Table 5.3: Jammy and sweetness attribute results from Marquette Grapes Year Two (2013). Shaded rows indicate significant differences among samples (dark gray is $p < 0.05$).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Jammy Aroma	1.2	1.1	1.2	0.6	0.55
Pulp Jammy Flavor	2.1 [b]	2.7 [a]	2.7 [a]	13	< 0.001
Skin Jammy Flavor	0.5 [b]	0.4 [b]	0.7 [a]	4.4	0.01
Pulp Sweetness	3.0 [b]	3.8 [a]	4.1 [a]	27	< 0.001
Skin Sweetness	1.1 [b]	1.4 [a]	1.4 [a]	5.3	0.01

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

5.4: Frontenac Wines

Allowing grapes to hang on the vines for extended ripening periods can allow for the development of dark fruit attributes (Bisson, 2001). This practice may also allow for these flavors to develop in the wines, and is supported by the late harvest wine being rated higher in black currant and cooked berry attributes than the early harvest wine (Table 5.4). The grapes were also rated higher in dark fruit attributes: both the pulp dried fruit flavor and the pulp jammy flavor were rated higher in the higher sugar level grapes than in the low sugar level grapes (Table 5.5).

Table 5.4: Cooked berry and black currant results from Frontenac Wines Year Two. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray p < 0.05).

	Wine Harvest			
Attribute	**Early**	**Late**	**F- statistic**	**P-value**
Cooked Berry Aroma	0.9	1.4	3.5	0.07
Cooked Berry Flavor	0.7	1.8	15	< 0.001
Black Currant Flavor	1.5	1.9	3.0	0.09

Table 5.5: Dried Fruit and jammy attributes from Frontenac Grapes Year Two. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray p < 0.05).*

	Sugar Level				
Attribute	**Low**	**Medium**	**High**	**F- statistic**	**p-value**
Pulp Dried Fruit Flavor	0.8[b]	0.9[ab]	1.1[a]	2.3	0.10
Pulp Jammy Flavor	1.8[c]	2.1[b]	2.3[a]	6.6	< 0.01
Skin Dried Fruit Flavor	1.0	1.1	1.1	0.9	0.40

*means within a row with the same lefttter superscript were not significantly different (p > 0.1)

5.5: Marquette Wines

The bitterness perception of a wine can be greatly increased by a relatively small increase in alcohol concentration (Fischer & Noble, 1994). This may have contributed to the higher ratings of the bitterness attributes and lower ratings of sweetness attributes in the Marquette late harvest wine compared to the early harvest wine, which was contrary to what might be expected as the grapes ripen and sugar levels increase (Table 5.6). The higher ratings of the bitterness attributes is supported by the correspondingly higher ratings of ethanol flavor and aftertaste in the late harvest wine. Of course, the potential increase in sugars in the late harvest grapes could have facilitated an increase in alcohol percentage of the resulting wine. Had that occurred, the assumption that the sweetness would increase and the bitterness would decrease would have been incorrect. Either way, the increase in perceived bitterness in late harvest Marquette wines was the opposite of the results in the Frontenac wines, in which the panelists rated the late wines higher in sweetness and lower in bitterness than the early wines (Table 5.6 and Table 5.7).

Table 5.6: Sweetness, bitterness and ethanol attribute results from Marquette Wine Year Two (2013). Shaded rows indicate significant differences among samples (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).

	Wine Harvest			
Attribute	**Early**	**Late**	**F- statistic**	**P-value**
Sweetness	1.6	0.9	8.0	< 0.01
Sweetness Aftertaste	1.1	0.7	4.0	0.05
Bitterness	3.5	4.2	4.2	0.04
Bitterness Aftertaste	2.2	2.9	6.3	0.02
Ethanol Flavor	1.4	2.0	5.9	0.02
Ethanol Aftertaste	1.6	2.0	3.2	0.08

Table 5.7: Sweetness, bitterness, and ethanol attribute results from Frontenac Wines Year Two. Shaded rows indicate significant differences among samples (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).

Attribute	Wine Harvest			
	Early	Late	F- statistic	P-value
Sweetness	0.5	2.2	29	< 0.001
Sweetness Aftertaste	0.5	1.2	16	< 0.001
Bitterness Aftertaste	2.7	1.8	9.2	< 0.001
Bitterness	4.0	2.8	16	< 0.001
Ethanol Flavor	1.7	1.9	0.3	0.61
Ethanol Aftertaste	1.6	1.6	0.1	0.74

The increase in bitterness and decrease in sweetness from the Marquette early harvest wine to the late harvest wine could potentially be explained if the labels for the early and late wines were switched (late labeled early and vice versa). I have traced the labeling of the data to the bottles of wine that I received, and feel confident that the samples were not switched in the sensory lab. It is then possible that the winery mislabeled the bottles. If this is the case then we could check the chemical analysis (which we are currently waiting on) to determine whether or not they match the sensory results. If in the late harvest wine acid level (TA) was found to be higher and the pH lower than in the early harvest wine, this would support panelists rating that the sourness aftertaste was higher in the late harvest wines than in the early harvest wines (Table 5.8). We might then be able to assume that all bottles were labeled in the same manner and have more confidence in the sensory results, but unfortunately there would not be any way to conclusively determine if the bottles were mislabeled.

Table 5.8: Sourness attribute results in Frontenac Wines from Year Two. Shaded rows indicate significant differences among samples (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).

Attribute	Wine Harvest			
	Early	**Late**	**F- statistic**	**P-value**
Sourness	3.6	3.8	0.5	0.50
Sourness Aftertaste	1.9	2.4	4.6	0.04

Chapter 6 : Conclusion

When the sugar levels of the grapes increased from low to medium to high, panelists rated the sweetness of the grapes higher, the sourness lower, and the astringency and bitterness lower. Panelists also tended to rate the jammy and dried fruit attributes higher as the sweetness of the grapes increased, though this may be due to confusion with the sweetness.

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Chapter 8 : Appendix

8.1: Citric Acid and Butanol Scales

Citric Acid Flavor Intensity Scale

Scale 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

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

The dilution to make the butanol scale value of 12 is 20.48 ml in 1000 ml propylene glycol.

The compound is 1-butanol (n-butanol) which should be of 99% + purity

Dilute with distilled water that is odor free. First make up scale point 12. After that the remaining scale points are just 50% dilutions of the higher step.

8.2: University of Minnesota Standard Protocol for Benchmarking

Black Grape Protocol:

Crush and De-stem grapes

Place must in a red-grape fermentation vessel, generally a food-grade plastic pail. It should not be completely full to allow for cap formation during fermentation. Fill to 75% capacity. Take a juice sample, then add SO2 at a rate of 30ppm. Mix well.

Must is inoculated on the same day as crush using ICV-GRE yeast at a rate of 40ppm. Yeast is rehyrdated with Go-Ferm (30ppm). Fermaid is added at 40ppm to the grape must prior to yeast addition. Fermentation is carried out at ambient temperature.

24 hours following fermentation, the MLF bacteria culture (Lallemand 'PN4') is added at a rate of 10mg/L. (We typically make a dilution of 1 g/20 mL and add the appropriate proportion using a micropipette)

During fermentation, the cap is gently plunged twice per day. On day 7 following inoculation, the must is pressed in the same manner as for white grapes (2 repetitions up to 2 bar over a period of 20 minutes).

The pressed wine is put into a carboy(s) filled to 90% capacity until fermentation is complete (< 0.5% RS) and malic acid is < 60 mg/L. Take a wine sample for analysis.

Adjust free SO2 to 1.0 ppm Molecular SO2.

Wine is racked into a clean carboy filled to capacity and placed in a -4ºC cooler for cold-stabilization. Take another wine sample following cold-stabilization.

8.3 Example Screener

Hello Descriptive Panelists,

We are beginning a study on wine and wine grapes that will last 4.5 weeks starting next Thursday, January 30th. Currently we have 20 training/testing sessions scheduled Tuesday through Friday of 2/3, 2/10 and Monday through Friday of 2/17 and 2/24.
(This schedule may be changed as needed, but you must be available for all 5 weeks of the study to participate.)

You will be compensated $10/hour for training, and $13/hour for testing. Payment will be made to you at the end of the study. If you are interested in participating, please indicate below when you are available for both group and individual training sessions, and testing. You must be at least 21 to participate.

Thanks!
Emily

STUDY 1- Grapes
Are you available on Thursday January 30th at 12:00pm for group training?
Yes:___ No:___
If no, please indicate all other times on Thursday January 30th that you are available for training: Time (1:00pm-5:00PM): _____

Are you available on Friday January 31st at *1:00pm* for group training?
Yes:___ No:___
If no, please indicate all other times on Friday January 31st that you are available for training: Time (10:00am-11:30am and 2:00-5:00PM): _____

Are you available on Tuesday, February 4th at 12:00pm for group training?
Yes:___ No:___
If no, please indicate all other times on Tuesday, February 4th that you are available for training:
Time (12:00pm-5:00PM): _____

What time would you like to complete your testing session on Wednesday February 5th?
Date: Wednesday February 5th
Time (10:00am-5:00PM): _____

Are you available on Thursday, February 6th at 12:00pm for group training?
Yes:___ No:___
If no, please indicate all other times on Thursday, February 6th that you are available for training:
Time (1:00pm-5:00PM): _____

What time would you like to complete your testing session on Friday February 7th?
Date: Friday February 7th
Time (10:00am-5:00PM): _____

8.4 Consent Form

Wine Grapes and Wine Study

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: Nuala Bobowski, Emily Del Bel, 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 $13/hour for testing for participating. Payment will be made to you at the end of the study.

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 question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researchers conducting this study are: Nuala Bobowski, Emily Del Bel, 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, bobo0005@umn.edu, delbe002@umn.edu, and zvickers@umn.edu.

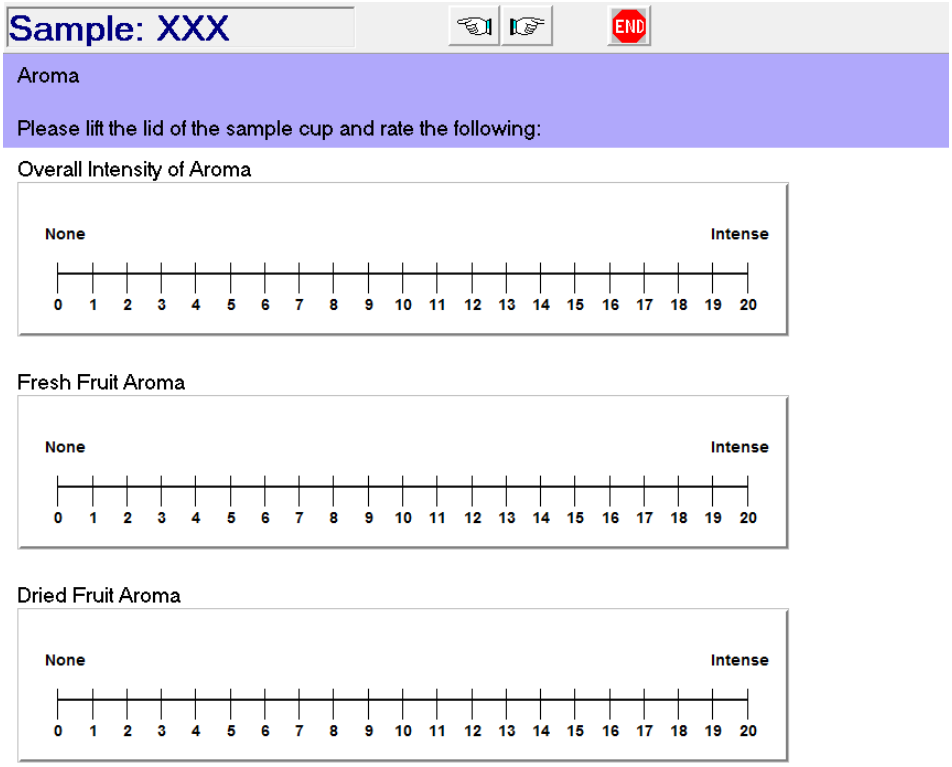
If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

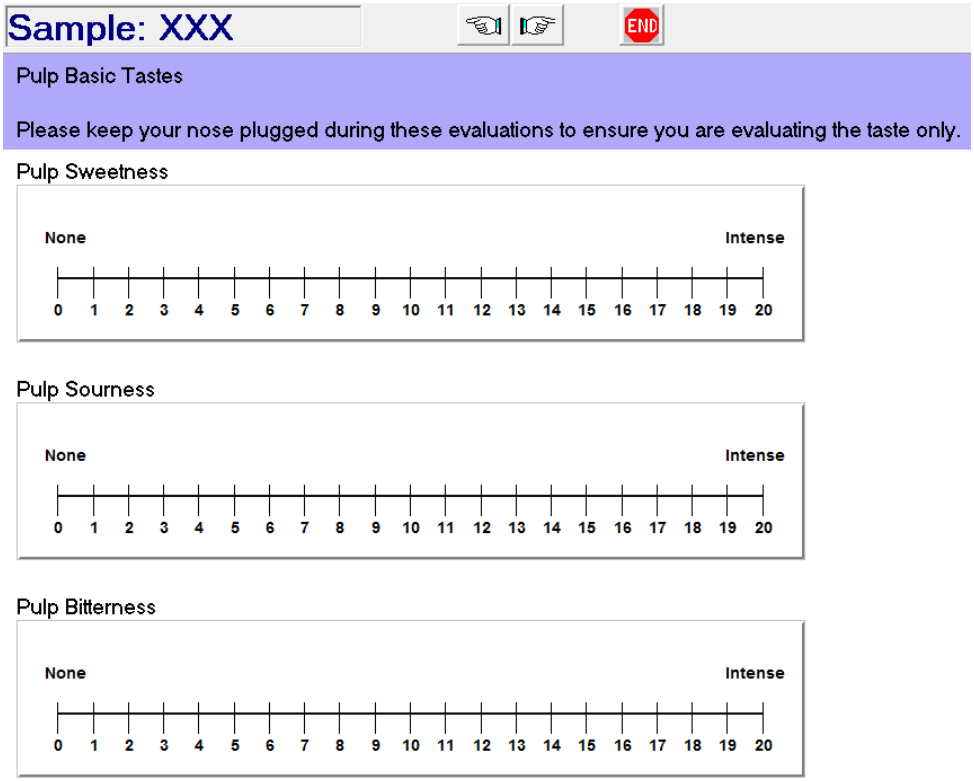
You will be given a copy of this information to keep for your records.

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.

8.5 Example Ballot Questions



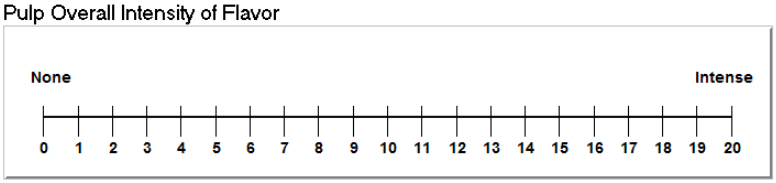


Sample: XXX

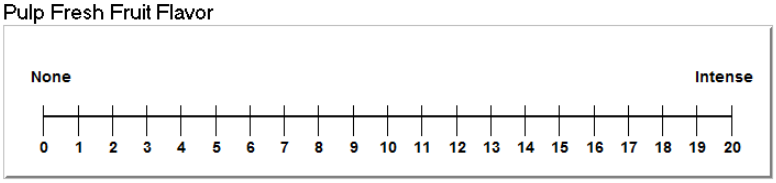
Pulp Flavor

You may now unplug your nose to rate the flavor of the PULP.

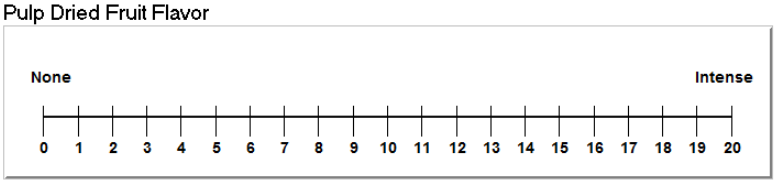
Pulp Overall Intensity of Flavor



Pulp Fresh Fruit Flavor



Pulp Dried Fruit Flavor



8.6 Master Reference Prep Sheet – Frontenac and Marquette Grapes

Make EVERY DAY

- **Fresh Fruit**- Wash and place two approximately 1 cm^2 pieces of each fruit in a tw ounce sample cup, making sure to include pieces with skin attached:
    - red delicious apple
    - comice pear
    - fresh strawberry
    - red plum
    - halved fresh blueberry
    - halved fresh raspberry

Make AS NEEDED (check each day for browning on the stems and peels, and mold on the jam and fermented fruit)

- **Green Wood**- Grape stems, Green stem parts only, cut into 1 inch long pieces
- **Citrus Fruit**- 1cm^2 piece of each lemon peel, lime peel, Mineola orange peel
- **Jammy**- Duerr's Premium Black currant Preserves, 1 Tablespoon
- **Fermented Fruit**- re-label from previous 'fresh fruit'
- **Fresh Green**- **Year 1** - Two 1-cm long piece of each cut fresh green bean and cut fresh asparagus, crushed to release aroma
  Year 2- Green strawberry tops, no fruit attached

Make EVERY WEEK (Monday)

- **Dried Fruit**- 5 Raisins (Sunmaid)
- **Citrus Fruit**- 1cm^2 piece of each lemon peel, lime peel, Mineola orange peel
- **Fermented Fruit**- Old "Fresh Fruit" stored in fridge
- **Jammy**- Duerr's Premium Black currant Preserves, 1 Tablespoon
- **Green Wood**- Grape stems, Green stem parts only, cut into 1 inch long pieces
- **Earthy/Musty**- Potting soil, 1 T

Make just once (save from week to week) (2 ounce cups)

- **Floral-** Crushed violet candy, ½ teaspoon (Chowards)
- **Artificial Grape**- Grape Jolly Rancher, 1 per cup
- **Hay**- Hay, enough to fill half of a 2 ounce cup

Solutions (2 ounce cups) to go on large tray with all other references

- **Metallic**- 0.005% Ferrous Sulfate (0.025g/500 ml)
- **Sweetness-** 5.0% sucrose in distilled water (25g/500 ml)
- **Sourness-** 0.075% citric acid in distilled water (0.375g/500 ml)
- **Bitterness-** 0.057% caffeine in distilled water (.285g/500 ml)
- **Astringency-** 1.25g alum in 500 mL water

Small Tray (1 ounce cups)

- **Citric Acid**: 3,5, 7, 10 (2,4,6,9 in 2014)
- **Butanol:** 3,5,7,10 (2,4,6,9 in 2014)

GRAPE SAMPLES:
Please make up the sample trays as early as possible, since they need to defrost for at least two hours before serving. **Two grapes per sample cup please!**

8.7 Master Reference Prep Sheet – Frontenac Wine

Make EVERY DAY

- **White Mushroom-** 1 Slice white button mushroom
- **Fresh Green-** Two 1-cm long piece of each cut fresh green bean and cut fresh asparagus, crushed to release aroma
- **Ethanol**- 1 drop (use pipet) onto cotton ball
- **Dark Fruit -**liquid mixture: 50 g blackberry jam, 100 mL unsweetened tart cherry juice, 100 mL plum juice, 100 mL pomegranate juice
  -5 mL of the above liquid mixture + 2 cm^2 pieces fresh plum with skin (about the size of a penny)

Place 15 mL in labeled wine glasses topped with upside-down 2-ounce cup lids:

- **Cooked Vegetable**- 5 ml each from canned asparagus and green beans (500 ml red wine)
- **Black Pepper**- 1 black peppercorn, crushed, (in 500 ml red wine) stirred for 5 minutes
- **Spice**- one allspice berry, crushed, (in 500 mL red wine) stirred for 5 minutes
- **Artificial Banana**- Banana Runt candy - crush 3 and stir using stir plate (no heat) until dissolved into 500 ml red wine, about 10 minutes.

Make AS NEEDED (check to make sure still fragrant)

- **Artificial Banana-** 1 banana Runt candy – broken in half
- **Ethanol-** 1 drop (use pipet) onto cotton round in each cup

Make EVERY WEEK (Monday)

- **Black Currant -** One-half gummy candy (Katjes Berry Cassis Gummie Candy)
- **Cooked Berry-** 12 ounce bag frozen berry mix (strawberry, blueberry, blackberry, raspberry), place in pot on medium heat with ½ cup water and bring to a boil; simmer 5 minutes; remove from heat. Smash large strawberries before distributing into cups.
- **Grapefruit-** 1 ounce Grapefruit juice (Ruby Red Ocean Spray)
- **Cooked Vegetable-** 5 ml liquid each from canned asparagus and green beans put into 250 mL filtered water, pour into 1 ounce cups.
- **Spice-** One allspice berry
- **Floral Year 1-**1 mL rose water in 500 mL distilled water (Nielsen-Massey)
- **Year 2-**Crushed violet candy, ½ teaspoon (Chowards)
- **Chemical-** 75 ml isopropyl alcohol, 425 ml filtered water
- **Caramel-** 1 cup unsalted butter, 1 lb light brown sugar, 1 (14 oz) can sweetened condensed milk, 1 cup light corn syrup, 1/8 tsp salt
  - In a saucepan over medium heat, combine butter, brown sugar, sweetened condensed milk, corn syrup and salt. Bring to a boil, stirring constantly. Heat to between 234 and 240 degrees F, or until a small amount of syrup dropped into cold water forms a soft ball that flattens when removed from the water and placed on a flat surface. Cook for 2 min at that temperature.
  - Pour caramel into foil-lined baking pan and allow to cool at room temp. Cut into squares and store in a Tupperware container with wax paper between rows
- **Dried Mushroom-** Soak 4 grams dried mushroom mix (Fungus Among Us brand Organic mushroom medley) in 1 cup hot filtered water for 30 minutes. Filter using cheesecloth and dilute 100 mL of the mushroom water with 400 mL filtered water.
- **Tamari -** 1 ounce San-J brand organic tamari

Make EVERY WEEK (continued)

- **Woody-** 1 cm^2 flake cedar, 1 American oak chip, and 1 French oak chip in each cup (each type of wood soaked in ½ cup hot filtered water for 30 minutes.)

Please place in labeled 1 ounce cups with lids:

- **Sweetness -** 5.0% sucrose in distilled water (25g/500 ml)
- **Sourness-** 0.075% citric acid in distilled water (0.375g/500 ml)
- **Bitterness 2-** 0.014% caffeine in distilled water (.071g/500 ml)
- **Bitterness -** 0.057% caffeine in distilled water (.285g/500 ml)
- **Astringency 20-** 0.062% alum in distilled water (0.31g /500 ml)
- **Astringency 12-** 0.25% alum in distilled water (1.25g /500 ml)

Make just once (save from week to week) (2 ounce cups)

- **Hay-** a few pieces of broken hay (from pet store) to fit in 2 ounce cup
- **Black Pepper-** 1 black peppercorn in each cup

WINE SAMPLES:
30 ml wine per wine glass, topped with upside-down 2-ounce cup lids

8.8 Master Reference Prep Sheet – Marquette Wine

Make EVERY DAY

- **White Mushroom-** 1 Slice white button mushroom
- **Fresh Green-** Two 1-cm long piece of each cut fresh green bean and cut fresh asparagus, crushed to release aroma
- **Ethanol**- 1 drop (use pipet) onto cotton ball
- **Dark Fruit -**liquid mixture**:** 50 g blackberry jam, 100 mL unsweetened tart cherry juice, 100 mL plum juice, 100 mL pomegranate juice
  -5 mL of the above liquid mixture + 2 cm^2 pieces fresh plum with skin (about the size of a penny)
- Cheese/Butyric- Cube of asiago cheese (BelGioioso)

Place 15 ml in labeled wine glasses topped with upside-down 2-ounce cup lids:

- **Artificial Banana**- Banana Runt candy - crush 3 and stir (no heat) until dissolved into 500 ml red wine, about 10 minutes.
- **Cooked Vegetable**- 5 ml liquid each from canned asparagus and green beans (500 ml red wine)
- **Spice**- one allspice berry, crushed, (in 500 ml red wine) stirred for 5 minutes
- **Pepper**- one black peppercorn (crushed) and equal weight white pepper (ground) in 500 ml red wine stirred for 5 minutes

Make AS NEEDED (check to make sure still fragrant)

- **Artificial Banana-** 1 banana Runt candy – broken in half
- **Ethanol-** 1 drop (use pipet) onto cotton round in each cup

Make EVERY WEEK (Monday)

- **Black Currant -** One-half gummy candy (Katjes Berry Cassis Gummie Candy)
- **Cooked Berry-** 12 ounce bag frozen berry mix (strawberry, blueberry, blackberry, raspberry), place in pot on medium heat with ½ cup water and bring to a boil; simmer 5 minutes; remove from heat. Smash large strawberries before distributing into cups.
- **Grapefruit-** 1 ounce Grapefruit juice (Ruby Red Ocean Spray)
- **Cooked Vegetable-** 5 ml liquid each from canned asparagus and green beans put into 250 mL filtered water, pour into 1 ounce cups.
- **Spice-** One allspice berry
- **Floral Year 1-**1 mL rose water in 500 mL distilled water (Nielsen-Massey)
- **Year 2-**Crushed violet candy, ½ teaspoon (Chowards)
- **Chemical-** 75 ml isopropyl alcohol, 425 ml filtered water
- **Caramel-** 1 cup unsalted butter, 1 lb light brown sugar, 1 (14 oz) can sweetened condensed milk, 1 cup light corn syrup, 1/8 tsp salt
  - In a saucepan over medium heat, combine butter, brown sugar, sweetened condensed milk, corn syrup and salt. Bring to a boil, stirring constantly. Heat to between 234 and 240 degrees F, or until a small amount of syrup dropped into cold water forms a soft ball that flattens when removed from the water and placed on a flat surface. Cook for 2 min at that temperature.
  - Pour caramel into foil-lined baking pan and allow to cool at room temp. Cut into squares and store in a Tupperware container with wax paper between rows
- **Dried Mushroom-** Soak 4 grams dried mushroom mix (Fungus Among Us brand Organic mushroom medley) in 1 cup hot filtered water for 30 minutes. Filter using cheesecloth and dilute 100 mL of the mushroom water with 400 mL filtered water.

Make EVERY WEEK (continued)

- **Tamari -** 1 ounce San-J brand organic tamari
- **Woody-** 1 cm^2 flake cedar, 1 American oak chip (medium toast) , and 1 French oak chip (medium toast) in each cup (each type of wood soaked in ½ cup hot filtered water for 30 minutes.)
- **Geranium-**0.1g of geranium extract in 100 mL ethanol (95.5%).
  -0.1 mL of the above geranium extract and ethanol solution stirred into 500 mL red wine (use pipet for accurate measurement)

Please place in labeled 1 ounce cups with lids:

- **Sweetness -** 5.0% sucrose in distilled water (25g/500 ml)
- **Sourness-** 0.075% citric acid in distilled water (0.375g/500 ml)
- **Bitterness 2-** 0.014% caffeine in distilled water (.071g/500 ml)
- **Bitterness -** 0.057% caffeine in distilled water (.285g/500 ml)
- **Astringency 20-** 0.062% alum in distilled water (0.31g /500 ml)
- **Astringency 12-** 0.25% alum in distilled water (1.25g /500 ml)

Make just once (save from week to week) (2 ounce cups)

- **Hay-** a few pieces of broken hay (from pet store) to fit in 2 ounce cup
- **Pepper -** 1 black peppercorn + same volume of white pepper in each cup

WINE SAMPLES:
30 ml wine per wine glass, topped with upside-down 2-ounce cup lids

8.9 Complete Results for Frontenac Grapes by Sugar Level

Table 8.1: Complete Frontenac Grapes results from Year One. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Overall Intensity Aroma	4.9	4.9	4.7	2.5	0.09
Fresh Fruit Aroma	1.8	1.9	1.7	0.9	0.42
Dried Fruit Aroma	0.8	0.9	0.9	0.7	0.49
Citrus Fruit Aroma	0.3	0.4	0.3	0.4	0.70
Jammy Aroma	1.3	1.2	1.3	0.2	0.81
Fermented Fruit Aroma	1.6	1.9	1.6	0.6	0.53
Fresh Green Aroma	1.4	1.4	1.5	2.8	0.06
Green Wood Aroma	2.6	2.6	2.6	0.2	0.86
Earthy Aroma	1.4	1.5	1.5	0.6	0.54
Hay Aroma	1.2	1.1	1.3	0.2	0.79
Floral Aroma	0.4	0.5	0.6	1.2	0.31
Metallic Aroma	0.2	0.1	0.1	0.9	0.42
Artificial Grape Aroma	0.4	0.2	0.4	4.0	0.02
Pulp Sweetness	3.4 [b]	3.5 [b]	4.1 [a]	12.5	< 0.001
Pulp Sourness	5.5 [a]	5.3 [a]	4.2 [b]	29.0	< 0.001
Pulp Bitterness	1.4 [a]	1.2 [ab]	1.1 [b]	3.7	0.03
Pulp Overall Intensity Flavor	6.3 [a]	6.4 [a]	6.0 [b]	8.7	< 0.001
Pulp Fresh Fruit Flavor	2.9	3.3	3.2	1.3	0.28
Pulp Dried Fruit Flavor	0.8	0.9	0.8	0.1	0.91
Pulp Citrus Flavor	1.4 [a]	1.4 [a]	0.9 [b]	10.5	< 0.001
Pulp Jammy Flavor	2.3	2.4	2.5	0.6	0.56
Pulp Fermented Fruit Flavor	2.0 [ab]	2.2 [a]	1.8 [b]	3.1	0.05
Pulp Fresh Green Flavor	1.4	1.5	1.4	1.0	0.36
Pulp Green Wood Flavor	1.6	1.4	1.6	0.6	0.52
Pulp Earthy Flavor	0.9 [ab]	1.1 [a]	0.8 [b]	3.1	0.05
Pulp Hay Flavor	0.7	0.6	0.6	1.1	0.35
Pulp Floral Flavor	0.6	0.7	0.7	1.4	0.25
Pulp Metallic Flavor	0.2	0.2	0.2	0.1	0.91
Pulp Artificial Grape Flavor	2.1	2.2	2.0	1.0	0.35
Pulp Astringency	3.3	3.3	3.1	1.2	0.30
Pulp Overall Aftertaste	2.7	3.0	2.7	0.7	0.50
Pulp Sweetness Aftertaste	1.3 [b]	1.5 [a]	1.6 [a]	5.8	< 0.001
Pulp Sourness Aftertaste	2.1 [a]	2.1 [a]	1.7 [b]	7.1	< 0.001
Pulp Bitterness Aftertaste	1.0	1.0	0.9	1.4	0.25
Skin Sweetness	1.2 [b]	1.4 [b]	1.7 [a]	13.0	< 0.001

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Skin Sourness	1.8 [a]	1.9 [a]	1.5 [b]	5.7	< 0.001
Skin Bitterness	1.2	1.0	1.0	2.1	0.12
Skin Overall Intensity Flavor	3.0 [ab]	3.2 [a]	2.9 [b]	3.3	0.04
Skin Fresh Fruit Flavor	0.8	0.8	0.9	0.6	0.53
Skin Dried Fruit Flavor	1.3	1.3	1.2	0.7	0.50
Skin Citrus Fruit Flavor	0.4 [ab]	0.5 [a]	0.3 [b]	7.3	< 0.001
Skin Jammy Flavor	0.7	0.6	0.6	0.3	0.77
Skin Fermented Fruit Flavor	0.9	1.0	0.8	1.1	0.34
Skin Fresh Green Flavor	0.8 [b]	1.0 [a]	1.0 [a]	2.5	0.08
Skin Green Wood Flavor	2.0	2.0	2.0	0.4	0.65
Skin Earthy Flavor	1.0 [a]	0.8 [b]	0.9 [ab]	2.4	0.09
Skin Hay Flavor	0.9	0.9	0.8	0.7	0.48
Skin Floral Flavor	0.3 [ab]	0.2 [b]	0.4 [a]	3.5	0.03
Skin Metallic Flavor	0.1	0.1	0.1	0.5	0.60
Skin Artificial Grape Flavor	0.3	0.3	0.3	0.3	0.71
Skin Astringency	2.3	2.4	2.1	2.0	0.13
Overall Skin Aftertaste	1.7	1.6	1.6	1.2	0.29
Skin Sweetness Aftertaste	0.6	0.6	0.7	2.2	0.11
Skin Sourness Aftertaste	0.9	0.9	0.7	3.4	0.03
Skin Bitterness Aftertaste	0.9	0.9	0.8	1.6	0.20

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Table 8.2: Complete Frontenac Grapes results from Year Two. Shaded rows indicate significant differences among sugar levels (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Overall Intensity Aroma	4.6	4.5	4.4	0.6	0.52
Fresh Fruit Aroma	1.3	1.1	1.1	2.3	0.10
Dried Fruit Aroma	0.9	0.8	0.8	0.2	0.86
Citrus Fruit Aroma	0.3	0.3	0.3	0.4	0.66
Jammy Aroma	1.1	1.0	1.0	0.1	0.89
Fermented Fruit Aroma	0.8	0.7	0.7	0.2	0.84
Fresh Green Aroma	1.1	1.2	1.1	0.2	0.79
Green Wood Aroma	1.9	1.8	1.9	0.9	0.41
Earthy Aroma	1.0 [ab]	0.8 [b]	1.1 [a]	2.6	0.08
Hay Aroma	0.9	0.9	1.0	0.5	0.59
Floral Aroma	0.4	0.5	0.3	1.6	0.20
Metallic Aroma	0.0	0.0	0.0	1.5	0.22
Artificial Grape Aroma	0.2	0.3	0.3	0.0	0.99

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Sweetness	2.6 [c]	3.3 [b]	3.8 [a]	26	< 0.001
Pulp Sourness	5.5 [a]	4.8 [b]	4.2 [c]	17	< 0.001
Pulp Bitterness	1.1	1.1	1.0	1.1	0.35
Pulp Overall Intensity Flavor	6.1 [a]	5.6 [b]	5.7 [b]	4.2	0.02
Pulp Fresh Fruit Flavor	2.0	2.0	2.1	0.6	0.55
Pulp Dried Fruit Flavor	0.8 [b]	0.9 [ab]	1.1 [a]	2.3	0.10
Pulp Citrus Flavor	2.1 [a]	1.6 [b]	1.3 [b]	8.8	< 0.001
Pulp Jammy Flavor	1.8 [c]	2.1 [b]	2.3 [a]	6.6	< 0.01
Pulp Fermented Fruit Flavor	1.1	1.2	1.2	0.0	1.00
Pulp Fresh Green Flavor	1.0	1.0	0.9	0.2	0.82
Pulp Green Wood Flavor	1.2	1.3	1.2	0.7	0.51
Pulp Earthy Flavor	0.5	0.6	0.5	1.1	0.32
Pulp Hay Flavor	0.3	0.4	0.5	2.1	0.13
Pulp Floral Flavor	0.5	0.5	0.5	0.3	0.75
Pulp Metallic Flavor	0.0	0.0	0.0	0.0	0.99
Pulp Artificial Grape Flavor	1.5	1.5	1.7	1.8	0.17
Pulp Astringency	2.9 [a]	2.8 [ab]	2.6 [b]	3.9	0.02
Pulp Overall Aftertaste	2.2	2.0	2.2	1.9	0.15
Pulp Sweetness Aftertaste	0.9 [b]	1.0 [b]	1.4 [a]	11	< 0.001
Pulp Sourness Aftertaste	1.7 [a]	1.5 [b]	1.1 [b]	16	< 0.001
Pulp Bitterness Aftertaste	0.7 [b]	0.9 [a]	0.7 [b]	3.7	0.03
Skin Sweetness	0.9 [b]	1.1 [b]	1.3 [a]	6.3	< 0.001
Skin Sourness	1.5 [a]	1.2 [b]	1.2 [b]	2.8	0.06
Skin Bitterness	1.0	1.0	1.1	0.2	0.82
Skin Overall Intensity Flavor	2.6	2.5	2.7	1.5	0.23
Skin Fresh Fruit Flavor	0.4	0.4	0.5	1.5	0.22
Skin Dried Fruit Flavor	1.0	1.1	1.1	0.9	0.40
Skin Citrus Flavor	0.4	0.3	0.3	2.7	0.07
Skin Jammy Flavor	0.5	0.5	0.4	0.5	0.60
Skin Fermented Fruit Flavor	0.34 [b]	0.46 [ab]	0.52 [a]	4.2	0.02
Skin Fresh Green Flavor	0.6	0.7	0.7	0.0	1.00
Skin Green Wood Flavor	1.7	1.5	1.6	1.7	0.18
Skin Earthy Flavor	0.6	0.6	0.7	0.8	0.43
Skin Hay Flavor	0.5	0.5	0.6	0.2	0.79
Skin Floral Flavor	0.3	0.2	0.2	1.1	0.33
Skin Metallic Flavor	0.0	0.0	0.1	1.8	0.17
Skin Artificial Grape Flavor	0.2	0.1	0.2	2.3	0.10
Skin Astringency	1.8	1.8	1.7	1.0	0.36
Overall Skin Aftertaste	1.2	1.2	1.3	0.4	0.64
Skin Sweetness Aftertaste	0.5 [b]	0.6 [ab]	0.7 [a]	2.8	0.06
Skin Sourness Aftertaste	0.7 [a]	0.6 [b]	0.4 [c]	4.2	0.02

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Skin Bitterness Aftertaste	0.8	0.8	0.9	0.4	0.65

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Table 8.3: Complete combined Frontenac Grapes results from Year One and Year Two. Shaded rows indicate significant differences among sugar levels (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Overall Intensity Aroma	4.7	4.6	4.6	2.1	0.12
Fresh Fruit Aroma	1.5	1.3	1.6	2.3	0.10
Dried Fruit Aroma	0.8	0.8	0.9	0.1	0.92
Citrus Fruit Aroma	0.3	0.3	0.3	0.7	0.50
Jammy Aroma	1.1	1.1	1.2	0.2	0.82
Fermented Fruit Aroma	1.1	1.0	1.3	0.3	0.72
Fresh Green Aroma	1.2	1.2	1.4	0.8	0.44
Green Wood Aroma	2.1	2.0	2.4	0.5	0.60
Earthy Aroma	1.1	1.0	1.4	0.9	0.40
Hay Aroma	1.0	1.0	1.2	1.2	0.30
Floral Aroma	0.4	0.5	0.5	1.3	0.27
Metallic Aroma	0.1	0.1	0.1	1.3	0.27
Artificial Grape Aroma	0.3	0.3	0.3	0.8	0.46
Pulp Sweetness	2.9 [c]	3.4 [b]	4.0 [a]	33.5	< 0.001
Pulp Sourness	5.5 [a]	5.0 [b]	4.2 [c]	39.4	< 0.001
Pulp Bitterness	1.2	1.2	1.1	3.4	0.03
Pulp Overall Intensity Flavor	6.1 [a]	5.9 [b]	5.9 [b]	5.4	< 0.01
Pulp Fresh Fruit Flavor	2.4	2.4	2.9	0.7	0.48
Pulp Dried Fruit Flavor	0.8	0.9	0.9	1.1	0.33
Pulp Citrus Flavor	1.8 [a]	1.5 [b]	1.1 [c]	18.2	< 0.001
Pulp Jammy Flavor	2.0 [c]	2.2 [b]	2.4 [a]	5.5	< 0.001
Pulp Fermented Fruit Flavor	1.5	1.5	1.6	1.8	0.17
Pulp Fresh Green Flavor	1.1	1.1	1.3	0.5	0.62
Pulp Green Wood Flavor	1.4	1.3	1.5	0.1	0.94
Pulp Earthy Flavor	0.7	0.6	0.8	0.1	0.92
Pulp Hay Flavor	0.5	0.5	0.6	0.2	0.84
Pulp Floral Flavor	0.6	0.6	0.7	1.5	0.23
Pulp Metallic Flavor	0.1	0.1	0.1	0.3	0.73
Pulp Artificial Grape Flavor	1.8	1.7	1.9	0.0	0.98
Pulp Astringency	3.1	2.9	2.9	3.0	0.05
Pulp Overall Aftertaste	2.4	2.3	2.6	0.2	0.82
Pulp Sweetness Aftertaste	1.1 [c]	1.2 [b]	1.6 [a]	13.4	< 0.001

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Sourness Aftertaste	1.9 [a]	1.6 [b]	1.5 [c]	17.9	< 0.001
Pulp Bitterness Aftertaste	0.8	0.9	0.8	4.7	0.01
Skin Sweetness	1.1 [b]	1.2 [b]	1.6 [a]	18.4	< 0.001
Skin Sourness	1.6 [a]	1.4 [b]	1.4 [b]	7.1	< 0.001
Skin Bitterness	1.1	1.0	1.0	0.5	0.62
Skin Overall Intensity Flavor	2.7	2.7	2.8	0.2	0.80
Skin Fresh Fruit Flavor	0.6	0.5	0.7	1.6	0.20
Skin Dried Fruit Flavor	1.1	1.1	1.1	1.0	0.37
Skin Citrus Fruit Flavor	0.4 [a]	0.4 [a]	0.3 [b]	4.3	0.01
Skin Jammy Flavor	0.6	0.5	0.6	0.6	0.55
Skin Fermented Fruit Flavor	0.6	0.6	0.7	0.9	0.42
Skin Fresh Green Flavor	0.7	0.8	0.9	1.8	0.16
Skin Green Wood Flavor	1.8	1.7	1.8	1.3	0.27
Skin Earthy Flavor	0.7	0.7	0.8	0.4	0.68
Skin Hay Flavor	0.7	0.7	0.8	0.0	0.99
Skin Floral Flavor	0.3 [a]	0.2 [b]	0.4 [a]	3.8	0.02
Skin Metallic Flavor	0.1	0.0	0.1	2.0	0.13
Skin Artificial Grape Flavor	0.2	0.2	0.3	0.7	0.52
Skin Astringency	2.0	2.0	2.0	2.9	0.06
Overall Skin Aftertaste	1.4	1.3	1.5	0.2	0.78
Skin Sweetness Aftertaste	0.5 [c]	0.6 [b]	0.7 [a]	4.4	0.01
Skin Sourness Aftertaste	0.8 [a]	0.7 [b]	0.6 [b]	5.8	< 0.001
Skin Bitterness Aftertaste	0.9	0.8	0.8	0.2	0.80

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

8.10 Complete Results for Marquette Grapes by Sugar Level

Table 8.4: Complete Marquette Grapes results from Year One. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Sugar Level			F- statistic	p-value
	Low	Medium	High		
Overall Intensity Aroma	4.9	4.9	4.8	0.1	0.90
Fresh Fruit Aroma	2.0 [a]	1.9 [a]	1.6 [b]	4.5	0.01
Dried Fruit Aroma	0.8	0.8	0.8	0.3	0.77
Citrus Fruit Aroma	0.4	0.4	0.3	0.7	0.50
Jammy Aroma	1.4 [a]	1.6 [a]	1.1 [b]	5.5	< 0.001
Fermented Fruit Aroma	1.9	1.9	1.8	0.1	0.89
Fresh Green Aroma	1.4	1.4	1.5	1.0	0.35
Green Wood Aroma	2.6 [b]	2.4 [b]	2.9 [a]	6.3	< 0.01
Earthy Aroma	0.9 [b]	1.1 [ab]	1.3 [a]	4.0	0.02
Hay Aroma	1.2	1.0	1.2	1.1	0.35
Floral Aroma	0.4	0.4	0.4	0.2	0.81
Metallic Aroma	0.2	0.1	0.1	1.9	0.14
Artificial Grape Aroma	0.5 [a]	0.6 [a]	0.3 [b]	8.0	< 0.001
Pulp Sweetness	3.3 [b]	3.1 [b]	4.3 [a]	51	< 0.001
Pulp Sourness	4.7 [a]	4.6 [a]	2.5 [b]	106	< 0.001
Pulp Bitterness	1.3 [a]	1.3 [a]	1.0 [b]	4.5	0.01
Pulp Overall Intensity Flavor	5.8 [a]	5.8 [a]	5.3 [b]	12	< 0.001
Pulp Fresh Fruit Flavor	2.7	2.8	2.8	0.3	0.71
Pulp Dried Fruit Flavor	0.6 [b]	0.9 [a]	0.8 [a]	2.6	0.07
Pulp Citrus Flavor	1.3 [a]	1.2 [a]	0.5 [b]	26	< 0.001
Pulp Jammy Flavor	2.1 [b]	2.2 [b]	2.7 [a]	14	< 0.001
Pulp Fermented Fruit Flavor	2.3	2.2	2.0	1.6	0.20
Pulp Fresh Green Flavor	1.0	1.2	1.0	1.8	0.16
Pulp Green Wood Flavor	1.4	1.4	1.4	0.1	0.88
Pulp Earthy Flavor	0.6	0.6	0.6	0.1	0.89
Pulp Hay Flavor	0.7	0.6	0.6	0.2	0.81
Pulp Floral Flavor	0.4 [b]	0.5 [b]	0.8 [a]	11	< 0.001
Pulp Metallic Flavor	0.1	0.1	0.2	1.5	0.22
Pulp Artificial Grape Flavor	1.7	1.9	1.7	1.7	0.18
Pulp Astringency	3.4 [a]	3.4 [a]	2.8 [b]	8.8	< 0.001
Pulp Overall Aftertaste	2.5	2.4	2.4	0.2	0.86
Pulp Sweetness Aftertaste	1.2 [b]	1.2 [b]	1.7 [a]	16	< 0.001
Pulp Sourness Aftertaste	1.9 [a]	1.8 [a]	1.0 [b]	30	< 0.001
Pulp Bitterness Aftertaste	1.0	0.8	0.8	1.4	0.25
Skin Sweetness	1.5 [b]	1.3 [b]	2.0 [a]	27	< 0.001
Skin Sourness	1.9 [a]	2.0 [a]	1.3 [b]	26	< 0.001
Skin Bitterness	1.2	1.2	1.0	1.4	0.26
Skin Overall Intensity Flavor	3.1 [b]	3.2 [ab]	3.4 [a]	3.4	0.04

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Skin Fresh Fruit Flavor	0.6	0.7	0.8	1.9	0.15
Skin Dried Fruit Flavor	0.8	0.9	0.9	0.6	0.57
Skin Citrus Fruit Flavor	0.4	0.5	0.3	3.2	0.04
Skin Jammy Flavor	0.6 [b]	0.6 [b]	0.9 [a]	8.3	< 0.001
Skin Fermented Fruit Flavor	1.0	0.9	1.0	0.1	0.87
Skin Fresh Green Flavor	1.0	0.9	0.9	0.7	0.48
Skin Green Wood Flavor	2.1	2.1	2.0	1.5	0.22
Skin Earthy Flavor	0.7	0.7	0.6	0.8	0.46
Skin Hay Flavor	0.9	0.8	0.8	1.4	0.25
Skin Floral Flavor	0.1 [b]	0.2 [b]	0.3 [a]	3.5	0.03
Skin Metallic Flavor	0.0	0.1	0.0	2.2	0.11
Skin Artificial Grape Flavor	0.2	0.2	0.2	0.1	0.88
Skin Astringency	2.6	2.8	2.7	2.5	0.08
Overall Skin Aftertaste	1.6	1.6	1.6	0.8	0.47
Skin Sweetness Aftertaste	0.6 [b]	0.5 [b]	0.8 [a]	14	< 0.001
Skin Sourness Aftertaste	0.8 [a]	0.9 [a]	0.6 [b]	5.2	0.01
Skin Bitterness Aftertaste	1.0	1.0	0.9	0.2	0.80

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Table 8.5: Complete Marquette Grapes results from Year Two. Shaded rows indicate significant differences among sugar levels (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$). *

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Overall Intensity Aroma	4.4	4.6	4.6	1.8	0.16
Fresh Fruit Aroma	1.4	1.5	1.4	0.1	0.90
Dried Fruit Aroma	0.8	0.9	0.8	0.7	0.51
Citrus Fruit Aroma	0.3	0.4	0.2	1.9	0.15
Jammy Aroma	1.2	1.1	1.2	0.6	0.55
Fermented Fruit Aroma	0.8	0.7	0.7	0.7	0.48
Fresh Green Aroma	1.0	1.0	1.0	0.2	0.84
Green Wood Aroma	1.8 [b]	2.1 [a]	2.0 [a]	2.5	0.09
Earthy Aroma	0.9	0.8	0.9	0.8	0.46
Hay Aroma	0.9	1.0	1.0	0.4	0.67
Floral Aroma	0.5	0.3	0.5	1.1	0.34
Metallic Aroma	0.0	0.0	0.0	1.0	0.37
Artificial Grape Aroma	0.4	0.5	0.4	0.3	0.76
Pulp Sweetness	3.0 [b]	3.8 [a]	4.1 [a]	27	< 0.001
Pulp Sourness	5.1 [a]	4.1 [b]	3.3 [c]	44	< 0.001
Pulp Bitterness	1.2 [a]	1.1 [a]	0.9 [b]	6.4	< 0.01
Pulp Overall Intensity Flavor	5.9 [a]	6.1 [a]	5.5 [b]	5.9	< 0.001
Pulp Fresh Fruit Flavor	2.2	2.4	2.4	0.7	0.50
Pulp Dried Fruit Flavor	0.8	0.9	0.9	1.5	0.24

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Pulp Citrus Flavor	1.9 [a]	1.3 [b]	1.0 [b]	24	< 0.001
Pulp Jammy Flavor	2.1 [b]	2.7 [a]	2.7 [a]	13	< 0.001
Pulp Fermented Fruit Flavor	1.3	1.3	1.2	0.7	0.50
Pulp Fresh Green Flavor	0.8	0.8	0.7	0.9	0.42
Pulp Green Wood Flavor	1.4	1.4	1.1	2.5	0.08
Pulp Earthy Flavor	0.44 [ab]	0.36 [b]	0.61 [a]	2.5	0.09
Pulp Hay Flavor	0.4	0.5	0.4	0.2	0.78
Pulp Floral Flavor	0.5	0.6	0.6	0.6	0.58
Pulp Metallic Flavor	0.0	0.0	0.0	0.7	0.52
Pulp Artificial Grape Flavor	1.6	1.9	1.7	1.0	0.37
Pulp Astringency	2.8 [a]	2.6 [ab]	2.4 [b]	5.0	0.01
Pulp Overall Aftertaste	2.0	2.1	2.1	0.1	0.93
Pulp Sweetness Aftertaste	1.0 [b]	1.6 [a]	1.5 [a]	21	< 0.001
Pulp Sourness Aftertaste	1.4 [a]	1.3 [a]	0.8 [b]	15	< 0.001
Pulp Bitterness Aftertaste	0.7	0.6	0.6	1.0	0.36
Skin Sweetness	1.1 [b]	1.4 [a]	1.4 [a]	5.3	0.01
Skin Sourness	1.4 [a]	1.2 [b]	0.8 [c]	13	< 0.001
Skin Bitterness	1.2	1.0	1.1	1.3	0.27
Skin Overall Intensity Flavor	2.9	2.9	2.7	2.1	0.12
Skin Fresh Fruit Flavor	0.5	0.5	0.4	0.7	0.50
Skin Dried Fruit Flavor	1.1	1.1	1.1	0.1	0.94
Skin Citrus Fruit Flavor	0.5 [a]	0.4 [ab]	0.3 [b]	6.6	0.00
Skin Jammy Flavor	0.5 [b]	0.4 [b]	0.7 [a]	4.4	0.01
Skin Fermented Fruit Flavor	0.4 [b]	0.4 [b]	0.6 [a]	4.3	0.01
Skin Fresh Green Flavor	0.8	0.7	0.7	1.3	0.27
Skin Green Wood Flavor	1.8 [a]	1.9 [a]	1.6 [b]	3.0	0.05
Skin Earthy Flavor	0.7	0.6	0.6	0.2	0.84
Skin Hay Flavor	0.9	0.9	0.7	2.4	0.09
Skin Floral Flavor	0.3	0.3	0.3	0.1	0.90
Skin Metallic Flavor	0.0	0.0	0.0	0.0	0.96
Skin Artificial Grape Flavor	0.2	0.4	0.3	1.5	0.22
Skin Astringency	2.1	2.0	2.0	0.7	0.48
Overall Skin Aftertaste	1.3	1.4	1.5	0.9	0.39
Skin Sweetness Aftertaste	0.66 [b]	0.75 [ab]	0.83 [a]	3.3	0.04
Skin Sourness Aftertaste	0.7 [a]	0.5 [b]	0.4 [b]	10	< 0.001
Skin Bitterness Aftertaste	0.8	0.8	0.8	0.1	0.88

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Table 8.6: Complete combined Marquette Grapes results from Year One and Year Two. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Overall Intensity Aroma	4.5	4.8	4.7	0.7	0.50
Fresh Fruit Aroma	1.6 [b]	1.8 [a]	1.5 [b]	3.3	0.04
Dried Fruit Aroma	0.8	0.8	0.8	0.3	0.74
Citrus Fruit Aroma	0.3	0.4	0.3	1.7	0.18
Jammy Aroma	1.3 [b]	1.5 [a]	1.2 [b]	3.4	0.03
Fermented Fruit Aroma	1.1	1.6	1.3	0.4	0.69
Fresh Green Aroma	1.1	1.3	1.3	1.3	0.28
Green Wood Aroma	2.0 [b]	2.4 [a]	2.5 [a]	6.0	< 0.001
Earthy Aroma	0.9	1.1	1.1	2.1	0.12
Hay Aroma	1.0	1.0	1.1	1.0	0.38
Floral Aroma	0.5	0.4	0.5	1.2	0.31
Metallic Aroma	0.1	0.1	0.1	0.5	0.60
Artificial Grape Aroma	0.5 [b]	0.6 [a]	0.3 [c]	7.6	< 0.001
Pulp Sweetness	3.1 [c]	3.3 [b]	4.2 [a]	62	< 0.001
Pulp Sourness	4.9 [a]	4.5 [b]	2.8 [c]	127	< 0.001
Pulp Bitterness	1.2 [a]	1.2 [a]	1.0 [b]	9.5	< 0.001
Pulp Overall Intensity Flavor	5.9 [a]	5.9 [a]	5.4 [b]	18	< 0.001
Pulp Fresh Fruit Flavor	2.4	2.8	2.6	1.2	0.30
Pulp Dried Fruit Flavor	0.7 [b]	0.9 [a]	0.8 [a]	2.9	0.06
Pulp Citrus Flavor	1.7 [a]	1.2 [b]	0.8 [c]	43	< 0.001
Pulp Jammy Flavor	2.1 [c]	2.3 [b]	2.7 [a]	23	< 0.001
Pulp Fermented Fruit Flavor	1.6	2.0	1.7	2.2	0.11
Pulp Fresh Green Flavor	0.9 [b]	1.1 [a]	0.9 [b]	2.5	0.08
Pulp Green Wood Flavor	1.4	1.4	1.2	2.0	0.14
Pulp Earthy Flavor	0.5	0.6	0.6	0.8	0.45
Pulp Hay Flavor	0.5	0.6	0.5	0.2	0.79
Pulp Floral Flavor	0.4 [b]	0.5 [b]	0.7 [a]	8.4	< 0.001
Pulp Metallic Flavor	0.1	0.1	0.1	1.8	0.16
Pulp Artificial Grape Flavor	1.7 [b]	1.9 [a]	1.7 [b]	3.3	0.04
Pulp Astringency	3.0 [b]	3.2 [a]	2.6 [c]	13	< 0.001
Pulp Overall Aftertaste	2.2	2.4	2.3	0.4	0.67
Pulp Sweetness Aftertaste	1.0 [c]	1.3 [b]	1.6 [a]	29	< 0.001
Pulp Sourness Aftertaste	1.6 [a]	1.7 [a]	0.9 [b]	40	< 0.001
Pulp Bitterness Aftertaste	0.8	0.8	0.7	2.8	0.06
Skin Sweetness	1.2 [c]	1.4 [b]	1.7 [a]	23	< 0.001
Skin Sourness	1.5 [b]	1.8 [a]	1.1 [c]	36	< 0.001
Skin Bitterness	1.2	1.1	1.0	1.5	0.23

Attribute	Sugar Level				
	Low	Medium	High	F- statistic	p-value
Skin Overall Intensity Flavor	3.0	3.2	3.1	0.1	0.93
Skin Fresh Fruit Flavor	0.5	0.7	0.6	0.6	0.54
Skin Dried Fruit Flavor	1.0	0.9	1.0	0.2	0.83
Skin Citrus Fruit Flavor	0.5 [a]	0.5 [a]	0.3 [b]	6.7	< 0.01
Skin Jammy Flavor	0.5 [b]	0.6 [b]	0.8 [a]	13	< 0.001
Skin Fermented Fruit Flavor	0.6	0.8	0.8	1.2	0.30
Skin Fresh Green Flavor	0.9	0.9	0.8	2.1	0.12
Skin Green Wood Flavor	1.9 [b]	2.1 [a]	1.8 [b]	4.1	0.02
Skin Earthy Flavor	0.7	0.7	0.6	0.8	0.43
Skin Hay Flavor	0.9	0.8	0.7	1.9	0.15
Skin Floral Flavor	0.3	0.2	0.3	1.6	0.20
Skin Metallic Flavor	0.0	0.0	0.0	0.9	0.40
Skin Artificial Grape Flavor	0.2	0.2	0.2	2.1	0.12
Skin Astringency	2.2	2.6	2.4	0.6	0.53
Overall Skin Aftertaste	1.4	1.6	1.6	1.0	0.39
Skin Sweetness Aftertaste	0.6 [b]	0.6 [b]	0.8 [a]	14	< 0.001
Skin Sourness Aftertaste	0.7 [a]	0.8 [a]	0.5 [b]	12	< 0.001
Skin Bitterness Aftertaste	0.8	0.9	0.9	0.2	0.78

*means within a row with the same letter superscript are not significantly different ($p > 0.1$

8.11 Complete Results for Frontenac Grapes by Harvest Date

Table 8.7: Complete Frontenac Grapes results from Year One. Shaded rows indicate significant differences among harvest dates (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Harvest Date				
	8/20/12	8/24/12	9/12/12	F- statistic	p-value
Overall Intensity Aroma	5.0 [a]	4.6 [b]	4.7 [b]	3.4	0.04
Fresh Fruit Aroma	1.9	1.7	1.8	0.8	0.44
Dried Fruit Aroma	0.8	0.9	0.9	0.2	0.82
Citrus Fruit Aroma	0.4	0.3	0.3	1.3	0.28
Jammy Aroma	1.2	1.2	1.3	0.2	0.85
Fermented Fruit Aroma	1.7	1.7	1.6	0.3	0.76
Fresh Green Aroma	1.4	1.4	1.6	1.7	0.18
Green Wood Aroma	2.6 [a]	2.4 [b]	2.7 [a]	3.5	0.03
Earthy Aroma	1.5	1.4	1.6	0.6	0.54
Hay Aroma	1.2	1.2	1.3	1.0	0.35
Floral Aroma	0.5	0.5	0.6	1.5	0.23
Metallic Aroma	0.2	0.1	0.1	0.8	0.46
Artificial Grape Aroma	0.3 [b]	0.3 [b]	0.4 [a]	3.2	0.04
Pulp Sweetness	3.3 [c]	3.9 [b]	4.3 [a]	19	< 0.001
Pulp Sourness	5.5 [a]	4.8 [b]	3.8 [c]	37	< 0.001
Pulp Bitterness	1.3 [a]	1.2 [a]	1.0 [b]	5.3	0.01
Pulp Overall Intensity Flavor	6.3 [a]	6.3 [a]	5.7 [b]	13	< 0.001
Pulp Fresh Fruit Flavor	3.0	3.3	3.2	1.9	0.15
Pulp Dried Fruit Flavor	0.8	0.9	0.8	0.4	0.65
Pulp Citrus Flavor	1.5 [a]	1.2 [b]	0.7 [c]	20	0.00
Pulp Jammy Flavor	2.3	2.4	2.6	2.1	0.12
Pulp Fermented Fruit Flavor	2.2 [a]	1.8 [b]	1.8 [b]	3.6	0.03
Pulp Fresh Green Flavor	1.4	1.5	1.4	0.5	0.61
Pulp Green Wood Flavor	1.6	1.6	1.6	0.0	0.99
Pulp Earthy Flavor	1.0	0.9	0.9	0.6	0.57
Pulp Hay Flavor	0.7	0.7	0.6	0.8	0.45
Pulp Floral Flavor	0.6 [b]	0.7 [b]	0.8 [a]	2.8	0.06
Pulp Metallic Flavor	0.2	0.2	0.1	2.0	0.14
Pulp Artificial Grape Flavor	2.1	2.1	1.9	1.1	0.34
Pulp Astringency	3.3 [a]	3.2 [a]	2.9 [b]	2.8	0.06
Pulp Overall Aftertaste	2.7	2.8	2.7	1.3	0.29
Pulp Sweetness Aftertaste	1.3 [b]	1.5 [b]	1.8 [a]	8.4	< 0.001
Pulp Sourness Aftertaste	2.1 [a]	1.8 [b]	1.6 [c]	11	< 0.001
Pulp Bitterness Aftertaste	1.0	0.9	0.8	1.2	0.30
Skin Sweetness	1.2 [c]	1.6 [b]	1.8 [a]	17	< 0.001
Skin Sourness	1.9 [a]	1.8 [a]	1.3 [b]	14	< 0.001
Skin Bitterness	1.2	1.0	1.0	1.9	0.15
Skin Overall Intensity Flavor	3.1 [a]	3.0 [ab]	2.9 [b]	2.5	0.09

Attribute	Harvest Date			F- statistic	p-value
	8/20/12	8/24/12	9/12/12		
Skin Fresh Fruit Flavor	0.8	0.8	0.9	0.7	0.50
Skin Dried Fruit Flavor	1.3	1.2	1.2	0.6	0.55
Skin Citrus Fruit Flavor	0.5 [a]	0.4 [a]	0.2 [b]	6.2	< 0.01
Skin Jammy Flavor	0.7	0.6	0.6	0.3	0.76
Skin Fermented Fruit Flavor	1.0	0.8	0.8	2.4	0.09
Skin Fresh Green Flavor	0.8	1.0	1.0	1.7	0.18
Skin Green Wood Flavor	2.0	2.0	1.9	0.6	0.58
Skin Earthy Flavor	0.9	0.9	0.8	1.6	0.20
Skin Hay Flavor	0.9	0.9	0.8	0.9	0.42
Skin Floral Flavor	0.3 [b]	0.3 [b]	0.5 [a]	5.1	0.01
Skin Metallic Flavor	0.1	0.1	0.1	0.1	0.87
Skin Artificial Grape Flavor	0.3	0.3	0.4	1.2	0.30
Skin Astringency	2.3	2.2	2.1	2.3	0.10
Overall Skin Aftertaste	1.7	1.6	1.6	1.3	0.27
Skin Sweetness Aftertaste	0.58 [b]	0.65 [ab]	0.74 [a]	3.1	0.04
Skin Sourness Aftertaste	0.9 [a]	0.8 [a]	0.7 [b]	5.4	0.01
Skin Bitterness Aftertaste	0.9	0.8	0.8	1.2	0.30

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

Table 8.8: Complete Frontenac Grapes results from Year Two. Shaded rows indicate significant differences among harvest dates (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$).*

Attribute	Harvest Date				F- statistic	p-value
	9/5/13	9/12/13	9/17/13	9/22/13		
Overall Intensity Aroma	4.6	4.4	4.6	4.4	1.1	0.37
Fresh Fruit Aroma	1.4	1.2	1.0	1.1	2.7	0.05
Dried Fruit Aroma	0.9	0.8	0.8	0.8	0.3	0.82
Citrus Fruit Aroma	0.4	0.3	0.2	0.3	1.3	0.28
Jammy Aroma	1.1	1.0	1.0	1.0	0.7	0.57
Fermented Fruit Aroma	0.8	0.7	0.7	0.7	0.4	0.77
Fresh Green Aroma	1.1	1.1	1.1	1.1	0.1	0.97
Green Wood Aroma	1.8	1.7	1.9	1.9	0.8	0.47
Earthy Aroma	0.9	0.9	1.0	1.0	1.1	0.33
Hay Aroma	0.9	0.8	1.0	1.0	1.6	0.19
Floral Aroma	0.5	0.4	0.5	0.3	1.5	0.22
Metallic Aroma	0.0	0.0	0.0	0.0	0.4	0.74
Artificial Grape Aroma	0.3	0.2	0.3	0.2	0.7	0.55
Pulp Sweetness	2.3	3.3	3.2	3.8	26	< 0.001
Pulp Sourness	5.8	5.0	4.7	4.2	16	< 0.001
Pulp Bitterness	1.2	1.2	1.0	1.0	1.3	0.28
Pulp Overall Intensity Flavor	6.1	5.8	5.5	5.8	2.9	0.03
Pulp Fresh Fruit Flavor	2.1	1.9	2.0	2.1	0.9	0.46
Pulp Dried Fruit Flavor	0.9	0.8	0.9	1.1	2.4	0.06

Attribute	Harvest Date					
	9/5/13	9/12/13	9/17/13	9/22/13	F- statistic	p-value
Pulp Citrus Flavor	2.1	1.6	1.6	1.4	6.7	0.00
Pulp Jammy Flavor	1.7	2.1	2.2	2.3	6.3	0.00
Pulp Fermented Fruit Flavor	1.1	1.1	1.1	1.2	0.3	0.80
Pulp Fresh Green Flavor	1.0	0.9	1.1	0.9	0.5	0.67
Pulp Green Wood Flavor	1.2	1.4	1.3	1.1	1.8	0.14
Pulp Earthy Flavor	0.4	0.5	0.6	0.5	1.7	0.16
Pulp Hay Flavor	0.4	0.4	0.3	0.5	1.7	0.17
Pulp Floral Flavor	0.5	0.5	0.5	0.6	0.5	0.70
Pulp Metallic Flavor	0.0	0.0	0.0	0.0	1.1	0.35
Pulp Artificial Grape Flavor	1.5	1.5	1.6	1.7	1.5	0.21
Pulp Astringency	3.0	2.8	2.6	2.7	2.7	0.04
Pulp Overall Aftertaste	2.3	2.1	2.0	2.2	2.5	0.06
Pulp Sweetness Aftertaste	0.9	1.0	1.1	1.4	8.8	< 0.001
Pulp Sourness Aftertaste	1.9	1.5	1.3	1.1	13	< 0.001
Pulp Bitterness Aftertaste	0.7	0.8	0.8	0.8	0.2	0.87
Skin Sweetness	0.8	1.0	1.1	1.3	4.8	< 0.01
Skin Sourness	1.6	1.3	1.2	1.2	5.4	< 0.01
Skin Bitterness	1.0	1.1	1.0	1.1	0.5	0.67
Skin Overall Intensity Flavor	2.5	2.6	2.6	2.7	0.6	0.59
Skin Fresh Fruit Flavor	0.4	0.4	0.4	0.5	0.3	0.81
Skin Dried Fruit Flavor	1.0	1.1	0.9	1.1	1.8	0.14
Skin Citrus Flavor	0.5	0.3	0.2	0.3	4.3	0.01
Skin Jammy Flavor	0.5	0.5	0.5	0.4	0.7	0.53
Skin Fermented Fruit Flavor	0.31	0.46	0.45	0.51	2.5	0.06
Skin Fresh Green Flavor	0.7	0.6	0.6	0.7	1.1	0.36
Skin Green Wood Flavor	1.8	1.6	1.5	1.6	2.3	0.07
Skin Earthy Flavor	0.6	0.6	0.6	0.7	1.3	0.28
Skin Hay Flavor	0.6	0.5	0.5	0.6	1.1	0.36
Skin Floral Flavor	0.3	0.2	0.2	0.2	0.8	0.51
Skin Metallic Flavor	0.0	0.0	0.0	0.1	1.6	0.18
Skin Artificial Grape Flavor	0.2	0.1	0.1	0.2	3.1	0.03
Skin Astringency	2.0	1.7	1.8	1.7	1.9	0.13
Overall Skin Aftertaste	1.3	1.2	1.4	1.2	2.0	0.11
Skin Sweetness Aftertaste	0.4	0.5	0.6	0.6	2.9	0.03
Skin Sourness Aftertaste	0.8	0.5	0.6	0.5	5.6	< 0.001
Skin Bitterness Aftertaste	0.9	0.7	0.9	0.9	1.0	0.41

*means within a row with the same letter superscript were not significantly different ($p > 0.1$)

8.12 Complete Results for Marquette Grapes by Harvest Date

Table 8.9: Complete Marquette Grapes results from Year One. Shaded rows indicate significant differences among harvest dates (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Harvest Date				
	8/21/12	8/24/12	9/12/12	F- statistic	p-value
Overall Intensity Aroma	5.0	4.8	4.8	1.3	0.28
Fresh Fruit Aroma	2.0 [a]	1.9 [a]	1.6 [b]	4.6	0.01
Dried Fruit Aroma	0.8	0.8	0.8	0.3	0.72
Citrus Fruit Aroma	0.4	0.4	0.3	0.7	0.48
Jammy Aroma	1.6 [a]	1.4 [a]	1.1 [b]	6.6	< 0.01
Fermented Fruit Aroma	1.9	1.8	1.8	0.5	0.59
Fresh Green Aroma	1.4	1.4	1.5	1.0	0.35
Green Wood Aroma	2.6 [b]	2.4 [c]	2.9 [a]	7.0	< 0.01
Earthy Aroma	1.0 [b]	1.1 [ab]	1.3 [a]	2.6	0.07
Hay Aroma	1.2	1.0	1.2	1.1	0.33
Floral Aroma	0.5 [a]	0.3 [b]	0.4 [ab]	2.3	0.10
Metallic Aroma	0.1	0.1	0.1	1.4	0.24
Artificial Grape Aroma	0.6 [a]	0.6 [a]	0.3 [b]	7.8	< 0.001
Pulp Sweetness	3.2 [b]	3.2 [b]	4.3 [a]	50	< 0.001
Pulp Sourness	4.7 [a]	4.5 [a]	2.5 [b]	108	< 0.001
Pulp Bitterness	1.2 [a]	1.3 [a]	1.0 [b]	5.3	0.01
Pulp Overall Intensity Flavor	5.8 [a]	5.8 [a]	5.3 [b]	12	< 0.001
Pulp Fresh Fruit Flavor	2.8	2.8	2.8	0.1	0.86
Pulp Dried Fruit Flavor	0.7	0.9	0.8	0.9	0.41
Pulp Citrus Flavor	1.2 [a]	1.2 [a]	0.5 [b]	26	< 0.001
Pulp Jammy Flavor	2.1 [b]	2.2 [b]	2.7 [a]	14	< 0.001
Pulp Fermented Fruit Flavor	2.3	2.2	2.0	1.8	0.16
Pulp Fresh Green Flavor	1.1	1.2	1.0	1.9	0.16
Pulp Green Wood Flavor	1.4	1.4	1.4	0.3	0.76
Pulp Earthy Flavor	0.7	0.6	0.6	0.1	0.89
Pulp Hay Flavor	0.6	0.6	0.6	0.2	0.85
Pulp Floral Flavor	0.4 [b]	0.5 [b]	0.8 [a]	11	< 0.001
Pulp Metallic Flavor	0.1	0.1	0.2	1.1	0.32
Pulp Artificial Grape Flavor	1.8	1.9	1.7	1.4	0.25
Pulp Astringency	3.4 [a]	3.3 [a]	2.8 [b]	8.8	< 0.001
Pulp Overall Aftertaste	2.5	2.4	2.4	0.0	1.00
Pulp Sweetness Aftertaste	1.2 [b]	1.2 [b]	1.7 [a]	16	< 0.001
Pulp Sourness Aftertaste	1.8 [a]	1.7 [a]	1.0 [b]	30	< 0.001
Pulp Bitterness Aftertaste	0.9	0.9	0.8	0.6	0.56
Skin Sweetness	1.4 [b]	1.4 [b]	2.0 [a]	26	< 0.001
Skin Sourness	2.0 [a]	1.9 [a]	1.3 [b]	26	< 0.001
Skin Bitterness	1.1	1.2	1.0	1.5	0.22
Skin Overall Intensity Flavor	3.1 [b]	3.3 [a]	3.4 [a]	4.5	0.01

Attribute	Harvest Date				
	8/21/12	8/24/12	9/12/12	F- statistic	p-value
Skin Fresh Fruit Flavor	0.6	0.7	0.8	2.0	0.14
Skin Dried Fruit Flavor	0.8	0.9	0.9	2.1	0.12
Skin Citrus Fruit Flavor	0.4	0.5	0.3	2.1	0.12
Skin Jammy Flavor	0.5 [b]	0.6 [b]	0.9 [a]	8.7	< 0.001
Skin Fermented Fruit Flavor	1.0	0.9	1.0	0.2	0.82
Skin Fresh Green Flavor	1.0	0.9	0.9	0.7	0.50
Skin Green Wood Flavor	2.2	2.1	2.0	2.1	0.13
Skin Earthy Flavor	0.7	0.7	0.6	0.9	0.42
Skin Hay Flavor	0.9	0.7	0.8	1.3	0.28
Skin Floral Flavor	0.1 [b]	0.2 [b]	0.3 [a]	3.7	0.03
Skin Metallic Flavor	0.0	0.1	0.0	2.3	0.10
Skin Artificial Grape Flavor	0.2	0.2	0.2	0.0	0.96
Skin Astringency	2.6	2.8	2.7	0.7	0.48
Overall Skin Aftertaste	1.6	1.6	1.6	0.0	0.98
Skin Sweetness Aftertaste	0.6 [b]	0.5 [b]	0.8 [a]	14	< 0.001
Skin Sourness Aftertaste	0.8 [a]	0.9 [a]	0.6 [b]	5.1	0.01
Skin Bitterness Aftertaste	1.0	0.9	0.9	0.4	0.65

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Table 8.10: Complete Marquette Grapes results from Year Two. Shaded rows indicate significant differences among harvest dates (light gray is $0.05 < p < 0.1$; dark gray is $p < 0.05$). *

Attribute	Harvest Date				
	9/3/13	9/10/13	9/18/13	F- statistic	p-value
Overall Intensity Aroma	4.3 [b]	4.5 [a]	4.6 [a]	2.9	0.06
Fresh Fruit Aroma	1.4	1.4	1.4	0.1	0.88
Dried Fruit Aroma	0.8	0.9	0.8	0.4	0.67
Citrus Fruit Aroma	0.3	0.3	0.2	1.4	0.26
Jammy Aroma	1.3	1.2	1.2	0.2	0.80
Fermented Fruit Aroma	0.8	0.8	0.7	0.3	0.76
Fresh Green Aroma	0.9	1.0	1.0	0.2	0.82
Green Wood Aroma	1.7 [b]	2.0 [a]	2.0 [a]	3.6	0.03
Earthy Aroma	0.9	0.8	0.9	0.4	0.67
Hay Aroma	0.9	0.9	1.0	0.0	1.00
Floral Aroma	0.4	0.5	0.5	1.0	0.36
Metallic Aroma	0.0	0.0	0.0	1.3	0.28
Artificial Grape Aroma	0.4	0.5	0.4	0.8	0.47
Pulp Sweetness	2.6 [c]	3.8 [b]	4.1 [a]	46	< 0.001
Pulp Sourness	5.6 [a]	4.1 [b]	3.3 [c]	65	< 0.001
Pulp Bitterness	1.3 [a]	1.1 [a]	0.9 [b]	7.5	< 0.001
Pulp Overall Intensity Flavor	6.1 [a]	5.8 [b]	5.5 [c]	8.4	< 0.001
Pulp Fresh Fruit Flavor	2.2	2.4	2.4	1.2	0.32
Pulp Dried Fruit Flavor	0.7	0.8	0.9	1.4	0.25

Attribute	Harvest Date				
	9/3/13	9/10/13	9/18/13	F- statistic	p-value
Pulp Citrus Flavor	2.1 [a]	1.4 [b]	1.0 [c]	26	< 0.001
Pulp Jammy Flavor	1.9 [b]	2.6 [a]	2.7 [a]	16	< 0.001
Pulp Fermented Fruit Flavor	1.3	1.3	1.2	0.7	0.52
Pulp Fresh Green Flavor	0.9 [a]	0.7 [b]	0.7 [b]	2.8	0.06
Pulp Green Wood Flavor	1.4 [a]	1.3 [ab]	1.1 [b]	3.0	0.05
Pulp Earthy Flavor	0.4	0.4	0.6	2.1	0.12
Pulp Hay Flavor	0.4	0.5	0.4	0.7	0.51
Pulp Floral Flavor	0.5	0.5	0.6	0.7	0.52
Pulp Metallic Flavor	0.0	0.0	0.0	0.4	0.69
Pulp Artificial Grape Flavor	1.5 [b]	1.9 [a]	1.7 [ab]	4.0	0.02
Pulp Astringency	2.9 [a]	2.6 [ab]	2.4 [b]	5.4	0.01
Pulp Overall Aftertaste	2.1	2.1	2.1	0.0	1.00
Pulp Sweetness Aftertaste	0.8 [b]	1.4 [a]	1.5 [a]	29	< 0.001
Pulp Sourness Aftertaste	1.6 [a]	1.2 [b]	0.8 [c]	20	< 0.001
Pulp Bitterness Aftertaste	0.7	0.7	0.6	1.3	0.27
Skin Sweetness	1.0 [b]	1.4 [a]	1.4 [a]	9.1	< 0.001
Skin Sourness	1.6 [a]	1.1 [b]	0.8 [c]	21	< 0.001
Skin Bitterness	1.2	1.1	1.1	1.1	0.32
Skin Overall Intensity Flavor	2.9	2.9	2.7	2.0	0.14
Skin Fresh Fruit Flavor	0.5	0.5	0.4	0.8	0.46
Skin Dried Fruit Flavor	1.1	1.1	1.1	0.1	0.90
Skin Citrus Fruit Flavor	0.5 [a]	0.5 [a]	0.3 [b]	5.6	< 0.01
Skin Jammy Flavor	0.4 [b]	0.5 [b]	0.7 [a]	4.9	0.01
Skin Fermented Fruit Flavor	0.4 [b]	0.4 [b]	0.6 [a]	3.3	0.04
Skin Fresh Green Flavor	0.8	0.7	0.7	1.1	0.33
Skin Green Wood Flavor	1.8 [a]	1.9 [a]	1.6 [b]	2.9	0.05
Skin Earthy Flavor	0.7	0.6	0.6	0.3	0.76
Skin Hay Flavor	0.9	0.9	0.7	2.3	0.10
Skin Floral Flavor	0.4	0.3	0.3	1.6	0.21
Skin Metallic Flavor	0.0	0.1	0.0	0.2	0.79
Skin Artificial Grape Flavor	0.2	0.3	0.3	0.4	0.69
Skin Astringency	2.1	2.0	2.0	0.7	0.52
Overall Skin Aftertaste	1.3	1.4	1.5	1.0	0.36
Skin Sweetness Aftertaste	0.6 [b]	0.8 [a]	0.8 [a]	8.3	< 0.001
Skin Sourness Aftertaste	0.8 [a]	0.6 [b]	0.4 [c]	10	< 0.001
Skin Bitterness Aftertaste	0.8	0.8	0.8	0.0	1.00

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

8.13 Complete Results for Frontenac Wine

Table 8.11: Complete Frontenac Wines results from Year Two. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Wine Harvest		F- statistic	P-value
	Early	Late		
Overall Intensity of Aroma	5.7	6.2	5.5	0.02
Artificial Banana Aroma	0.7	1.2	3.3	0.08
Black Currant Aroma	1.6	1.6	0.0	0.94
Cooked Berry Aroma	0.9	1.4	3.5	0.07
Dark Fruit Aroma	2.6	2.5	0.3	0.61
Cooked Vegetable Aroma	0.8	1.7	6.8	0.01
Fresh Green Aroma	0.3	0.3	0.0	0.95
Woody Aroma	0.9	0.7	0.5	0.49
Hay Aroma	0.3	0.5	0.8	0.36
Black Pepper Aroma	0.4	0.6	0.8	0.37
Spice Aroma	0.9	0.5	3.0	0.09
Floral Aroma	0.3	0.7	3.1	0.09
Ethanol Aroma	1.3	1.4	0.2	0.66
Chemical Aroma	0.6	0.5	0.2	0.69
White Mushroom Aroma	0.8	0.9	0.2	0.62
Dried Mushroom Aroma	1.3	0.5	8.6	< 0.001
Tamari Aroma	1.9	0.6	21	< 0.001
Geranium Aroma	0.1	0.1	0.0	0.86
Sweetness	0.5	2.2	29	< 0.001
Sourness	3.9	3.8	0.1	0.80
Bitterness	4.0	2.8	16	< 0.001
Astringency	3.3	3.8	2.6	0.11
Overall Intensity of Flavor	5.7	6.3	1.6	0.22
Artificial Banana Flavor	0.3	0.8	9.7	< 0.001
Black Currant Flavor	1.5	1.9	3.0	0.09
Cooked Berry Flavor	0.7	1.8	15	< 0.001
Dark Fruit Flavor	2.2	2.6	2.8	0.10
Cooked Vegetable Flavor	1.6	1.1	2.5	0.12
Fresh Green Flavor	0.4	0.4	0.1	0.75
Woody Flavor	1.3	1.1	1.1	0.29
Hay Flavor	0.8	0.1	12	< 0.001
Black Pepper Flavor	0.7	0.9	1.0	0.32
Spice Flavor	0.6	0.6	0.0	0.95
Floral Flavor	0.3	0.4	0.6	0.44
Ethanol Flavor	1.7	1.9	0.3	0.61

Attribute	Wine Harvest			
	Early	Late	F- statistic	P-value
Chemical Flavor	0.6	0.7	0.1	0.81
White Mushroom Flavor	1.2	0.6	6.5	0.01
Dried Mushroom Flavor	1.7	0.4	21	< 0.001
Tamari Flavor	1.9	0.4	25	< 0.001
Geranium Flavor	0.1	0.3	0.8	0.37
Overall Aftertaste	3.8	3.5	1.0	0.31
Sweetness Aftertaste	0.5	1.2	16	< 0.001
Sourness Aftertaste	2.4	2.6	0.8	0.36
Bitterness Aftertaste	2.7	1.8	9.2	< 0.001
Ethanol Aftertaste	1.6	1.6	0.1	0.74

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Table 8.12: Mean and standard errors of all Frontenac Wine attributes from Year One (2012) and Year Two (2013). All wines could be considered to be produced from Late Harvest grape berries. The wine from 2012 was evaluated in both 2012 and 2013 after aging.

Attribute	Wine Sample			Standard error		
	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Overall Intensity of Aroma	6.9	6.4	6.2	0.2	0.2	0.2
Artificial Banana Aroma	1.5	1.0	1.2	0.2	0.2	0.3
Black Currant Aroma	1.7	1.9	1.6	0.3	0.3	0.2
Cooked Berry Aroma	2.0	1.4	1.4	0.2	0.3	0.3
Dark Fruit Aroma	3.1	2.5	2.5	0.2	0.2	0.2
Cooked Vegetable Aroma	1.4	1.8	1.7	0.3	0.3	0.3
Fresh Green Aroma	0.7	0.4	0.3	0.2	0.1	0.1
Woody Aroma	1.1	0.6	0.7	0.2	0.2	0.2
Hay Aroma	0.1	0.3	0.5	0.0	0.2	0.2
Black Pepper Aroma	0.5	0.6	0.6	0.1	0.2	0.2
Spice Aroma	0.8	0.9	0.5	0.2	0.2	0.2
Floral Aroma	1.5	0.9	0.7	0.2	0.2	0.2
Ethanol Aroma	2.0	1.5	1.4	0.2	0.3	0.3
Chemical Aroma	0.5	0.6	0.5	0.1	0.2	0.2
White Mushroom Aroma	0.8	0.7	0.9	0.2	0.2	0.2
Dried Mushroom Aroma	0.3	0.6	0.5	0.1	0.2	0.2
Tamari Aroma	0.7	0.3	0.6	0.2	0.1	0.2
Geranium Aroma*		0.5	0.1		0.2	0.1
Sweetness	2.1	2.4	2.2	0.3	0.3	0.4
Sourness	4.8	3.1	3.8	0.3	0.4	0.5
Bitterness	2.8	3.1	2.8	0.3	0.3	0.3
Astringency	4.2	4.3	3.8	0.3	0.3	0.3

Attribute	Wine Sample			Standard error		
	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Overall Intensity of Flavor	6.7	6.3	6.3	0.2	0.2	0.5
Artificial Banana Flavor	0.8	0.4	0.8	0.2	0.1	0.3
Black Currant Flavor	1.7	1.7	1.9	0.2	0.2	0.2
Cooked Berry Flavor	2.3	1.4	1.8	0.2	0.2	0.3
Dark Fruit Flavor	3.0	2.6	2.6	0.3	0.2	0.2
Cooked Vegetable Flavor	1.3	1.3	1.1	0.2	0.3	0.3
Fresh Green Flavor	0.8	0.3	0.4	0.2	0.1	0.2
Woody Flavor	0.9	1.5	1.1	0.2	0.2	0.2
Hay Flavor	0.0	0.4	0.1	0.0	0.2	0.1
Black Pepper Flavor	1.0	0.9	0.9	0.2	0.2	0.2
Spice Flavor	1.0	1.3	0.6	0.2	0.2	0.2
Floral Flavor	1.3	0.6	0.4	0.3	0.2	0.2
Ethanol Flavor	2.9	1.4	1.9	0.3	0.3	0.3
Chemical Flavor	1.0	0.7	0.7	0.2	0.2	0.2
White Mushroom Flavor	0.6	0.8	0.6	0.1	0.2	0.2
Dried Mushroom Flavor	0.2	0.3	0.4	0.1	0.1	0.2
Tamari Flavor	0.2	0.2	0.4	0.1	0.1	0.2
Geranium Flavor*		0.5	0.3		0.2	0.1
Overall Aftertaste	4.8	4.1	3.5	0.3	0.2	0.2
Sweetness Aftertaste	1.2	1.2	1.2	0.2	0.2	0.2
Sourness Aftertaste	3.1	2.9	2.6	0.2	0.3	0.2
Bitterness Aftertaste	2.2	2.3	1.8	0.1	0.2	0.2
Ethanol Aftertaste	2.6	1.7	1.6	0.3	0.3	0.3

*Geranium attributes were added to the lexicon in 2013 and were not rated in 2012

8.14 Complete Results for Marquette Wine

Table 8.13: Complete Marquette Wines results from Year Two. Shaded rows indicate significant differences among sugar levels (light gray is 0.05 < p < 0.1; dark gray is p < 0.05).*

Attribute	Wine Harvest		F- statistic	P-value
	Early	Late		
Overall Intensity of Aroma	5.7	5.8	0.3	0.61
Artificial Banana Aroma	1.1	0.7	1.9	0.18
Black Currant Aroma	1.8	2.0	0.4	0.54
Cooked Berry Aroma	1.5	1.5	0.0	0.99
Dark Fruit Aroma	2.4	2.5	0.2	0.66
Grapefruit Aroma	1.1	1.3	0.6	0.45
Cooked Vegetable Aroma	1.2	1.1	0.3	0.56
Fresh Green Aroma	0.0	0.2	1.9	0.17
Woody Aroma	0.8	0.8	0.1	0.72
Hay Aroma	0.1	0.3	2.1	0.16
Pepper Aroma	0.6	0.4	0.8	0.37
Spice Aroma	0.5	0.5	0.0	0.98
Floral Aroma	0.8	0.5	2.3	0.14
Geranium Aroma	0.5	0.2	2.7	0.11
Ethanol Aroma	1.3	1.2	0.0	0.93
Chemical Aroma	0.3	0.4	1.1	0.29
Caramel Aroma	0.1	0.1	0.1	0.74
White Mushroom Aroma	0.5	0.4	0.1	0.77
Dried Mushroom Aroma	0.3	0.8	5.8	0.02
Tamari Aroma	0.3	0.2	0.4	0.54
Cheese Butyric Aroma	0.6	0.6	0.0	0.95
Sweetness	1.6	0.9	8.0	0.01
Sourness	3.6	3.8	0.5	0.50
Bitterness	3.5	4.2	4.2	0.04
Astringency	2.9	3.9	6.2	0.02
Overall Intensity of Flavor	5.7	6.0	2.6	0.11
Artificial Banana Flavor	0.6	0.4	0.3	0.56
Black Currant Flavor	2.0	1.7	1.2	0.28
Cooked Berry Flavor	1.1	0.8	1.3	0.25
Dark Fruit Flavor	2.6	2.5	0.0	0.84
Grapefruit Flavor	1.4	1.1	1.2	0.29
Cooked Vegetable Flavor	1.4	2.0	4.1	0.05
Fresh Green Flavor	0.0	0.0	0.2	0.70
Woody Flavor	1.4	1.6	2.3	0.14

Attribute	Wine Harvest			
	Early	Late	F- statistic	P-value
Hay Flavor	0.3	0.1	2.7	0.11
Pepper Flavor	0.7	1.1	2.8	0.10
Spice Flavor	0.7	0.5	1.9	0.17
Floral Flavor	0.7	0.7	0.0	0.90
Geranium Flavor	0.3	0.3	0.0	0.97
Ethanol Flavor	1.4	2.0	5.9	0.02
Chemical Flavor	0.4	0.5	0.3	0.60
Caramel Flavor	0.1	0.1	1.0	0.33
White Mushroom Flavor	0.9	0.5	3.4	0.07
Dried Mushroom Flavor	0.4	0.9	6.6	0.01
Tamari Flavor	0.2	0.3	0.6	0.44
Cheese Butyric Flavor	0.4	0.5	0.4	0.52
Overall Aftertaste	3.3	4.1	14.0	0.00
Sweetness Aftertaste	1.1	0.7	4.0	0.05
Sourness Aftertaste	1.9	2.4	4.6	0.04
Bitterness Aftertaste	2.2	2.9	6.3	0.02
Ethanol Aftertaste	1.6	2.0	3.2	0.08
Chemical Aftertaste	0.4	0.6	2.8	0.10
Cooked Vegetable Aftertaste	0.8	1.4	6.0	0.02
Woody Aftertaste	0.8	0.7	0.3	0.60
Geranium Aftertaste	0.2	0.1	0.6	0.43

*means within a row with the same letter superscript are not significantly different ($p > 0.1$)

Table 8.14: Mean and standard errors of all Marquette Wine attributes from Year One (2012) and Year Two (2013). All wines could be considered to be produced from Late Harvest grape berries. The wine from 2012 was evaluated in both 2012 and 2013 after aging.

	Wine Sample			Standard error		
Attribute	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Overall Intensity of Aroma	7.3	6.3	5.8	0.2	0.3	0.2
Artificial Banana Aroma	0.9	1.4	0.7	0.2	0.4	0.3
Black Currant Aroma	2.0	1.9	2.0	0.2	0.2	0.3
Cooked Berry Aroma	1.5	1.4	1.5	0.2	0.3	0.3
Dark Fruit Aroma	2.8	2.2	2.5	0.2	0.3	0.3
Grapefruit Aroma	0.7	0.8	1.3	0.1	0.3	0.3
Cooked Vegetable Aroma	2.1	1.8	1.1	0.2	0.2	0.3
Fresh Green Aroma	0.4	0.1	0.2	0.1	0.1	0.1
Woody Aroma	1.4	0.9	0.8	0.2	0.2	0.2
Hay Aroma	0.1	0.2	0.3	0.1	0.1	0.1
Pepper Aroma	0.9	0.5	0.4	0.2	0.1	0.2
Spice Aroma	1.2	0.5	0.5	0.2	0.2	0.2
Floral Aroma	0.4	0.7	0.5	0.1	0.2	0.2
Geranium Aroma*		0.6	0.2		0.2	0.1
Ethanol Aroma	2.5	1.4	1.2	0.3	0.3	0.2
Chemical Aroma	0.9	0.4	0.4	0.2	0.2	0.2
Caramel Aroma	0.2	0.1	0.1	0.1	0.1	0.1
White Mushroom Aroma	1.3	0.6	0.4	0.2	0.2	0.2
Dried Mushroom Aroma	0.7	0.7	0.8	0.2	0.2	0.2
Tamari Aroma	0.5	0.2	0.2	0.1	0.1	0.1
Cheese Butyric Aroma*		0.9	0.6		0.2	0.2
Sweetness	1.9	3.1	0.9	0.3	0.3	0.2
Sourness	3.7	3.0	3.8	0.3	0.3	0.3
Bitterness	3.4	2.9	4.2	0.4	0.4	0.3
Astringency	3.6	3.8	3.9	0.2	0.3	0.3
Overall Intensity of Flavor	6.6	6.0	6.0	0.1	0.3	0.2
Artificial Banana Flavor	0.7	1.2	0.4	0.2	0.3	0.2
Black Currant Flavor	2.3	1.8	1.7	0.2	0.2	0.2
Cooked Berry Flavor	1.5	1.6	0.8	0.2	0.3	0.2
Dark Fruit Flavor	2.8	2.8	2.5	0.2	0.3	0.3
Grapefruit Flavor	1.4	1.6	1.1	0.2	0.3	0.2
Cooked Vegetable Flavor	1.3	1.2	2.0	0.2	0.2	0.3
Fresh Green Flavor	0.2	0.3	0.0	0.1	0.2	0.0
Woody Flavor	1.6	1.4	1.6	0.2	0.2	0.2

Attribute	Wine Sample			Standard error		
	2012 in 2012	2012 in 2013	2013 Late	2012 in 2012	2012 in 2013	2013 Late
Hay Flavor	0.3	0.1	0.1	0.1	0.1	0.1
Pepper Flavor	0.8	0.7	1.1	0.2	0.2	0.2
Spice Flavor	1.2	0.8	0.5	0.2	0.2	0.1
Floral Flavor	0.5	0.9	0.7	0.1	0.2	0.2
Geranium Flavor*		0.8	0.3		0.3	0.1
Ethanol Flavor	3.0	1.8	2.0	0.3	0.3	0.3
Chemical Flavor	1.4	0.4	0.5	0.3	0.2	0.2
Caramel Flavor	0.1	0.1	0.1	0.1	0.1	0.0
White Mushroom Flavor	0.9	0.8	0.5	0.2	0.2	0.2
Dried Mushroom Flavor	0.6	0.4	0.9	0.2	0.2	0.2
Tamari Flavor	0.4	0.2	0.3	0.2	0.1	0.2
Cheese Butyric Flavor*		0.6	0.5		0.2	0.2
Overall Aftertaste	4.8	3.8	4.1	0.2	0.2	0.3
Sweetness Aftertaste	1.1	1.5	0.7	0.2	0.2	0.1
Sourness Aftertaste	2.7	2.0	2.4	0.2	0.2	0.2
Bitterness Aftertaste	2.8	2.3	2.9	0.2	0.2	0.3
Ethanol Aftertaste	3.0	2.0	2.0	0.3	0.3	0.3
Chemical Aftertaste	1.3	0.4	0.6	0.2	0.2	0.2
Cooked Vegetable Aftertaste	0.7	0.6	1.4	0.2	0.2	0.2
Woody Aftertaste	0.9	0.8	0.7	0.2	0.2	0.2
Geranium Aftertaste*		0.5	0.1		0.2	0.1

*Geranium and cheese/butyric attributes were added to the lexicon in 2013 and were not rated in 2012

8.15 Frontenac Grapes Attribute Development: Year 1

The lexicon that panelists began with contained basic tastes (sweet, sour and bitter), astringency, herbaceous, jammy, and fresh fruit. Citrus, fermented fruit, green wood, metallic, hay, dried fruit, artificial grape and earthy attributes were added by panel discussion and consensus.

Many different earthy attributes were talked about such as dead leaves, musty, moldy, and wet earth, but through moderated discussion panelists decided that these should be condensed into one attribute called earthy. First, a reference of a blend of old and new potting soils was made in an attempt to get the moldy/decay/dead leaves description that some panelists described. That reference was described as too moldy, so panelists were then given a reference of new (fresh) potting soil which was determined to be a better reference than the blend.

They also requested an alternative reference for jammy (from the original strawberry jam). Three different jam samples were presented in attempt to define jammy: the previously used strawberry jam, black currant jam, and a triple berry jam. Black currant jam was determined to be the best reference for jammy. It was also described to have a sort of "tropical note" by one panelist.

Using parsley to define the Fresh Green attribute was determined to not have the correct green scent and an alternate was requested. Since green grass was hard to come by in Minnesota winters, strawberry tops were used as a green references. Even though it was not perfect, the panelists agreed that strawberry tops were similar enough with the

definition of "A 'green' aroma/flavor typical of fresh grass." to recollect to them the scent of fresh green grass.

8.16: Marquette Grapes Attribute Development: Year 1

A panelist-led discussion was held on the complexities of the astringency attribute and the bitterness attribute. Some panelists felt that this overlapped with sour because of a "puckering" sensation. Panelists were reminded to use their citric acid references for sour, and additional low intensity scaling references were requested for both bitter and astringent.

On the second training day one panelist described an "other aroma" for one sample as having a "spicy, almost cinnamon" aroma of 3.1. At the following session panelists were shown a new potential reference standard of "spicy" that consisted of 4 allspice berries. Panelists determined the intensity of this reference standard was much too high in intensity, and suggested that one berry might be enough. Even though, some panelists agreed that some of the samples of berries might contain this attribute but it was such a low intensity ("1-1.2") that it would be hard to discriminate if not specifically asked if it was there. One panelist suggested that they typically classified the "burning in the back of the throat" and specific aroma that allspice recollected under "fermented fruit". The panel agreed that they would be comfortable with this and the use of spice was decided against.

Panelists were also shown 3 new Bitterness and 3 new Astringent references: ¼, ½, and ¾ of each of the basic bitterness and astringency references. Previous work with the panel for another project had put the intensity of the full-strength astringency at 12. The panel agreed with that rating and determined the ¼ astringency as a 2. They determined to keep

the full bitterness as a 6 and the ½ bitterness as a 2. They were reminded make sure that they were using their citric acid references for scaling of attributes, sourness in particular.

8.17: SAS Code

8.17.1: Grape Analysis by sugar level

Example SAS code for single year analysis (Frontenac year 1 in this example):

```
data xxx.year1;
set year1;
year='2012';
if Brix <22 then Sugar_Level = 'a-low';
if Brix >=22 AND Brix <24 then Sugar_Level = 'b-med';
if Brix >=24 then Sugar_Level = 'c-high';
run;

proc sort data = xxx.year1;
by Sugar_Level;
run;

proc means data =xxx.year1;
by Sugar_Level;
var
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
output out = year1mean mean =
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
stderr =
sOverall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes);
run;

Proc glm data = xxx.year1 outstat=year1stats;
class Sugar_Level Location Sensory_Rep Judge;
model
Overall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes)
= Location Sensory_Rep Judge Sugar_Level/ solution;;
means Sugar_Level/snk alpha=.1;
run;

quit;
```

Example SAS code for both years together:

```
data xxx.both;
merge xxx.year1 xxx.year2;
by year Sugar_Level;
run;
```

```
Proc glm data = xxx.both outstat=bothstats;
class Sugar_Level Location Year Panelist;
model
Overall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes)
= Location Panelist(Year) Sugar_Level Year/ solution;;
means Sugar_Level/snk alpha=.1;
run;
```

8.17.2: Grape Analysis by harvest date

Example SAS code for single year analysis (Frontenac year 1 in this example):

```
data xxx.year1;
set year1;
run;

proc sort data = xxx.year1;
by Harvest_Date;
run;

proc means data =xxx.year1;
by Harvest_Date;
var
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
output out = year1mean mean =
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
stderr =
sOverall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes);
run;

Proc glm data = xxx.year1 outstat=year1stats;
class Harvest_Date Location Sensory_Rep Judge;
model
Overall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes)
= Location Sensory_Rep Judge Harvest_Date / solution;;
means Harvest_Date /snk alpha=.1;
run;

quit;
```

8.17.3: Wine Analysis

Example SAS code for analysis of Frontenac year 2:

```
data xxx.year1;
set year1;
run;

proc sort data = xxx.year1;
by Sample;
run;

proc means data =xxx.year1;
by Sample;
var
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
output out = year1mean mean =
Overall_Intensity_Aroma
 (all other aroma, taste, flavor, and astringency attributes)
stderr =
sOverall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes);
run;


Proc glm data = xxx.year1 outstat=fwinestats14;
class Sample Sensory_Rep Panelist;
model
Overall_Intensity_Aroma
(all other aroma, taste, flavor, and astringency attributes)
Ethanol_Aftertaste
=Panelist Sample Sensory_Rep/ solution;
contrast '2012 vs 2013 Late' Sample 1 0 -1;
contrast '2013 Early vs 2013 Late' Sample 0 1 -1 ;
means Sample/snk alpha=0.1;
run;

quit;
```