HUMAN PERCEPTION OF VAPOR-PHASE STIMULI PROVIDED BY ALCOHOLIC AND DEALCOHOLIZED WINES

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Francine Henderson Hollis

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HUMAN PERCEPTION OF VAPOR-PHASE STIMULI PROVIDED BY ALCOHOLIC AND DEALCOHOLIZED WINES

Francine Henderson Hollis, Ph.D.
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Human perception of dealcoholized and alcoholic wine vapor-phase stimuli presented retronasally and orthonasally was determined by 57 participants using citation frequencies. Ariel Chardonnay concentrate (35.45%) and Ariel Rouge concentrate (35.19%) were provided by J. Lohr Vineyards & Wines from their reverse osmosis process. Concentrate (<0.5% alcohol by volume (abv)), distilled water, and Everclear® (95% abv grain alcohol) created 5 wine stimuli (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv). No significant differences resulted among qualitative wine descriptions. But, ethanol was found to enhance perceived floral and wood odor intensities retronasally and fruit and floral odor intensities orthonasally in Chardonnay wine. In Rouge wine, ethanol enhanced perceived fruit, spice, and vegetative odor intensities retronasally and earth, spice, and vegetative odor intensities orthonasally. Inverse response probability patterns regarding retronasal and orthonasal smelling found for caramelized, floral, and alcohol attributes in Chardonnay wine and animal, earth, and fruit attributes in Rouge wine indicate orthonasal and retronasal qualitative descriptions are not equivalent.

Animal and Earth attributes in Rouge wine could suppress synergistic effects of ethanol on vegetative and fruit attributes retronasally. The type of vapor-phase stimuli (i.e. fruit or spice) modified by ethanol could depend on specific ethanol concentration. Understanding the impact of ethanol on vapor-phase stimuli in real

wine can aid in the production of targeted wine aroma profiles and improve consumer acceptability of alcohol-removed and low alcohol content wines. Recognizing qualitative descriptions differ orthonasally and retronasally signifies that orthonasal wine evaluations should not be used to predict wine aroma profiles or investigate volatile interactions for food/ beverage products.

BIOGRAPHICAL SKETCH

Francine Henderson Hollis was born and raised in Huntsville, AL. It was in the 9th grade when she decided to pursue a career in Food Science. Once Francine graduated from James Oliver Johnson High School, she went to Alabama Agricultural and Mechanical University on a full academic scholarship. During her matriculation, she had the opportunity to conduct colon cancer research using blackberries, carrots, and mangoes and present research findings at the Institute of Food Technologists (IFT) Annual Meeting and Food Expo in 2005 and 2007. In addition, Francine has had the opportunity to conduct research on the anti-hypertensive effects of rice bran at the University of Arkansas (Fayetteville, AR) and investigate the impact of chemical treatments on gluten cloth quality at Cargill (Memphis, TN). She received a B.S. Degree in Food Science and Technology with a minor in Chemistry from Alabama Agricultural and Mechanical University in 2008.

When Francine was a Summer Scholar in the Cornell Food Science Department, she had the opportunity to conduct smell research involving human olfactory and trigeminal responses with her current advisor, Dr. Bruce P. Halpern. As a result, Francine's interest in Sensory Evaluation emerged and led her to pursue a Ph.D. in Food Science with a concentration in Sensory Evaluation.

Francine is currently a member of the Cornell Food Science Club, IFT, Western New York Section of IFT, Sensory and Consumer Sciences Division of IFT, National Scholars Honor Society, Phi Tau Sigma Honorary Society, Inc., Delta Sigma Theta Sorority, Inc., and the National Association for the Advancement of Colored People (NAACP). Not to mention, she has aided with departmental student recruitment efforts for graduate students in Ithaca, NY and high school students in Chicago, IL.

Francine looks forward to pursuing a career in academia to help mold future leaders and researchers and encourage others to be the best that they can be to reach their full potential.

I dedicate my dissertation to my husband, Rachad L. Hollis, and my parents, Arthur and Rose (Noel) Henderson. My research is dedicated to the wine industry and the Cornell Enology and Viticulture Program. I hope that my research provides some insight about ethanol's impact on human vapor-phase stimuli perceptions and contributes to the growing collection of knowledge and data regarding sensory and wine evaluations.

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RESEARCH OBJECTIVES

1. To find a stimulus delivery container capable of delivering wine vapor-phase stimuli retronasally and orthonasally.

2. To develop a methodology for wine vapor-phase stimuli administration retronasally and orthonasally.

3. To determine how ethanol impacts perceived wine vapor-phase stimuli qualitative descriptions provided by human participants for retronasal and orthonasal smelling.

CHAPTER 1

LITERATURE REVIEW

1.1 Climate Change Effects on Ethanol Production in Wine

Environmental changes regarding CO_2 concentrations, radiation shifts, and temperature fluctuations directly impact grape vine maturation consequently affecting grape wine production and quality (Mira de Orduña 2010). Excessive heat can cause premature véraison or grape ripening (Jones and others 2005) resulting with higher sugar concentrations possibly attributable to evaporative loss (Keller 2010). Elevated sugar concentrations yield higher ethanol concentrations (Mira de Orduña 2010). High ethanol concentrations can lead to stuck or incomplete malolactic fermentations which can impede wine aging subsequently altering sensorial attributes of wine (Lonvaud-Funel 1999).

Ethanol concentrations of Australian wines rose from about 12.3% abv to 14% abv between 1984 and 2004. In addition, California wines experienced a 2% increase in ethanol content from 1978 to 2001 (Rees 2006). Increased ethanol concentrations in wines may lead to shifts in wine styles (Jones and others 2005) in an effort to compensate for altered wine sensory attributes. Wines with ethanol concentrations higher than 13% abv to 15% abv have been criticized for undesirable wine attributes and have been described as "hot" (Mira de Orduña 2010).

Understanding the impact of ethanol on human perceptions of real wine attributes such as vapor-phase stimuli perceptions will enable wine producers to maintain wine quality under less than optimal climatic conditions and anticipate necessary process adjustments to improve wine sensorially.

1.2 Ethanol

1.2.1 Health Impact

Ethanol is absorbed mostly in the small intestine and, to a lesser extent, in the stomach (Koob and Le Moal 2006), mouth, and esophagus (Spotlight), and metabolized in the liver (Guenthner 2000; Koob and Le Moal 2006). Excessive consumption of ethanol can cause cirrhosis of the liver, pancreatitis, cancers, hypertension, psychological disorders (Fact Sheets), skeletal myopathy, cardiomyopathy (Guenthner 2000), brain cell death, Type II Diabetes, ulcers, malnutrition (Spotlight), and Fetal Alcohol Syndrome in unborn babies (Guenthner 2000). Although numerous health problems are associated with excessive or chronic ethanol consumption, low and moderate wine consumption may still increase the incidence of various cancers including breast, liver, and oral cavity (Allen and others 2009). Higher ethanol concentrations can prevent "digestive juice flow, the release of bile, and induce stomach spasms" (Jackson 2008). Not only does ethanol interfere with vitamin and mineral metabolism, but it also affects amino acid absorption (Spotlight). Furthermore, ethanol may counteract benefits of wine polyphenolics (Pal and others 2003).

Chronic ethanol consumption has been associated with sexual dysfunction (Peugh and Belenko 2001), low testosterone levels and sperm production (Emanuele and Emanuele 2001), feminization, and gynecomastia in men (Gordon and others 1979) while women have experienced sexual (Beckman and Ackerman 1995) and menstrual dysfunctions such as anovulation and early menopause (Hugues and others 1980).

1.2.2 Ethanol Removal From Wine

Wine dealcoholization can occur indirectly by decreasing fermentable sugar via grape juice dilution, utilization of unripe fruit, freeze concentration and fractionation, and enzymes, using low-ethanol producing yeast strains, or "arresting fermentation early" or directly by removing ethanol from wine. Indirect wine dealcoholization techniques can reduce wine flavor intensity, cause gustatory attribute imbalances, and elicit undesirable aromas. Furthermore, commercial wine producers typically use direct wine dealcoholization via thermal, membrane, adsorption, and/ or extraction methods to produce ethanol-removed wines (Pickering 2000).

Thermal processes such as distillation, evaporation, and freeze concentration can be used to dealcoholize wine. Distillation via evaporators or columns is the most popular thermal process. It is commonly used to concentrate fruit juices (Diban and others 2008). Recent advances and modifications such as performing distillation under a vacuum have permitted wine dealcoholization at significantly lower temperatures. A recent thermal process favored for energy efficiency that causes little heat damage and maintains non-volatiles such as minerals is the spinning cone column. Even though distillation techniques are time-intensive and expensive, they are one of the most utilized dealcoholization methods for commercial wine production (Pickering 2000).

Membrane processes such as dialysis and reverse osmosis are popular techniques because dealcoholization occurs within a low temperature range, 5°C to 10°C. Reverse osmosis is the most utilized wine dealcoholization process because hydrostatic pressure is used to separate water and ethanol from other wine components via a porous membrane. The porous membrane is not permeable to most dissolved wine components (Pickering 2000). However, some volatiles such as esters and aldehydes can diffuse with ethanol (Schobinger and others 1986; Villettaz 1986; Pickering 2000) which can alter the perceived wine aroma profile. Wine quality regarding the wine aroma profile and flavor intensity could be diminished if the concentration of wine volatiles in the resulting (dealcoholized) wine is different from the original wine (alcoholic). Not to mention, water must be added back to the resulting wine concentrate which can create legality issues in countries that prohibit water additions to wine (Pickering 2000). The latter can be resolved via a double reverse osmosis process (Bui and others 1986).

Resins such as styrol/ divinylbenzol copolymers and silica gels have been extensively utilized in laboratory research areas (Pickering 2000) such as chromatographic separation (Mousdale 2008). While resin and silica gel usage is less common for dealcoholization, they have been used in wine treatments such as clarification (27 CFR 24.246). Resin and silica gel usage stipulations according to the Code of Federal Regulations (27 CFR 24.248; 27 CFR 24.246) along with reports of resin effectiveness at low ethanol concentrations may explain why adsorption methods are not typically used. Nonetheless, there is interest by biofuel producers in the usage of adsorption methods throughout the fermentation process to optimize resin efficiency by preventing ethanol accumulation and be cost-effective (Mousdale 2008).

Direct, liquid-liquid, and high-pressure extraction may be used for wine dealcoholization. Direct extraction via organic solvents can cause heat damage and impart traces of solvent which can alter wine quality. Therefore, it is not used for commercial wine production. Liquid CO_2 has solvent properties at specific temperatures and pressures. So, it can be used for liquid-liquid and high-pressure extraction. But, subsequent temperature and pressure modifications are needed to precipitate ethanol and aroma compounds allowing for ethanol separation. The complexity of the latter extraction techniques proves to be very expensive (Pickering 2000). Extraction techniques may not be cost-effective if the demand for dealcoholized and/ or low alcohol content wines is low.

1.2.3 Ethanol-removed Wines

Dealcoholized wines which contain less than 0.5% abv (U.S. Food) have been on the market for over 20 years but have received less attention than alcoholic wines (Pickering 2000). Ariel Vineyards wines produced by J. Lohr Vineyards and Wines and Fre® wines produced by Sutter Home® Winery are a couple of dealcoholized wine brands that offer a variety of dealcoholized wines produced in the U.S. (Ariel Wines; Fre Info). J. Lohr Vineyards and Wines produces 7 types of dealcoholized wines available in 22 countries (Ariel Wines; About Ariel), and Sutter Home® Winery produces 7 types of dealcoholized wines (Fre Alcohol). Carl Jung Wines is an international company that exports 7 types of dealcoholized wines in 3 sizes to more than 25 countries (Jung).

Explicit research data for human perceptions of dealcoholized wines is lacking, but some wine connoisseurs and sensory panel participants feel that dealcoholized wines are not sensorially pleasing. While white dealcoholized wines have been reported to have greater consumer acceptance than red dealcoholized wines, the need for improvements in dealcoholized wine attribute qualities has been implied. Gustatory attribute imbalances and lack of mouthfeel, viscosity, and flavor have been reported (Cromley 2007). "White and sparkling de-alcoholized wines were bland to the point of being water-like; a red "no-alcohol" wine was outright disgusting, reeking of sulfur and rotting fruit" (Garr 2010). Despite sensorial deprivation, some apparent success of the dealcoholized wine market is evident by J. Lohr Wines and Vineyards who sold 1.2 million bottles of Ariel Vineyards wine in 2006 (Cromley 2007).

Statistical information is deficient for dealcoholized wine consumers, but dealcoholized wines and low alcohol content wines may serve as an alcoholic wine alternative for individuals who have health problems, medical conditions, and play sports. Dealcoholized wines may also be suitable for individuals who choose to refrain from ethanol consumption because of personal preference or religious reasons (Clarety; Cromley 2007).

1.3 Grape Wine

1.3.1 History

Grape wine, regardless of invention, was and still is an intricate part of many societies. Wine, viewed as a gift from gods (Estreicher 2006), "permeated all aspects of society" (Division): diet (Estreicher 2006), "literature, mythology, medicine, leisure, and religion." It even distinguished elite members of society from lower class members (Introduction).

Grape wine derivation had been debated due to the absence of a clear definition for wine composition and inadequate procedures for wine residue identification. Scientists questioned whether evidence of intentional grape wine production and storage should constitute wine. Apart from evidence of spontaneously fermented grapes, the Egyptians were recognized as the first to implement intentional grape wine production practices around 3000 B.C. Archeologists had found wine presses and amphorae containing wine residues in tombs belonging to Egyptian kings such as King Tutankhamun (Jackson 2008). However, a recent archaeological exhibition unearthed evidence of advanced vinification techniques in the Areni-1 cave complex dating back to 4000 B.C. (Kaufman 2011; Barnard and others 2011). The Areni-1 cave complex, located in Armenia, is now considered the earliest known site for intentional grape wine production (Kaufman 2011). A novel technique incorporating solid-phase extraction with alkaline treatment and liquid chromatography-tandem mass spectrometry confirmed chemical residue composition. Chemical residue was identified as malvidin, an anthocyanin found in red wine (Barnard and others 2011). Nevertheless, Egyptians provided the first written documentation of viticulture and enology practices (Introduction).

1.3.2 Grape Cultivars

Grape vines, members of the Vitaceae family, belong to the genus *Vitis* (Jackson 2008). *Vitis vinifera* subsp. *vinifera* is the standard domesticated grape cultivar. Vegetative propagation and cultivar crossings have produced an array of grape cultivars used in wine production today. The USDA grape germplasm collection contains at least 10,000 cultivar names (Alleweldt 1997), but only 583 distinct *vinifera* cultivars have been confirmed (Myles and others 2011).

While grape cultivars have been traditionally classified into different families, such classification has proven to be inaccurate. Recent research indicates that *vinifera* cultivars are actually interconnected and belong to one family. In fact, approximately 75% of the 583 *vinifera* cultivars possess first-degree relationships. Apparently, genetic variations have been minimal for *vinifera* grape vines since initial domestication. As control of grape vine genetic diversity has enabled quality wine production, the wine industry and grape vine sustainability will rely on grape vine breeding to overcome emerging grape vine threats such as pathogens in the future (Myles and others 2011).

1.3.3 Grape Still Table Wine Vinification

The predominant type of wine produced in the United States (U.S.) is grape still table wine. Grape still table wines are produced by vinification which involves ten imperative steps: harvesting, stemming, crushing, maceration, pressing, fermentation, maturation and clarification, finishing and stabilization, storage, and bottling. Grapes are harvested and kept cool to minimize flavor deterioration and preserve quality. Additions of sulfites may be used to halt flavor deterioration. "Stems, leaves, and stalks" are removed from grapes to prevent extraction of undesirable compounds (U.S. Environmental) attributed to phenolics and lipids (Jackson 2008) before crushing. Grapes are crushed via a perforated wall, rollers, or centrifugal force to initiate fermentation by a selected yeast strain introduced into the grape juice. Since yeast fermentation immediately starts, indigenous yeast and microbial contamination are minimized. Maceration is conducted to break down grape solids permitting compound extraction. Although most maceration results from crushing, some grape solids can be enzymatically broken down. Grape juice is extracted from the grape pomace which is composed of grape solids via a horizontal, pneumatic, or continuous screw press. Grape juice is fermented permitting glucose and fructose conversions (U.S. Environmental) by the yeast enzyme, zymase (Shakhashiri 2009), into alcohol and carbon dioxide (U.S. Environmental). It has been reported that fermentation stops once an ethanol concentration around 14% is attained (Jackson 2008; Shakhashiri 2009). However, the attainable ethanol concentration is dependent upon yeast strain type along with sugar content and fermentation temperature. Fermentation ends when an ethanol concentration too toxic for the yeast is attained (Jackson 2008). Higher ethanol concentrations can be obtained by the usage of genetically modified yeast strains (Jackson 2008) or fortification (U.S. Environmental). The resulting wine is matured via necessary wine adjustments such as particle precipitation, sweetening, blending, and dealcoholization. Wine can be clarified to remove wine particulate by racking, centrifugation, and filtration. Stabilization is conducted to age wine and prevent sediment formation. Finishing agents such as "activated charcoal, albumin, bentonite, casein, gelatin, kieselsol, isinglass, polyvinylpolypyrrolidone," and tannin can be used to precipitate suspended particles such as tartrates, proteins, and sugars to produce a permanently clear wine ready for bottling (U.S. Environmental).

Variation in the sequence of vinification steps regarding red and white grape cultivars occurs after maceration. White grape juice is extracted from grape solids before fermentation initiation to prevent undesirable compound extraction (U.S. Environmental).

1.3.4 Grape Wine Classification

Although grape wines can be classified as still, sparkling, or fortified for taxation purposes (Jackson 2002), they can be divided into two categories, table wines and dessert wines, based on ethanol concentration. Table wines have ethanol concentrations ranging from 7% abv to 14% abv and can be further divided into still and sparkling wines (U.S. Environmental) while dessert wines have ethanol concentrations in excess of 14% abv to 24% abv (GPO) and can be further separated into dry (unsweet) and sweet wines (U.S. Environmental). Since the conducted research involved still table wine, only still table wines will be discussed.

Still table wines can be categorized by color: red, white, and rosé (U.S. Environmental). Red still table wines are mostly dry with high tannin contents responsible for bitterness and astringency. Red still table wine quality improves with aging as the tannin content diminishes. Bitterness and astringency imbalances associated with young red still table wines can be reduced via food accompaniment. A few types of red grapes include: *Barbera*, *Pinot Noir*, *Zinfandel*, and *Syrah* (Jackson 2002). However, *Cabernet Sauvignon* is one of the most regarded red grapes (Jackson 2009).

Most white still table wines are dry and possess acidity. Fruity aromas are minimal because esters, responsible for fruity attributes, rapidly degrade. *Riesling, Chardonnay*, and *Sauvignon Blanc* are a few white grapes recognized for aging potential and are used to produce white still table wines with distinctive bouquets. As esters degrade, an aged bouquet emerges (Jackson 2009).

Since Rosé or blush still table wines are produced using red grape cultivars, they possess bitterness. As a result, rosé still table wines are produced as semi-sweet to eliminate bitterness imbalance (Jackson 2002).

1.3.5 Consumption

Despite negative correlations established for alcoholic beverages with domestic violence, poverty, addiction, illness, and unemployment (Prohibition; Leadley and others 2000; Li and others 2009; Mullahy and Sindelar 1996;

Mossakowski 2008), over 60% of Americans still continue to drink alcoholic beverages (Newport 2010). In comparison to other alcoholic beverages, wine has a higher social image. Wine has been positively correlated with social pleasures, desirable emotions (Lindman and Lang 1986), and food consumption (Pettigrew and Charters 2006) and negatively correlated with intoxication and ethanol-induced problems (Smart and Walsh 1999).

According to the Wine Institute, wine consumption in the U.S. has consecutively increased from 1993 until 2010. In fact, wine was the most preferred alcoholic beverage in 2005. An increase in the number of U.S. wineries resulted with at least one winery in each state (2010 California). Over 64% of U.S. grapes are used for commercial wine production (U.S. Wine). Consequently, the U.S. produced over 700 million gallons of wine in 2009 (US/ California) with California, Oregon, Washington, and New York as the leading wine-producing states (New York). "The U.S. surpassed France as the world's largest wine-consuming nation" (2010 California). An increase in U.S wine consumption and a decrease in U.S. beer consumption are indicative of the shift in American preference (Newport 2010).

1.3.6 Health Benefits

For millennia, many cultures have used wine to combat various health ailments. Wine has served as an "appetite stimulant, anesthetic, tonic, antiseptic, vasodilator, diuretic, antibacterial agent, and diaphoretic" (Gordetsky and others 2009). Recent interests in wine health benefits emerged, in part, because of the "French Paradox"- low prevalence of heart disease despite high saturated fat intake and smoking among French and Mediterranean populations (Novakovic and others 2010).

Wine polyphenolics have been found to elicit antioxidant, anti-inflammatory, and anti-microbial properties (Pal and others 2003; Mertens-Talcott and others 2008;

Jackson 2008; Covas and others 2010). Red wine polyphenolics such as resveratrol- a stilbene with greater antioxidant power than Vitamin E (Frankel and others 1993; Zern and Fernandez 2005), caffeic acid, gallic acid, quercitin, catechin, and proanthocyanidins, (Dell'Agli and others 2004; Covas and others 2010) were found to inhibit low-density lipoprotein oxidation (Santos-Buelga and Scalbert 2000) and prevent blood clotting (Jackson 2008). Wine has also been reported to reduce the risk of cardiovascular disease by decreasing hypertension, heart attacks, and peripheral arterial disease (Camargo and others 1997; Keil and others 1998; Mukamal and others 2006). Even though anti-inflammatory mechanisms are less understood, a reduction in the concentration of C-reactive protein, an inflammatory indicator, was observed. Arthritis symptoms of muscle spasms and swelling can also be minimized as a result of diuretic and muscle relaxation properties. Not to mention, the incidences of poliovirus, hepatitis A, and rhinoviruses were reduced, and pathogenic food contaminants such as *Escherichia*, *Shigella*, and *Vibrio* were inactivated (Jackson 2008). Despite wine's low vitamin and mineral composition, wine polyphenolics can help combat macular degeneration and cataracts (Fraser-Bell and others 2006), Alzheimer's disease (Luchsinger and others 2004), osteoporosis (Ilich and others 2002), and kidney stone formation (Curhan and others 1998). Lower incidence of Type II diabetes has also been reported (Dixon and others 2001).

Most wine health benefits have been highly correlated with red wine consumption, yet white wine contains antioxidants such as "caffeic acid, tyrosol, hydroxytyrosol, and shikimic acid" (Bertelli 2007). Although wine polyphenolic content is dependent upon grape cultivar, enological practices impact wine polyphenolic extraction (Corder and others 2006). White wine produced by fermentation with grape solids contact significantly increased total antioxidant capacity. The onset of white wine antioxidant action even proved to be faster than red wine antioxidant action. Furthermore, total antioxidant capacity of wine could be dependent on enological practices (Pinzani and others 2010).

Phenolic-enriched food/ beverage products such as Resveratrol WineTime Bar^{TM} (Resvez, Inc.), Nutra Resveratrol anti-aging water ^{TM} (Nutra), EVR ^{TM} Resveratrol Antioxidant Beverage (Preventive Beverages, L.L.C.), and stilbene-enriched wine (Guerrero and others 2010) emerged in response to research emphasis on wine polyphenolics, especially resveratrol. However, conflicting views of resveratrol are evident. Sirtris, a pharmaceutical company, has ended clinical trials investigating resveratrol. Resveratrol was considered to be an unsuitable drug because "it is hard to maintain a consistent level of resveratrol in the bloodstream and that it seems to have different effects at different doses." Accurate assessment of benefits attributed to resveratrol consumption may be difficult because its impact depends on tissue type and metabolism. Rather, interest in synthetic drugs that mimic resveratrol action has emerged (Wade 2011).

1.3.7 Sensory Evaluation

Three types of sensory evaluation techniques that can be used to evaluate food/ beverage products include: discrimination tests, descriptive analysis, and affective tests. Discrimination tests determine whether there are perceptual differences between products. Two discrimination tests that were used in conducted research are the triangle and difference paired comparison tests. For the triangle test, a set of 3 samples would be presented simultaneously to participants. Two samples would be the same, and one would be different. The objective for participants would be to either select the different sample or match the two similar samples. The probability for selecting a correct response due to chance is 1/3. For the difference paired comparison test, two samples would be simultaneously presented to participants. The 2 samples would either be the same or different. Thus, the objective for participants would be to determine whether or not the samples are the same or different. The probability for selecting a correct response due to chance is 1/2. The difference paired comparison test is less powerful than the triangle test in conveying product differences but is useful when products may have lingering effects or product supplies are limited (Lawless and Heymann 1998).

Discrimination testing should be conducted first to verify that perceptual differences exist between products. If no perceptual differences exist between products, then descriptive analysis and affective tests should not be conducted (Lawless and Heymann 1998). For the conducted research, discrimination testing was used to examine a participant's ability to recognize perceptual differences between wine vapor-phase stimuli.

When perceptual differences exist between products, descriptive analysis techniques such as Flavor Profile®, Quantitative Descriptive Analysis®, Texture Profile®, Sensory Spectrum®, and Free Choice Profiling can be used to determine specific product qualitative attribute differences. Descriptive analysis is important in product development and quality assurance (Lawless and Heymann 1998) and has been widely used to determine wine aroma profiles for Zinfandel, Chardonnay, Sauvignon Blanc, Cabernet Sauvignon, Shiraz, Pinot Noir, Parellada, etc (De La Presa-Owens and Noble 1995) and characterize wines by appellation (Fischer and Noble 1994). Non-volatile wine components such as polyphenolics have also been examined for gustatory and tactile input (Vidal and others 2004). Not to mention, enological treatments (Ortega-Heras and others 2002) and techniques such as oak aging and oxygenation have been investigated to determine sensorial impact (Koussissi and others 2009; Caillé and others 2010; and Cejudo-Bastante and others 2011).

Descriptive analysis incorporates 5 basic elements: product familiarization, term generation and reduction, participant training, panel monitoring, and product evaluation (Campo and others 2010). While term interpretation and intensity scale usage can be problematic for descriptive analysis implementation, such issues can be minimized with extensive participant training. Thus, descriptive analysis techniques prove to be expensive and time-intensive (Lawless and Heymann 1998; Campo and others 2008).

The application of traditional descriptive analysis to smell research involving complex vapor-phase stimuli evaluations is questionable. The basic assumption that vapor-phase stimuli perceptions can be described using independent qualitative descriptor attributes may be inaccurate for complex vapor-phase stimuli mixtures because humans can only identify 3 or 4 individual vapor-phase stimuli components. Often, complex vapor-phase stimuli mixtures are perceived as a single volatile or vapor-phase stimulus (Keller and Vosshall 2004). Furthermore, intensity scales may be inappropriate as humans have difficulty differentiating vapor-phase stimuli intensities (Lawless 1997, 1999). As a result, scientists have investigated sorting tasks and projective mapping techniques in conjunction with qualitative attribute descriptions to address such an issue. Sorting tasks and projective mapping techniques could serve as alternatives to traditional descriptive analysis but provide limited descriptive information (Lelièvre and others 2008; Perrin and Pagès 2009). Other emerging descriptive analysis techniques for olfactory research include the Flash Profile (Dairou and Sieffermann 2002) and Frequency of Citation (Campo and others 2008; Campo and others 2010; and Ballaster and others 2010).

Frequency of Citation has been used to characterize Chardonnay (McCloskey and others 1996; Le Fur and others 2003), Spanish (Campo and others 2008), and Burgundy red (Ballester and others 2010) wines. For Frequency of Citation, a list of qualitative descriptor attributes is generated for wine under investigation. Trained participants are asked to select the most pertinent qualitative descriptor attribute terms from the generated list of attributes to describe the wine. The quantity of selected qualitative descriptor attribute terms by participants is predetermined by the experimenter (Campo and others 2008).

Frequency of citation involves extensive participant training and a large attribute descriptor list which allows participants to "precisely describe their perception" (Campo and others 2010).

For the conducted research, a frequency of citation-based method was used. Participants would not receive extensive training since subjective evaluation of vapor-phase stimuli perceptions is the focal point. Rather, participants would receive exposure to pre-selected reference odors. Participant responses would be based on the provided reference odors.

The described methodology may potentially serve as an approach to obtain qualitative data subjectively as trained participants are used to obtain qualitative data objectively. Observed responses from trained participants may not be representative of consumer and/ or untrained-individual perceptions (Roberts and Vickers 1994), so a subjective approach is necessary. The objective for participants would be to select between 1 and 4 qualitative descriptor attribute terms that best convey vapor-phase stimuli perceptions.

Affective tests convey consumer opinions and perspectives regarding products (Lawless and Heymann 1998). Such tests will not be further discussed because they were not incorporated into the conducted research.

1.4 Olfaction

The term "smelling" will be used instead of "olfaction" because volatiles can activate olfactory and trigeminal receptors (Halpern 2004).

1.4.1 Oral Smelling

Oral smelling occurs when vapor-phase stimuli provided by foods/ beverages are held in the oral cavity. Gustation, oral chemesthesis, and oral mechanical stimulation are involved. Oral smelling has been investigated in efforts to better understand drinking of beverages and mastication of foods (Halpern 2004).

1.4.2 Orthonasal Smelling

Orthonasal smelling occurs when vapor-phase stimuli are inhaled through one's anterior nares (Halpern 2004). It aids in volatile identifications and determinations of changes in volatile concentrations (Spors and Grinvald 2002). Orthonasal thresholds have been reported to be lower than retronasal thresholds (Heilmann and Hummel 2004). Not to mention, different airflow patterns for orthonasal and retronasal smelling have been observed (Halpern 2008).

1.4.3 Retronasal Smelling

Retronasal smelling occurs when vapor-phase stimuli are inhaled into one's oral cavity and, with the mouth closed, expired air is exhaled through the anterior nares. Gustatory, oral chemesthesis, and oral mechanical stimulation are not involved (Halpern 2004). Electrophysiological experiments have confirmed that retronasal vapor-phase stimulation leads to lower activation of the olfactory system (Hummel and others 2006). In fact, retronasal vapor-phase stimuli concentrations are approximately 1/8 of orthonasal vapor-phase stimuli concentrations (Linforth and others 2002). Thus, retronasal vapor-phase stimuli identifications are more difficult than orthonasal vapor-phase stimuli identifications which are indicative by lower correct response rates for retronasal vapor-phase stimuli identifications (Pierce and Halpern 1996).

1.4.4 Wine Volatiles

Wine contains approximately 1 gram of volatiles/ liter of wine (Schobinger and others 1986; Jackson 2008). Many volatiles with concentrations below the human detection threshold do not individually contribute sensorial input. However, such volatiles may collectively impart sensorial significance (Jackson 2008).

Wine aromas are mostly attributed to fusel alcohols, volatile acids, and fatty acid esters. Fusel alcohols, primarily yeast by-products, can be extremely pungent at high concentrations producing off-odors (Jackson 2009). Lower concentrations can yield fruit qualitative attributes (Swiegers and others 2005). Hexanols are an exception because they possess vegetative qualitative attributes. While ethanol is not a fusel alcohol, it is related to fusel alcohols and has a distinct odor (Jackson 2002, 2009).

Volatile acids are associated with off-odors such as rancid, goaty, and fatty. Acetic acid is the most common volatile acid (Yang and Choong 2001). At low concentrations it can enhance wine aroma (Jackson 2009).

Although aldehydes possess oxidized qualitative attributes such as vanilla and caramel, most ketones have no sensory significance except diacetyl. Acetaldehyde is the dominant wine aldehyde considered to be an off-odor at high concentrations (Jackson 2009). Other aldehydes such as cinnamaldehyde and vanillin can be found in oak-aged wines as a result from lignins (Rapp and Mandery 1986).

Esters, produced by yeast (Jackson 2002), have fruity odors. Over 160 esters have been identified in wine. While most esters have low volatility (Jackson 2009), common esters like ethyl acetate, isoamyl acetate, isobutyl acetate (Swiegers and others 2005) and benzyl acetate are key impact odorants. Their impact is short-lived because of rapid degradation during wine aging. Qualitative descriptions of esters change as the hydrocarbon chain-length of esters increases. Qualitative descriptor attributes transition from fruit to soap to lard (Jackson 2009).

Hydrogen sulfide, a yeast metabolism by-product, and organosulfur compounds such as mercaptans have unpleasant odors. At high concentrations, hydrogen sulfide smells like a rotten egg (Jackson 2009). Organosulfur volatiles have unpleasant qualitative descriptor attributes such as cabbage, onion, and rubber (Mestres and others 2000). Organosulfur volatile concentrations in bottled wine increase with light exposure (Jackson 2009).

Other volatile derivatives include terpenes, phenolics, and pyrazines (Jackson 2009). Terpenes possess qualitative descriptor attributes like floral, camphoraceous, and herbaceous (Marais 1983). Phenolics provide spicy, pharmaceutical, and animal qualitative descriptor attributes. Pyrazines elicit herbaceous qualitative descriptor attributes such as bell pepper (Jackson 2009).

1.4.5 Olfactory Perception

Techniques such as "gas chromatography, thin-layer chromatography, high-performance liquid chromatography, droplet countercurrent chromatography, infrared spectroscopy, solid-phase microextraction, and nuclear magnetic resonance spectroscopy" along with mass spectrometry have aided in the identification (Hayasaka and others 2005) of approximately 800 wine volatiles (Rapp 1998). The detection threshold for a volatile refers to the concentration at which the volatile is just noticeable. Human sensitivity to volatiles can vary over 10 orders of magnitude. For example, ethane can be detected at 2×10^{-2} M while mercaptans can be detected at 10^{-10} - 10^{-12} M (Jackson 2009).

One problem associated with analytical techniques that attempt to identify volatiles with sensory significance is that instrument sensitivity may not be sufficient for impact volatiles at low concentrations (Acree and others 1994; Blank 1997). As a result, gas chromatography-olfactometry (GC-O) approaches have evolved (Acree and others 1994). A few types of GC-O approaches that incorporate human perceptions include: detection frequency (Linssen and others 1993), posterior intensity (Casimir and Whitfield 1978), time-intensity (Sanchez and others 1992), and dilution analysis

(Acree and Barnard 1984; Ullrich and Grosch 1987). For such approaches, participants smell wine vapor-phase stimuli from a gas chromatography column and evaluate qualitative descriptor attributes (Van Ruth 2001).

One factor that affects olfactory thresholds is the solvent. An ethanol concentration of 10% abv increased the detection threshold of ethyl isobutanoate (Guth and Sies 2002) while lower ethanol concentrations decreased detection thresholds of some esters (Guth 1998). Escalona-Buendia and others (1999) and Conner and others (1998) reported reductions in the volatility of fusel alcohols, aldehydes, and esters in higher ethanol concentrations.

Besides solvent, volatility of wine volatiles can be affected by non-volatile components such as sugars, oils, polyphenolics (Sorrentino and others 1986; Roberts and others 2003; Aronson and Ebeler 2004), and proteins (Lubbers and others 1994). Sugars influence the release of esters and alcohols (Dufour and Bayonove 1999a) while polyphenolics release esters and aldehydes (Dufour and Bayonove 1999b). In addition, mannoproteins decreased the volatility of ethyl hexanoate and octanal and increased the volatility of ethyl octanoate and ethyl decanoate (Lubbers and others 1994).

CHAPTER 2

LOW-DENSITY POLYETHYLENE SQUEEZE BOTTLE ASSESSMENT FOR WINE VAPOR-PHASE STIMULI DELIVERY

2.1 INTRODUCTION

Qualitative wine descriptions for gustatory and olfactory attributes are typically obtained by human participants using descriptive analysis techniques (Heymann and Noble 1989; Varela and Gámbaro 2006; Cardello and Wise 2008; Carlucci and Monteleone 2008). Such techniques involve qualitative descriptor generation, participant training, and wine evaluations (Campo and others 2010). Participants evaluate wine vapor-phase stimuli orthonasally followed by wine flavor (Aubry and others 1999; Peña Y Lillo and others 2005; Ballester and others 2005) using a glass delivery container such as a wine glass (Lawless 1984; Vilanova 2006; Ballester and others 2008; Buettner and others 2008; Campo and others 2008; Carlucci and Monteleone 2008; Diban and others 2008; Cortés and others 2009; Meillon and others 2009).

Flavor is comprised of two sensory modalities, olfaction and gustation, along with chemesthesis (Laing and Jinks 1996) and results from direct oral cavity contact with foods/ beverages such as wine. When vapor-phase stimuli are perceived as a result of a food/ beverage being held in the oral cavity, such perception is termed as "oral smelling." As previously mentioned, retronasal smelling only involves volatile stimulation. It is not "accompanied by oral gustatory or thermal stimulation and with minimal oral mechanical stimulation" (Halpern 2004). Wine flavor evaluations are not equivalent to retronasal wine evaluations. So, wine flavor evaluations that have been described as retronasal evaluations (Aubry and others 1999; Peña y Lillo and others 2005) should not be termed as such but as "oral" evaluations.

Olfactory perception can be influenced by other sensory modalities (Keller and Vosshall 2004) such as gustation (Murphy and others 1977; Murphy and Cain 1980; Cardello and Wise 2008). Increased sweetness via sugar (Von Sydow and others 1974; Perng and McDaniel 1989; Stevenson and others 1995) or aspartame (Bonnans and Noble 1993) enhances perceived fruity and pleasant vapor-phase stimuli intensities while minimizing perceived unpleasant vapor-phase stimuli intensities. Not to mention, increased sourness by acids such as citric and malic acid minimizes perceived fruity vapor-phase stimuli intensities (Perng and McDaniel 1989; Stevenson and others 1995). It should be noted that McBride and Johnson (1987) reported enhanced fruity vapor-phase stimuli intensities for sugar-acid mixtures.

Gustatory impact on olfactory perception may be attributed to a halo effect which entails that an increase in one pleasant food/ beverage attribute will increase the degree of pleasantness of other pleasant attributes. If a pleasant food/ beverage attribute decreases, the degree of pleasantness for other pleasant attributes will be minimized (Lawless and Heymann 1998).

Since a wine glass does not permit retronasal wine vapor-phase stimuli evaluations, an alternative delivery container is needed. A potential wine glass alternative would be a low-density polyethylene squeeze bottle. Squeeze bottles have been commonly used to deliver vapor-phase stimuli to the nasal cavity in smell research (Wysocki and Beauchamp 1984; Olsson and Cain 2000; Cometto-Muñiz and others 2003; Lundström and others 2006), determine volatile (Lund and Scadding 1994) and nasal pungency thresholds (Cometto-Muñiz and others 2000), and conduct lateralization (Lundström and Hummel 2006; Frasneli and others 2008) and localization tests (Frasneli and others 2008).

2.2 OBJECTIVE

Research was conducted to investigate the wine vapor-phase stimuli administration potential of a 118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap and develop a methodology for wine administration to be used in subsequent wine vapor-phase stimuli evaluations.

2.3 HYPOTHESIS

Wine vapor-phase stimuli administered in a 118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap would be perceived retronasally and orthonasally.

2.4 PARTICIPANTS

Participants were recruited on Cornell University's campus using SUSAN (http://susan.psych.cornell.edu), a program sponsored by Cornell's Department of Psychology which displays research studies on-line. Research studies on SUSAN may offer students extra credit for a course or monetary compensation for participation. Recruitment was also conducted using recruitment posters (See Figure A.1 for a recruitment poster replica). All information placed on SUSAN and recruitment posters was approved by Cornell University's Institutional Review Board for Human Participants (IRBHP).

All participants had to be at least 21 years old, healthy, neither pregnant nor lactating, a non-smoker, and an American English communicator. Prior to any wine evaluation, each potential participant read and signed a consent form approved by the IRBHP. After informed consent was obtained, each participant was questioned as to whether or not he or she was experiencing nasal congestion and given an odorant recognition test. The study contained a total of 33 participants (14 males; 19 females) ranging in age from 21 to 32 years of age (Mean Age = 22.2 years of age, SD = 2.6 years).

2.5 MATERIALS

2.5.1 Stimuli

Three flavor extracts were used for the odorant recognition test: orange (67%), peppermint (33%), and coffee (65%). Orange (QAI Certified Organic, KSA Certified), peppermint (KSA Certified), and coffee (KSA Certified) flavor extracts were purchased from Frontier™ Natural Products Co-op (Norway, IA). Specified orange and peppermint flavor extract concentrations were prepared by dilution with organic expeller pressed high heat sunflower oil (Spectrum® Naturals, Inc. a subsidiary of the Hain Celestial Group, Inc., Boulder, CO). The specified concentration of coffee flavor extract was attained by dilution with U.S.P-F.C.C.-grade glycerin (CAS # 56-81-5) purchased from Mallinckrodt Baker, Inc. (Phillipsburg, NJ). Orange, peppermint, and coffee flavor extracts were selected because of their previous usage in olfactory research (Sun and Halpern 2005; Dragich and Halpern 2008; and Stephenson and Halpern 2009).

The wine stimuli used to evaluate the wine vapor-phase stimuli administration potential of a 118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap included Ariel 2008 Chardonnay Premium Dealcoholized Wine (<0.5% abv) and Ariel 2007 Merlot Premium Dealcoholized Wine (<0.5% abv) produced by J. Lohr Vineyards and Wines and purchased at retail.

Five milliliters of the appropriate flavor extract or wine stimulus was presented to participants in a squeeze bottle. The specified quantity, 5mL, was selected based on preliminary laboratory research involving squeeze bottles.

2.5.2 Squeeze Bottle Delivery Container

A 118.29mL low-density polyethylene Boston Round squeeze bottle (#41580) with a white 24mm flip-top cap (#412141) purchased from Consolidated™ Plastics (Stow, OH) was used to present flavor extracts and wine stimuli. Each squeeze bottle was wrapped with a rectangular piece of aluminum foil (Reynold’s Wrap® Aluminum Foil, Richmond, VA), 11.3cm x 16.4cm. A small piece of double-sided tape (12.7mm x 11.4m, Target Corporation, Minneapolis, MN) was placed on one of the foil's shorter axes. Two additional pieces of double-sided tape were placed equidistant from each other on the foil's other short axis. The squeeze bottle was laid parallel on the foil's short axis with one piece of tape and wrapped. Foil was compressed around the neck of the squeeze bottle and smoothed underneath the bottom of the bottle. Aluminum foil eliminated any visual input capable of affecting vapor-phase stimuli evaluations. Squeeze bottles were also labeled with randomly selected 3-digit code numbers generated via a random number table (http://ts.nist.gov/WeightsAndMeasures/upload/AppenB-HB133-05-Z.pdf). Squeeze bottles used by each participant were discarded at the end of his or her session.

2.5.3 Nose clips

Disposable, latex-free nose clips (D-1060-2/ Former Part #2110) purchased from Spirometrics (Gray, ME) were used by participants for oral-cavity-only (OCO) and/ or retronasal wine vapor-phase stimuli evaluations. Each nose clip was used by only one participant and discarded at the end of his or her session.

2.6 METHODS

2.6.1 Participant Training

Each participant received training in the form of a practice trial on how to use a squeeze bottle for OCO, retronasal smelling, and orthonasal smelling. For the practice trial, the experimenter provided directions verbally followed by a non-verbal demonstration for the specified method. Once the experimenter presented directions and a non-verbal demonstration, the participant demonstrated the method. Any participant questions regarding the demonstrated method were answered, and the experimenter proceeded to the next method. The described procedure was repeated until participant demonstrations for all methods (i.e. OCO, retronasal smelling, and orthonasal smelling) had been executed.

2.6.2 Participant Instructions for OCO

The OCO methodology was adapted from previous laboratory research involving squeeze bottles. OCO is used to restrict vapor-phase stimuli to the oral cavity. Since the oral cavity does not have olfactory innervation, OCO can be used to prevent olfactory stimulation and/ or investigate trigeminal stimulation produced by vapor-phase stimuli (Chen and Halpern 2008).

For OCO, each participant put on his or her nose clip. He or she opened the flip portion or spout of the squeeze bottle top and placed it in his or her mouth. (The participant was not allowed to tilt the squeeze bottle horizontally because wine stimulus contact with the oral cavity and ingestion were prohibited.) With lips closed around the squeeze bottle top spout, the participant squeezed the bottle twice and removed it from his or her mouth. He or she breathed normally through his or her mouth keeping the nose clip in place.

2.6.3 Participant Instructions for Retronasal Smelling

The procedure for retronasal smelling was established from prior laboratory research using squeeze bottles. Retronasal smelling directions began with each participant inhaling and putting on his or her nose clip. He or she opened the flip portion of the squeeze bottle top and placed it in his or her mouth. (The participant was not allowed to tilt the squeeze bottle horizontally because wine stimulus contact with the oral cavity and ingestion were prohibited.) With lips closed around the squeeze bottle top spout, the participant squeezed the bottle twice and removed it from his or her mouth. Keeping lips closed, the participant removed the nose clip and breathed normally through his or her nose.

2.6.4. Participant Instructions for Orthonasal Smelling

The orthonasal smelling methodology was acquired from previous laboratory research involving squeeze bottles. For orthonasal smelling, the participant opened the flip portion of the squeeze bottle top and placed it just outside one of his or her nostrils. (In order to prevent physical contact with the wine stimulus, the participant was not allowed to tilt the squeeze bottle horizontally.) He or she squeezed the bottle twice while inhaling. The bottle was removed, and he or she breathed normally through his or her nose.

2.6.5 Procedure

All stimuli were prepared in the Olfaction Wet Laboratory, stored at 5.5°C in the Olfaction Laboratory, and evaluated in the Retronasal Laboratory at 21 ± 1°C. All laboratories are located in Uris Hall on Cornell University's campus.

For the odorant recognition test, 3 flavor extracts (i.e. 67% orange, 33% peppermint, and 65% coffee) were presented orthonasally to each participant. The objective for each participant was to select the appropriate qualitative description for the presented flavor extract from a list of 4 descriptor terms: coffee, orange, peppermint, and strawberry. All flavor extracts were evaluated individually by each participant 1 time. Each participant was allowed to re-smell the presented flavor extract if needed. The flavor extract presentation order was randomized among all participants. An incorrect response by a participant for the odorant recognition test did not prevent subsequent participation in wine vapor-phase stimuli evaluations.

Once the odorant recognition test was completed, each participant was presented with a tray which contained an empty squeeze bottle, a nose clip, and squeeze bottles containing wine stimuli (See Figure 2.1 for tray layout). The participant was told that he or she would be asked to smell wine using 3 methods: oral-cavity-only, retronasal smelling, and orthonasal smelling. Each participant was asked whether or not he or she had ever heard of retronasal and orthonasal smelling. Regardless of whether or not the participant had heard of retronasal and orthonasal smelling, the 2 methods were defined. Retronasal smelling was described as inhaling through the mouth and exhaling through the nose. Orthonasal smelling was described as inhaling through the nose. (OCO was not defined at this point.) Each participant was told that he or she would complete 4 trials. For each trial, he or she would be given a wine sample to smell using OCO, retronasal smelling, and orthonasal smelling. Each participant was told that there would be a 2-minute break in between trials. Each participant was told that he or she would receive a practice trial (See Section 2.6.1) before actual wine evaluations.

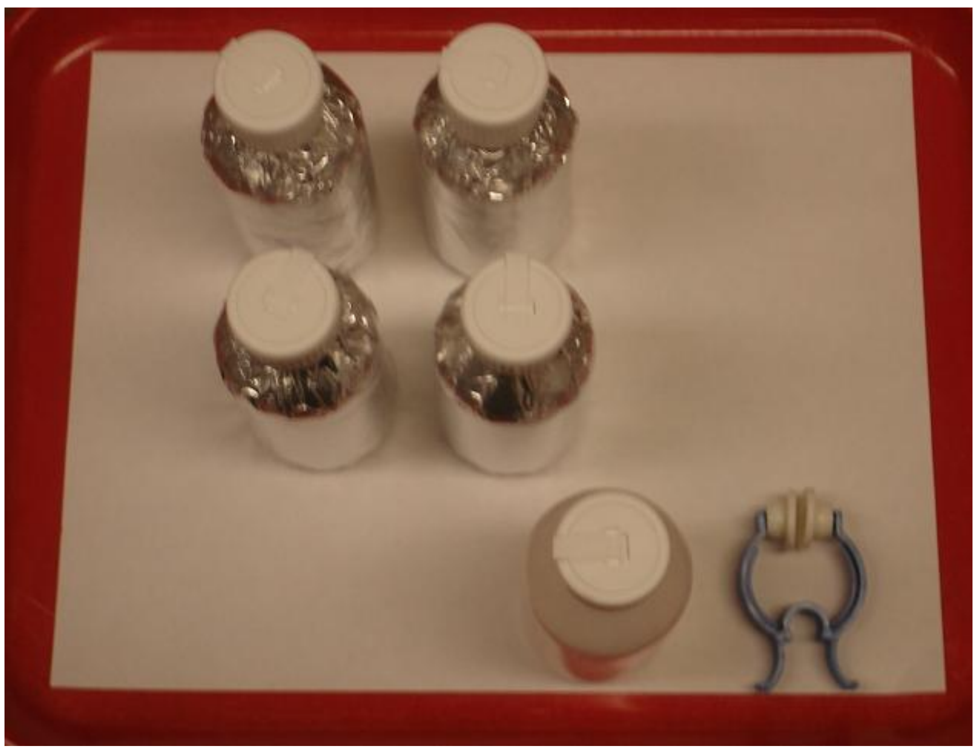


Figure 2.1: Tray Layout for Chardonnay and Merlot Wine Evaluations.

After the practice trial, participants received 2 paper ballots for Chardonnay and Merlot wine vapor-phase stimuli evaluations. The first ballot format, Ballot 1 (See Figure A.2), asked participants to write qualitative descriptions of what he or she smelled. The second ballot format, Ballot 2 (See Figure A.3), asked participants to select appropriate category descriptor terms to convey what he or she smelled and also provided the option for participants to write descriptions. Trials 1 and 2 were conducted using Ballot 1 while Trials 3 and 4 were completed using Ballot 2. The experimenter explained the objective for wine evaluations to each participant again and explained how to use Ballot 1. Each participant was reminded that experiment instructions along with OCO, retronasal smelling, and orthonasal smelling instructions were provided on the ballot. Once Trial 1 was completed, each participant was given a 2-minute break to allow olfactory acuity to be re-established. The participant then proceeded to Trial 2. Once Trial 2 was conducted, the experimenter explained to the participant how to use Ballot 2. The described procedure was repeated until Trials 3 and 4 were completed. Chardonnay and Merlot wine vapor-phase stimuli were evaluated 1 time via OCO, retronasal smelling, and orthonasal smelling for Ballot 1 and Ballot 2.

The sequence of wine administration methods for all participants consisted of OCO, retronasal smelling, and orthonasal smelling. Wine stimuli presentation order was randomized across all participants.

After wine vapor-phase stimuli evaluations were completed, each participant's familiarity and consumption frequency of grape juice, wine, and dealcoholized wine were indicated via Likert-scale items (See Figure A. 4) with 5 response options. The 5 response options for Likert-scale items regarding participant familiarity consisted of: strongly agree, agree, undecided, disagree, and strongly disagree. For Likert-scale items pertaining to participant consumption frequency, the response options were: very frequently, frequently, occasionally, rarely, and never.

2.7 DATA ANALYSIS

2.7.1 Odorant Recognition Test

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether vapor-phase stimuli recognitions occurred above chance level.

2.7.2 Wine Evaluations

Descriptive statistics were used to graphically display collected data.

2.7.3 Product Familiarity and Consumption

Descriptive statistics were used to graphically display collected data.

2.8 RESULTS

2.8.1 Odorant Recognition Test

All 33 participants gave correct responses for the 3 flavor extracts (67% orange, 33% peppermint, and 65% coffee) presented orthonasally. The calculated z-score for each odorant was determined to be 9.749 ($p < 2.9 \times 10^{-7}$). As a result, there was sufficient evidence to conclude that vapor-phase stimuli recognitions were not due to chance.

2.8.2. Wine Evaluations

Participant responses for OCO, retronasal, and orthonasal Chardonnay wine vapor-phase stimuli evaluations can be seen in Table A.1. For OCO, 15.15% of participants reported smelling Chardonnay wine vapor-phase stimuli for Ballot 1 while 3.03% of participants reported smelling Chardonnay wine vapor-phase stimuli in Ballot 2. For retronasal smelling, 54.55% of participants smelled Chardonnay wine vapor-phase stimuli for Ballot 1 while 66.67% of participants smelled Chardonnay wine vapor-phase stimuli for Ballot 2. For orthonasal smelling, all participants reported smelling Chardonnay wine vapor-phase stimuli for Ballot 1 and Ballot 2.

Participant responses for OCO, retronasal, and orthonasal Merlot wine vapor-phase stimuli evaluations can be seen in Table A.2. For OCO, 6.06% of participants reported smelling Merlot wine vapor-phase stimuli for Ballot 1 while 9.09% of participants reported smelling Merlot wine vapor-phase stimuli for Ballot 2. For retronasal smelling, 60.61% of participants reported smelling Merlot wine vapor-phase stimuli for Ballot 1 while 69.70% of participants smelled Merlot wine vapor-phase stimuli for Ballot 2. For orthonasal smelling, 96.97% of participants reported smelling Merlot wine vapor-phase stimuli for Ballot 1 while all participants smelled Merlot wine vapor-phase stimuli for Ballot 2.

Percentages of participant responses for each qualitative descriptor category regarding Chardonnay wine can be seen in Figure 2.2. The most frequently used qualitative descriptor categories for Chardonnay wine were fruit (21.88%), sweet (22.92%), and wood (14.58%) for Ballot 1 and fruit (18.58%), sweet (23.01%), and chemical (16.81%) for Ballot 2. The Chardonnay wine aroma profile was composed of qualitative descriptor attributes such as grape, orange, cherry, chocolate, caramel, coffee, oak, vanilla, and alcohol (See Table A.3).

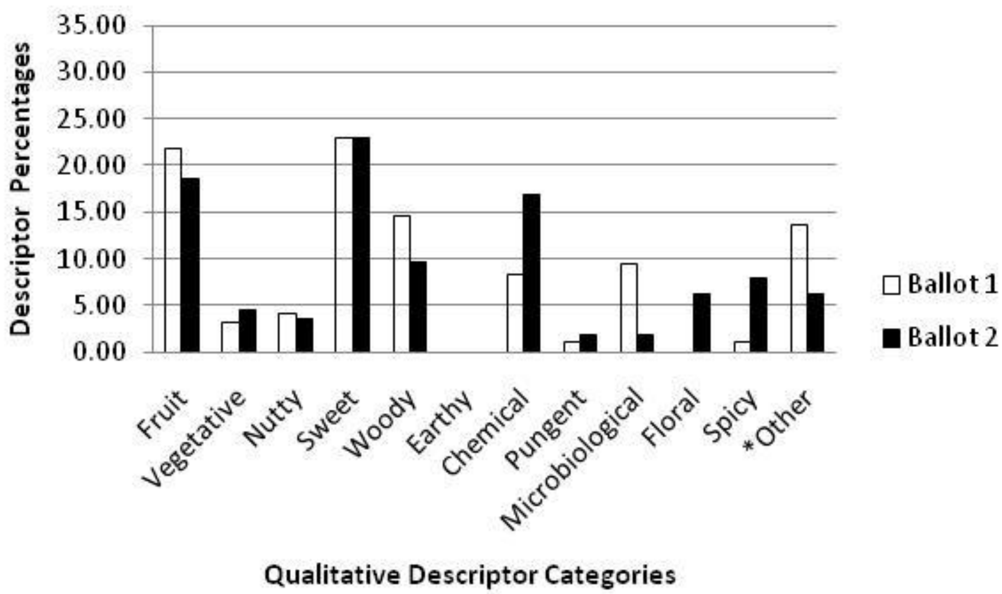


Figure 2.2: Response Percentages for Chardonnay Wine Qualitative Descriptor Categories.
** The term "Other" is not considered a qualitative description.*

Figure 2.3 shows percentages of participant responses for each qualitative descriptor category for Merlot wine. The most frequently used qualitative descriptor categories for Merlot wine were fruit (31.33%), sweet (20.48%), and wood (10.48%) for Ballot 1 and fruit (26.56%), sweet (17.97%), and chemical (19.53%) for Ballot 2. The aroma profile for Merlot wine consisted of qualitative descriptor attributes such as grape, apple, caramel, chocolate, coffee, oak, and alcohol (See Table A.3).

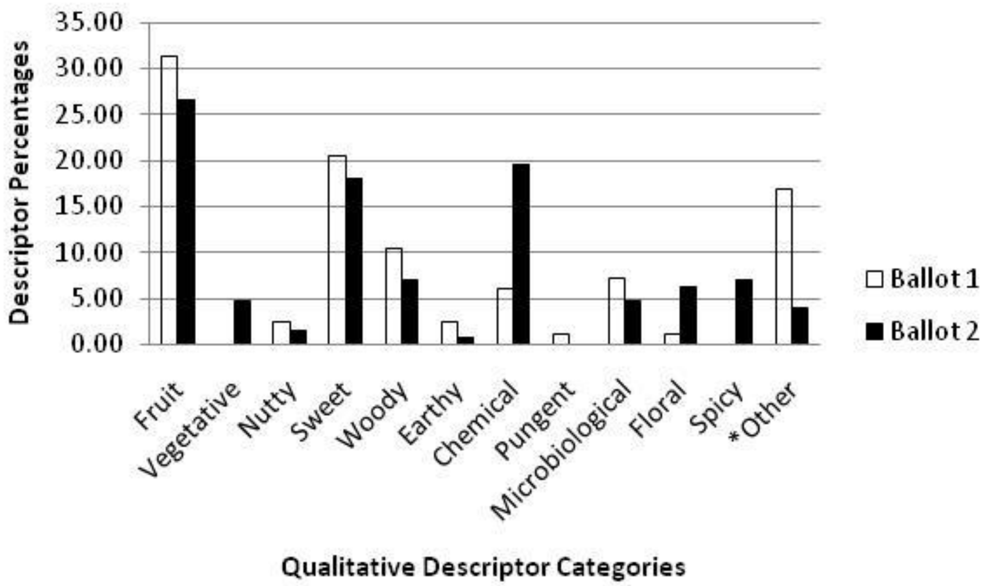


Figure 2.3: Response Percentages for Merlot Qualitative Descriptor Categories.
** The term "Other" is not considered a qualitative description.*

2.8.3 Product Familiarity and Consumption

Figure 2.4 shows participant familiarity with grape juice, wine, and dealcoholized wine. Approximately 85% of participants were familiar with grape juice. Participant familiarities with red and white wines were very similar. Approximately 54% of participants were familiar with red wine while about 58% of participants were familiar with white wine. Participant familiarity with dealcoholized wine was low. Only approximately 20% of participants were familiar with dealcoholized wine.

Figure 2.5 shows participant consumption frequency of grape juice, wine, and dealcoholized wine. Approximately 6% of participants drank red grape juice regularly while no participants drank white grape juice on a regular basis. As for wine, about 20% of participants drank red wine regularly compared to roughly 40% of participants who drank white wine regularly. Only 3% of participants drank red dealcoholized wine while no participants drank white dealcoholized wine regularly. In fact, about 75% of participants never drank white dealcoholized wine.

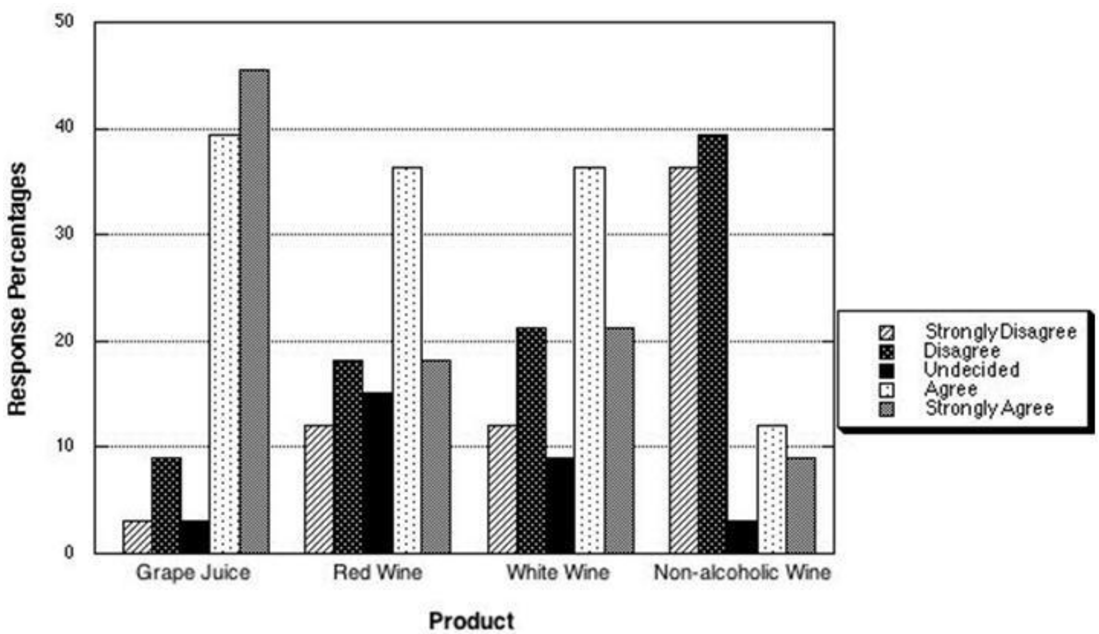


Figure 2.4: Response Percentages for Participant Familiarity with Grape Juice, Wine, and Non-alcoholic (N/A) (Dealcoholized) Wine.

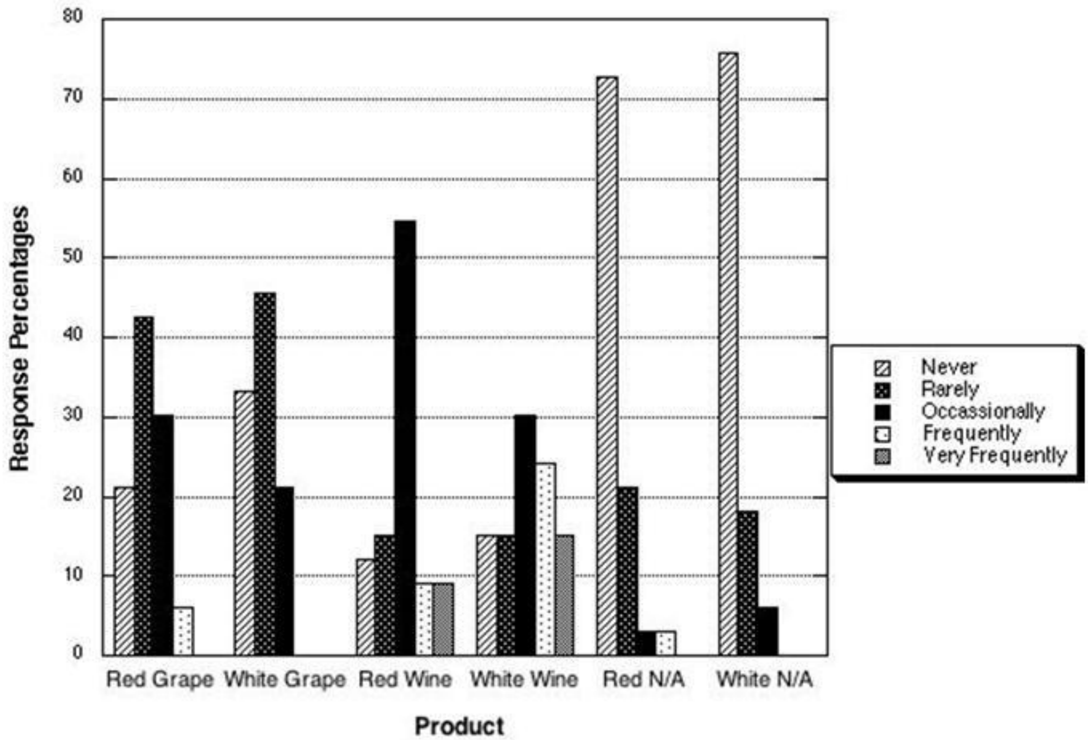


Figure 2.5: Response Percentages for Participant Consumption Frequency of Red and White Grape Juice, Red and White Wine, and Red and White Non-Alcoholic (N/A) (Dealcoholized) Wine.

2.9 DISCUSSION

2.9.1 Odorant Recognition Test

Vapor-phase stimuli familiarization and/ or identification training for flavor extracts was not provided prior to the odorant recognition test. Correct qualitative descriptions by all participants indicated that the 3 selected flavor extracts (67% orange, 33% peppermint, and 65% coffee) were familiar, and participants were not experiencing sufficient nasal congestion to prevent odorant recognitions. Therefore, no relationship between nasal congestion and odorant recognitions was established.

2.9.2 Wine Evaluations

Since olfaction should not occur for OCO, such data were not used to determine qualitative wine descriptions. Participants who indicated smelling wine vapor-phase stimuli presented as OCO could have been responding to trigeminal stimulation. It is also possible that the nose clip used by such participants was not effectively positioned to prevent volatile stimulation in the nasal cavity.

Percentages of reported orthonasal smelling were higher than retronasal smelling which was to be expected. Since the concentration of retronasal vapor-phase stimuli is approximately 1/8 of the orthonasal vapor-phase stimuli concentration (Linforth and others 2002), retronasal detection thresholds have proven to be higher than orthonasal detection thresholds (Heilmann and Hummel 2004).

The two different ballot formats (i.e. Ballot 1 and Ballot 2) used for wine vapor-phase stimuli evaluations yielded similar response patterns for some qualitative descriptor categories regarding Chardonnay and Merlot wine. Participant responses for fruit, nutty, woody, and microbiological qualitative descriptor attributes were higher when participants provided their own qualitative descriptions (Ballot 1) as opposed to selecting appropriate qualitative descriptor categories from a list (Ballot 2). Participant responses for vegetative, chemical, floral, and spicy qualitative descriptor attributes increased when participants were provided a list of qualitative descriptor categories to choose from (Ballot 2).

Although it is often very difficult for untrained panelists to provide qualitative descriptions (Keller and Vosshall 2004), attributes selected by participants indicate that wine vapor-phase stimuli could be perceived from a 118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap. According to J. Lohr Vineyards and Wines, the Ariel Chardonnay wine aroma profile is composed of "buttery apple and butterscotch characteristics, combined with a toasty French oak bouquet" (Chardonnay) while the Ariel Merlot wine aroma profile consists of "cherry, raspberry and cassis, combined with a white chocolate, clove and oak bouquet from barrel aging" (Merlot). Some qualitative descriptor attributes such as oak for Chardonnay wine and chocolate and oak for Merlot wine corresponded with expected wine aroma profiles. However, qualitative descriptor attributes such as apple and cherry did not coincide with expected wine aroma profiles. "Apple" was used to describe Merlot wine more than Chardonnay wine, and "Cherry" was used to describe Chardonnay wine more than Merlot wine. Despite discrepancies between some observed and expected qualitative descriptor attributes, the use of the squeeze bottle to deliver wine vapor-phase stimuli is still promising since qualitative descriptor attributes were perceived.

Specific qualitative descriptor attributes conveyed by participants are questionable and conclusions should be drawn with caution regarding Chardonnay and Merlot wine aroma profiles since untrained participants may have difficulty verbalizing qualitative vapor-phase stimuli perceptions (Keller and Vosshall 2004). Not to mention, participant responses can be variable. Chapman and Lawless (2005) found that in repeated preference tests only 56% of participants selected the same answer for a given product. In addition, more than 50% of participants identified similar samples as different. Since participant qualitative descriptions were highly variable, distinct response patterns based on gender were not observed.

2.9.3 Product Familiarity and Consumption

Even though about 85% of participants were familiar with grape juice, regular grape juice consumption was very low; only 3% of participants drank red grape juice on a regular basis, and no participants drank white grape juice regularly. Participant familiarity with both red and white wine was extremely similar. However, twice as many participants consumed white wine on a regular basis than red wine. Participant unfamiliarity with dealcoholized wine was evident by low dealcoholized wine consumption.

2.10 CONCLUSION

Participants use vegetative, chemical, floral, and spicy qualitative descriptor attributes more when such qualitative descriptor terms are provided. Participants are more likely to choose fruit, nutty, woody, and microbiological qualitative descriptor attributes when qualitative descriptor terms are not provided. Chardonnay and Merlot wine vapor-phase stimuli administered using 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps can be perceived retronasally and orthonasally. Subsequent research should be conducted to determine the perceptual impact of low-density polyethylene on wine components such as vapor-phase stimuli.

CHAPTER 3

ASSESSMENT OF LOW-DENSITY POLYETHYLENE IMPACT ON WINE VAPOR-PHASE STIMULI PERCEPTIONS

3.1 INTRODUCTION

Odorant migration and scalping are two common problems associated with plastic polymers. Odorant migration occurs when constituents of the packaging material contaminate food products compromising food integrity (Licciardello and others 2009). Odorant scalping, which involves sorption of food product volatiles by the packaging material, can lead to diminished flavor and/ or flavor imbalance (Nielsen and Jägerstad 1994). Therefore, odorant scalping can have detrimental effects on sensorial attributes (Licciardello and others 2009).

Numerous studies have investigated scalping of citrus volatiles into polyethylene and polypropylene (Sadler and Braddock 1991; Charara and others 1992; Lebossé and others 1997). In fact, limonene is the "most extensively studied" volatile regarding scalping. Limonene has been examined in aqueous and vapor phases. High temperatures increased aqueous sorption while vapor sorption decreased (Hirose and others 1988; Baner and others 1991).

The extent of odorant scalping is dependent upon volatile and plastic properties. Volatile "temperature, concentration, chemical structure, molecular weight," (Nielsen and Jägerstad 1994), polarity, and functional groups (Shimoda and others 1988) affect odorant sorption. Sorption of lipids and organic acids into polymers can cause delamination of several polymer layers (Nielsen and Jägerstad 1994). Other compounds such as mercaptans and sulfides (Plastic) can act like plasticizers causing the polymer to swell (Nielsen and Jägerstad 1994). Polymer sorption of esters was found to be greater than sorption of aldehydes, and polymer sorption of aldehydes was greater than sorption of alcohols. In addition, larger molecules were absorbed to a greater extent than smaller molecules (Shimoda and others 1988; Charara and others 1992).

Polymer properties such as polymer conformation, "competition between sorbates", chemical structure (Nielsen and Jägerstad 1994), and crystallinity (Shimoda and others 1988) dictate volatile diffusion rates. Odorant sorption was minimized in mixtures possibly due to competition of plastic sorption sites. In addition, odorant sorption increased with polymer thickness. High-density polymers absorbed more volatiles than low-density polymers. Not to mention, copolymers absorbed more than homopolymers (Nielsen and Jägerstad 1994). According to Nielsen and others (1992), polyolefins (i.e. low density polyethylene, polypropylene) absorbed more volatiles than polar polymers (i.e. polyethylene terephthalate and polyamide).

Polyethylene terephthalate, polyvinyl chloride, polystyrene, and polypropylene have been investigated and suggested for potential usage for wine packaging (Pasquarelli 1983; Mentana and others 2009). The effectiveness of polymers to preserve wine has been determined based on total phenolic content, pH, volatile acidity, chemical changes in wine volatile fractions, and sulfur dioxide (Buiatti and others 1997). Polyethylene terephthlate in the presence of an oxygen scavenger (Mentana and others 2009) or a Saran layer yielded wine preservation similar to a glass bottle. In fact, Ough (1987) found that wine could be preserved for about 10 months with added sulfur dioxide. Although Licciardello and others (2009) investigated ethyloctanoate and linalool scalping in a model wine solution via linear low-density polyethylene and cast polypropylene, few studies have been conducted to convey data regarding the scalping of wine volatiles provided by real wine into plastics (Mentana and others 2009).

3.2 OBJECTIVE

Research was conducted to determine if low-density polyethylene significantly alters human perception of wine vapor-phase stimuli.

3.3 HYPOTHESIS

Vapor-phase stimuli provided by wine stored in a 118.29mL low-density polyethylene squeeze bottle with 24mm flip-top cap and a covered wine glass for 24 hours would not be discriminated.

3.4 PARTICIPANTS

The participants for the study were recruited on Cornell University's campus using SUSAN and recruitment posters (See Section 2.4). For participant criteria, see Section 2.4. This study contained 25 participants (7 males; 18 females) ranging in age from 21 to 31 years of age (Mean Age = 25.9 years of age, SD = 2.69 years).

Prior to any wine evaluation, each potential participant read and signed a consent form approved by Cornell University's IRBPH. After informed consent was obtained, each participant was questioned as to whether or not he or she was experiencing nasal congestion and given an odorant discrimination test.

3.5 MATERIALS

3.5.1 Stimuli

For the odorant discrimination test, a strawberry flavor extract (KSA Certified) purchased from Frontier^{TM} Natural Products Co-op (See Section 2.5.1) was used. A concentration of 25% was prepared by dilution with sunflower oil (See Section 2.5.1). Strawberry flavor extract was selected because of its previous use in olfactory research (Sun and Halpern 2005; Dragich and Halpern 2008; Stephenson and Halpern 2009).

J. Lohr Estates Seven Oaks 2007 Cabernet Sauvignon (13.5% abv) produced by J. Lohr Vineyards and Wines and purchased at retail was the wine stimulus used for this study.

3.5.2 Squeeze Bottle Delivery Container

A 118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap was used for flavor extract and wine vapor-phase stimuli administrations and low-density polyethylene wine incubation. See Section 2.5.2 for details regarding squeeze bottles. Squeeze bottles were labeled with randomly selected 3-digit code numbers produced from a random number generator (University).

3.5.3 Wine Glass

A 414.03mL wine glass with a tapered bulb shape (Libbey® Charisma 200 03 0431, CTN./CART./CAJ 503049, Libbey® Glass, Inc., Toledo, OH) was used for wine incubation (See Figure 3.1).

Figure 3.1: Wine Glass Used for Wine Incubation.

3.5.4 Nose Clips

See Section 2.5.3 for details regarding nose clips.

3.6 METHODS

3.6.1 Participant Training

Participants were trained how to use a squeeze bottle for retronasal smelling and orthonasal smelling. Details for retronasal smelling and orthonasal smelling training procedures can be found in Section 2.6.1. SuperLab® 4.0 Stimulus Presentation Software by Cedrus® Corporation (San Pedro, CA) was used to display participant instructions via computer screen.

3.6.2 Participant Instructions for Retronasal Smelling

See Section 2.6.3 for retronasal smelling instructions.

3.6.3 Participant Instructions for Orthonasal Smelling

See Section 2.6.4 for orthonasal smelling instructions.

3.6.4 Procedure

For vapor-phase stimuli provided by wine incubated in a covered wine glass, 60mL of the wine stimulus was placed in a wine glass and covered with a plastic petri dish (CAT # 25384-070, VWR® International, LLC, Radnor, PA). For vapor-phase stimuli provided by wine incubated in low-density polyethylene, 5mL of the wine stimulus was placed in a squeeze bottle (See Section 2.5.2). All prepared stimuli were incubated at 5.5°C for 24 hours.

For the odorant discrimination test, 5mL of the strawberry flavor extract (25%) was placed in a squeeze bottle (See Section 2.5.2) representing the odorant discrimination test stimulus while 5mL of sunflower oil was placed in a squeeze bottle to represent a stimulus blank. Stimuli for the odorant discrimination test were stored at 5.5°C. For all sample preparation, storage, and evaluation locations, see Section 2.6.5.

One hour before evaluations all stimuli were removed from the refrigerator and allowed to reach room temperature 21.1±1°C. Five milliliters of the wine stimulus incubated in a covered wine glass was placed in a squeeze bottle (See Section 2.5.2) 10 minutes before evaluation time.

A difference paired comparison test was used to administer the odorant discrimination test. Each participant received 2 squeeze bottles simultaneously. The 2 squeeze bottles either both contained the strawberry flavor extract (25%) stimulus or 1 squeeze bottle contained the strawberry flavor extract (25%) stimulus and 1 squeeze bottle contained the strawberry flavor extract diluent, sunflower oil. The objective for each participant was to determine whether the 2 presented squeeze bottles contained the same or different stimuli. Each participant conducted the odorant discrimination test once. All possible combinations of the strawberry flavor extract (25%) stimulus and sunflower oil were presented in a random, balanced order. Participants were allowed to re-smell squeeze bottles as needed. An incorrect response for the odorant discrimination test did not prevent subsequent participation in wine-vapor phase stimuli evaluations.

Once the odorant discrimination test was completed, each participant was presented with a tray which contained an empty squeeze bottle, a nose clip, and squeeze bottles containing wine stimuli (See Figure 3.2 for tray layout). The participant was told that he or she would be asked to smell wine using 2 methods of smell: retronasal and orthonasal smelling. Each participant was asked whether or not he or she had ever heard of retronasal and orthonasal smelling. Regardless of whether or not the participant had heard of retronasal and orthonasal smelling, the 2 methods were defined. Retronasal smelling was described as inhaling through the mouth and exhaling through the nose. Orthonasal smelling was described as inhaling through the nose.

Figure 3.2: Tray Layout for Retronasal and Orthonasal Wine Vapor-phase Stimuli Triangle Tests via Squeeze Bottles.

Wine vapor-phase stimuli evaluations were conducted using discrimination testing via a triangle test. Each participant received either 2 squeeze bottles with wine incubated in a wine glass and 1 squeeze bottle with wine incubated in low-density polyethylene or vice versa. All possible combinations of the wine stimuli were presented in a random, balanced order retronasally and orthonasally. The objective for each participant was to select the different stimulus out of the three.

So, each participant was told that the objective for the experiment was to select which wine sample was different out of 3 wine samples. The participant was told that the empty squeeze bottle on the tray would be used to practice each method (i.e. retronasal and orthonasal smelling) before actual wine evaluations. The experimenter told the participant that retronasal smelling (See Section 2.6.3) would be practiced and used first. The experimenter provided directions verbally followed by a non-verbal demonstration for the specified method. Once the experimenter presented directions and a non-verbal demonstration, the participant demonstrated the method. Any participant questions were answered, and the participant proceeded with the retronasal wine vapor-phase stimuli evaluation. Participants were allowed to re-smell wine stimuli if needed. Once the retronasal wine vapor-phase stimuli evaluation was completed, the described procedure was repeated for the orthonasal wine vapor-phase stimuli evaluation. Each participant evaluated wine vapor-phase stimuli retronasally and orthonasally 1 time.

3.7 DATA ANALYSIS

3.7.1 Odorant Discrimination Test

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether the strawberry flavor extract (25%) stimulus could be discriminated from its diluent, sunflower oil.

3.7.2 Wine Evaluations

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether vapor-phase stimuli provided by wine incubated in a low-density polyethylene squeeze bottle and a covered wine glass could be discriminated.

3.8 RESULTS

3.8.1 Odorant Discrimination Test

All 25 participants provided correct responses. The calculated z-score was determined to be 4.8 ($p < 3.4 \times 10^{-6}$). As a result, there was sufficient evidence to conclude that discrimination between the strawberry flavor extract stimulus and its diluent, sunflower oil occurred.

3.8.2 Wine Evaluations

Out of a total of 25 participants, 7 participants provided correct responses for retronasal smelling while 12 participants provided correct responses for orthonasal smelling (See Table A.4). Calculated z-scores were determined to be -0.778 ($p < 0.2206$) for retronasal smelling and 1.344 ($p < 0.0901$) for orthonasal smelling. There was not sufficient evidence to conclude that discrimination occurred between the vapor-phase stimuli of a wine incubated in low-density polyethylene and a covered wine glass for 24 hours.

Gender differences were observed regarding retronasal and orthonasal correct triangle test responses. Although females provided more correct responses retronasally and orthonasally than males, the number of correct responses provided by females was higher for orthonasal smelling than retronasal smelling. The number of correct responses provided by males was the same for orthonasal and retronasal smelling.

3.9 DISCUSSION

3.9.1 Odorant Discrimination Test

Vapor-phase stimuli familiarization and/ or identification training for the flavor extract was not provided prior to the odorant discrimination test. Since discrimination occurred between the strawberry flavor extract (25%) stimulus and sunflower oil, participants were able to discriminate. It is evident that participants were not experiencing sufficient nasal congestion to prevent odorant discrimination. The impact of trigeminal stimulation on odorant discrimination may have been minimal. Strawberry has been considered to be strictly an olfactory stimulant (Dragich and Halpern 2008).

3.9.2 Wine Evaluations

Since discrimination between the vapor-phase stimuli of a wine incubated in a squeeze bottle and a covered wine glass was not evident, a 118.29mL low-density polyethylene squeeze bottle with 24mm flip-top cap may potentially be used to administer wine vapor-phase stimuli prepared up to 24 hours in advance for evaluation without significantly altering perceived quality of the vapor-phase stimuli. Sensorial depreciation as a result of possible odorant scalping may be minimal especially for Cabernet Sauvignon wine. The impact of low-density polyethylene on wine vapor-phase stimuli may vary among different types of wine due to compositional differences.

Since females provided more correct responses retronasally and orthonasally for triangle tests, their smell acuity seemed to be higher than the smell acuity for males. Females have been reported to have higher smell sensitivity (Choudhury and others 2003) especially for floral and food odors (Doty 1986).

3.10 CONCLUSION

A 118.29mL low-density polyethylene squeeze bottle with 24mm flip-top cap may be an effective delivery container for wine vapor-phase stimuli, especially Cabernet Sauvignon wine vapor-phase stimuli, prepared up to 24 hours prior to evaluations. Further research should be conducted to investigate the ability of a squeeze bottle to convey qualitative vapor-phase stimuli differences between different wines.

CHAPTER 4

DISCRIMINATION TESTING INVOLVING ALCOHOLIC AND DEALCOHOLIZED WINE VAPOR-PHASE STIMULI VIA LOW-DENSITY POLYETHYLENE SQUEEZE BOTTLES

4.1 INTRODUCTION

Ethanol and its behavior have been examined. In addition to having a bitter (Le Berre and others 2007) and sweet taste (Shakhashiri 2009), ethanol has a small, distinct aroma. Ethanol has been determined to impact gustative and tactile attributes. Modifications of bitterness, acidity, and astringency have been reported (Fontoin and others 2008; Diban and others 2008). Martin and Pangborn (1970) observed that ethanol slightly enhanced the perceived sweetness of sucrose and decreased the perceived intensity of saltiness and sourness. Ethanol was also found to enhance perceived bitterness (Fischer and Noble 1994; Vidal and others 2004), hotness, body, and viscosity in wines (Gawel and others 2007) while minimizing perceived astringency (Fontoin and others 2008).

Diban and others (2008) stated that ethanol impacts odorant volatility. Solubility of wine vapor-phase stimuli was reported to be higher in ethanol/ water mixtures than in pure water (Da Porta and Nacoli 2002). Decreases of odorant volatility in ethanol solutions under static conditions were observed (Lubbers and others 1994; Escalona-Buendia and others 1999; Da Porto and Nicoli 2002). However, odorant volatility increased in the presence of ethanol under dynamic conditions (Tsachaki and others 2005). Furthermore, one would hypothesize that ethanol concentration in conjunction with alterations to wine vapor-phase stimuli caused by dealcoholization processes would produce qualitative differences between perceived vapor-phase stimuli of an alcoholic and dealcoholized wine.

4.2 OBJECTIVE

Research was conducted to determine whether vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine could be discriminated using 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps.

4.3 HYPOTHESIS

Vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine could be discriminated using 118.29mL polyethylene squeeze bottles with 24mm flip-top caps.

4.4 PARTICIPANTS

The participants for the study were recruited on Cornell University's campus using SUSAN and recruitment posters (See Section 2.4). For participant criteria, see Section 2.4. This study contained 33 participants (12 males; 21 females) ranging in age from 21 to 26 years of age (Mean Age = 21.7 years of age, SD = 1.14 years).

Prior to any wine evaluations, each potential participant read and signed a consent form approved by Cornell University's IRBPH.

4.5 MATERIALS

4.5.1 Stimuli

The wine stimuli consisted of Painter Bridge 2008 Cabernet Sauvignon (13% abv) bottled for retail and Ariel Rouge wine created by diluting Ariel Rouge concentrate (35.19%) provided by J. Lohr Vineyards and Wines from its reverse osmosis process (< 0.5% abv) with 99.9% pure distilled water (Nature's Way Purewater Systems, Inc., Pittston, PA). The Painter Bridge 2008 Cabernet Sauvignon and Ariel Rouge concentrate were provided by J. Lohr Vineyards & Wines.

4.5.2 Squeeze Bottle Delivery Container

See Section 2.5.2 for details regarding squeeze bottles and Section 3.5.2 for details regarding squeeze bottle labels.

4.5.3 Nose Clips

See Sections 2.5.3 for details regarding nose clips.

4.6 METHODS

4.6.1 Participant Training

Participants were trained how to use a squeeze bottle for retronasal smelling and orthonasal smelling. Details for retronasal smelling and orthonasal smelling training procedures can be found in Section 2.6.1. SuperLab® 4.0 Stimulus Presentation Software (See Section 3.6.1) was used to display instructions via computer screen.

4.6.2 Participant Instructions for Retronasal Smelling

See Section 2.6.3 for retronasal smelling instructions.

4.6.3 Participant Instructions for Orthonasal Smelling

See Section 2.6.4 for orthonasal smelling instructions.

4.6.4 Procedure

The alcoholic wine stimulus was prepared by placing 5mL of Cabernet Sauvignon wine into a squeeze bottle (See Section 2.5.2). The dealcoholized wine stimulus was prepared by placing 5mL of Rouge wine into a squeeze bottle (See Section 2.5.2). All stimuli were stored at 5.5°C. For sample preparation, storage, and evaluation locations, see Section 2.6.5.

Each participant was presented with a tray which contained an empty squeeze bottle, a nose clip, and squeeze bottles containing wine stimuli (See Figure 3.1 for tray layout). The participant was told that he or she would be asked to smell wine using 2 methods of smell: retronasal and orthonasal smelling. Each participant was asked whether or not he or she had ever heard of retronasal and orthonasal smelling. Regardless of whether or not the participant had heard of retronasal and orthonasal smelling, the 2 methods were defined. Retronasal smelling was described as inhaling through the mouth and exhaling through the nose. Orthonasal smelling was described as inhaling through the nose.

For wine vapor-phase stimuli evaluations, discrimination testing was conducted via a triangle test. Each participant received 2 squeeze bottles with the Cabernet Sauvignon wine stimulus and 1 squeeze bottle with the Rouge wine stimulus or vice versa. All possible combinations of the wine stimuli were presented in a random, balanced order retronasally and orthonasally. The objective for each participant was to select the different stimulus out of the three.

So, each participant was told that the objective for the experiment was to select which wine sample was different out of 3 wine samples. The participant was told that the empty squeeze bottle on the tray would be used to practice each method (i.e. retronasal and orthonasal smelling) before actual wine evaluations. The experimenter told the participant that retronasal smelling would be practiced and used first. The experimenter provided directions verbally followed by a non-verbal demonstration for the specified method. Once the experimenter presented directions and a non-verbal demonstration, the participant demonstrated the method. Any participant questions were answered, and the participant proceeded with the retronasal wine vapor-phase stimuli evaluation. Once the retronasal wine vapor-phase stimuli evaluation was completed, the described procedure was repeated for the orthonasal wine vapor-phase stimuli evaluation. Each participant evaluated wine vapor-phase stimuli retronasally and orthonasally 1 time.

4.7 DATA ANALYSIS

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether wine vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine could be discriminated.

4.8 RESULTS

Out of a total of 33 participants, 14 participants gave correct responses for retronasal smelling while 13 participants gave correct responses for orthonasal smelling (See Table A.5). Calculated z-scores were determined to be 0.923 ($p < 0.1788$) for retronasal smelling and 0.554 ($p < 0.2912$) for orthonasal smelling. As a result, there was not sufficient evidence to conclude that discrimination occurred between wine vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine retronasally and orthonasally.

4.9 DISCUSSION

Since discrimination between the vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine was not evident, the vapor-phase stimuli of the alcoholic and dealcoholized wines may have been indistinguishable. Results contradict Diban and others (2008) who stated ethanol impacts odorant volatility. Result discrepancies may be due to the condition under which vapor-phase stimuli were evaluated (i.e. static vs. dynamic). As previously mentioned, ethanol decreased odorant volatility under static conditions (Lubbers and others 1994; Conner and others 1998; Da Porta and Nicoli 2002) and increased odorant volatility under dynamic conditions (Tsachaki and others 2005). Perhaps, odorant volatility of the wine vapor-phase stimuli provided by the alcoholic wine was reduced. It may also be possible that the impact of ethanol on odorant volatility may be different in real foods/ beverages such as wine than in model wine and ethanol solutions. Another possible explanation for result discrepancies may be insufficient discrimination test power since correct response frequencies fell just below chance level.

The correct response rate for females was similar retronasally and orthonasally. The correct response rate for males was the same retronasally and orthonasally. Females provided more correct responses than males.

4.10 CONCLUSION

Vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine may not be distinguishable via 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps. Vapor-phase stimuli of the alcoholic and dealcoholized wine versions may have been perceptually similar in 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps although ethanol concentrations were different. Results should be validated by replicating the experiment and comparing correct response rates for triangle tests using squeeze bottles and wine glasses.

CHAPTER 5

DISCRIMINATION TESTING OF VAPOR-PHASE STIMULI PROVIDED BY ALCOHOLIC AND DEALCOHOLIZED WINE BOTTLED FOR RETAIL VIA LOW-DENSITY POLYETHYLENE SQUEEZE BOTTLES

5.1 INTRODUCTION

One would hypothesize that ethanol concentration in conjunction with alterations to wine vapor-phase stimuli caused by dealcoholization processes would produce qualitative differences between perceived vapor-phase stimuli of an alcoholic and dealcoholized version of a wine. But, when research was conducted to determine if wine vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine via low-density polyethylene squeeze bottles with 24mm flip-top caps could be distinguished, discrimination was not evident. The wines used for the experiment were provided by J. Lohr Vineyards and Wines, and the dealcoholized wine (Ariel Rouge) was provided in a wine concentrate form (See Chapter 3). The experimenter decided to replicate the experiment using alcoholic and dealcoholized wine bottled for retail to ensure that wine source was not responsible for such results.

5.2 OBJECTIVE

Research was conducted to determine whether vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail could be discriminated using 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps.

5.3 HYPOTHESIS

Vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail could be discriminated using 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps.

5.4 PARTICIPANTS

The participants for the study were recruited on Cornell University's campus using SUSAN and recruitment posters (See Section 2.4). For participant criteria, see Section 2.4. This study contained 33 participants (13 males; 20 females) ranging in age from 21 to 57 years of age (Mean Age = 24.5 years of age, SD = 8.6 years).

Prior to any wine evaluations, each potential participant read and signed a consent form approved by Cornell University's IRBPH.

5.5 MATERIALS

5.5.1 Stimuli

The wine stimuli consisted of Painter Bridge 2008 Cabernet Sauvignon (13% abv) and Ariel Rouge Premium Dealcoholized Wine produced by J. Lohr Vineyards and Wines. Both wine stimuli were bottled for retail.

5.5.2 Squeeze Bottle Delivery Container

See Section 2.5.2 for details regarding squeeze bottles. See Section 3.5.2 for details regarding squeeze bottle labels.

5.5.3 Nose Clips

See Section 2.5.3 for details regarding nose clips.

5.6 METHODS

5.6.1 Participant Training

Participants were trained how to use a squeeze bottle for retronasal smelling and orthonasal smelling. Details for retronasal smelling and orthonasal smelling training procedures can be found in Section 2.6.1. SuperLab® 4.0 Stimulus Presentation Software (See Section 3.6.1) was used to display instructions via computer screen.

5.6.2 Participant Instructions for Retronasal Smelling

See Section 2.6.3 for retronasal smelling instructions.

5.6.3 Participant Instructions for Orthonasal Smelling

See Section 2.6.4 for orthonasal smelling instructions.

5.6.4 Procedure

The alcoholic wine stimulus was prepared by placing 5mL of Cabernet Sauvignon wine into a squeeze bottle (See Section 2.5.2). The dealcoholized wine stimulus was prepared by placing 5mL of Rouge wine into a squeeze bottle (See Section 2.5.2). All stimuli were stored at 5.5°C. For sample preparation, storage, and evaluation locations, see Section 2.6.5.

For wine evaluations, each participant was presented with a tray which contained an empty squeeze bottle, a nose clip, and squeeze bottles containing wine stimuli (See Figure 3.1 for tray layout). The participant was told that he or she would be asked to smell wine using 2 methods of smell: retronasal and orthonasal smelling. Each participant was asked whether or not he or she had ever heard of retronasal and orthonasal smelling. Regardless of whether or not the participant had heard of retronasal and orthonasal smelling, the 2 methods were defined. Retronasal smelling was described as inhaling through the mouth and exhaling through the nose. Orthonasal smelling was described as inhaling through the nose.

For wine vapor-phase stimuli evaluations, discrimination testing was conducted via a triangle test. Each participant received 2 squeeze bottles with the Cabernet Sauvignon wine stimulus and 1 squeeze bottle with the Rouge wine stimulus or vice versa. All possible combinations of the wine stimuli were presented in a random, balanced order retronasally and orthonasally. The objective for each participant was to select the different stimulus out of the three.

So, each participant was told that the objective for the experiment was to select which wine sample was different out of 3 wine samples. The participant was told that the empty squeeze bottle on the tray would be used to practice each method (i.e.

retronasal and orthonasal smelling) before actual wine evaluations. The experimenter told the participant that retronasal smelling would be practiced and used first. The experimenter provided directions verbally followed by a non-verbal demonstration for the specified method. Once the experimenter presented directions and a non-verbal demonstration, the participant demonstrated the method. Any participant questions were answered, and the participant proceeded with the retronasal wine vapor-phase stimuli evaluation. Once the retronasal wine vapor-phase stimuli evaluation was complete, the described procedure was repeated for the orthonasal wine vapor-phase stimuli evaluation. Each participant evaluated wine vapor-phase stimuli retronasally and orthonasally 1 time.

5.7 DATA ANALYSIS

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether wine vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine could be discriminated.

5.8 RESULTS

Out of a total of 33 participants, 22 participants gave correct responses for retronasal smelling while 25 participants gave correct responses for orthonasal smelling (See Table A.6). Calculated z-scores were determined to be 3.877 ($p < 2.326 \times 10^{-4}$) for retronasal smelling and 4.985 ($p < 3.4 \times 10^{-6}$) for orthonasal smelling. As a result, there was sufficient evidence to conclude that vapor-phase stimuli recognitions were not due to chance.

5.9 DISCUSSION

Since discrimination occurred between the vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail, the vapor-phase stimuli of the alcoholic and dealcoholized wines were perceptually different. A

118.29mL low-density polyethylene squeeze bottle with a 24mm flip-top cap is sufficient in conveying qualitative wine vapor-phase stimuli differences. The reason why dealcoholized wine (Ariel Rouge) provided in a concentrate form and bottled for retail yielded different results is questionable. Again, insufficient discrimination test power could have been a contributing factor. Production and storage conditions could have also been contributing factors. Wine concentrate was received directly from J. Lohr Vineyards and Wines from its reverse osmosis process while dealcoholized wine bottled for retail may have undergone adverse storage conditions such as temperature fluctuations during transportation and distribution.

The number of correct responses for orthonasal smelling was higher than the number of correct retronasal smelling responses. The correct response rate for females was similar retronasally and orthonasally. The correct response rate for males was the same retronasally and orthonasally. Females provided more correct responses than males.

5.10 CONCLUSION

Vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail could be discriminated via 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps. Vapor-phase stimuli of the alcoholic and dealcoholized wines bottled for retail were perceptually different. Since wine vapor-phase stimuli could be discriminated using squeeze bottles, squeeze bottle performance should be compared to wine glass performance for validation.

CHAPTER 6

DISCRIMINATION TESTING OF VAPOR-PHASE STIMULI PROVIDED BY ALCOHOLIC AND DEALCOHOLIZED WINE VIA LOW-DENSITY POLYETHYLENE SQUEEZE BOTTLES AND WINE GLASSES

6.1 INTRODUCTION

Since discrimination occurred between vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail retronasally and orthonasally via 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps, squeeze bottle performance should be compared to wine glass performance. Correct response rates obtained from squeeze bottle evaluations and wine glass evaluations should be compared.

6.2 OBJECTIVE

Research was conducted to determine whether correct response rates for discrimination testing involving vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine presented in 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps would be similar to correct response rates for discrimination testing of the same vapor-phase stimuli presented in covered wine glasses.

6.3 HYPOTHESIS

Orthonasal correct response rates for discrimination testing of alcoholic and dealcoholized wine vapor-phase stimuli presented in 118.29mL low-density polyethylene squeeze bottles would be similar to orthonasal correct response rates for discrimination testing of the same alcoholic and dealcoholized wine vapor-phase stimuli presented in wine glasses.

6.4 PARTICIPANTS

The participants for the study were recruited on Cornell University's campus using SUSAN and recruitment posters (See Section 2.4). For participant criteria, see Section 2.4. This study contained 30 participants (8 males; 22 females) ranging in age from 21 to 33 years of age (Mean Age = 22.3 years of age, SD = 3.19 years).

Prior to any wine evaluations, each potential participant read and signed a consent form approved by Cornell University's IRBPH.

6.5 MATERIALS

6.5.1 Stimuli

The wine stimuli consisted of Painter Bridge 2008 Cabernet Sauvignon (13% abv) and Ariel Rouge Premium Dealcoholized Wine produced by J. Lohr Vineyards and Wines. Both wine stimuli were bottled for retail.

6.5.2 Squeeze Bottle Delivery Container

See Section 2.5.2 for details regarding squeeze bottles. See Section 3.5.2 for details regarding squeeze bottle labels.

6.5.3 Wine Glass

A wine glass was used as a delivery container for the study (See Section 3.5.3). Wine glasses were labeled with randomly selected 3-digit digit code numbers. Random 3-digit code numbers were produced from a random number generator (University).

6.6 METHODS

6.6.1 Participant Training

Participants were trained how to use a squeeze bottle and wine glass for orthonasal smelling. Training procedures for orthonasal smelling via squeeze bottles can be found in Section 2.6.1. Once participants received training for orthonasal smelling via squeeze bottles, training for orthonasal smelling via wine glasses was provided. SuperLab® 4.0 Stimulus Presentation Software (See Section 3.6.1) was used to display instructions via computer screen.

6.6.2 Participant Instructions for Orthonasal Smelling via Squeeze Bottles

See Section 2.6.4 for orthonasal smelling instructions.

6.6.3 Participant Instructions for Orthonasal Smelling via Wine Glasses

For orthonasal smelling via a wine glass, each participant removed the plastic petri dish cover (See Section 3.5.3). He or she picked up the wine glass by the stem right below the base of the glass. The participant carefully swirled the glass 3 times and then took a sniff of the wine. He or she carefully swirled the glass 3 more times and took another sniff of the wine.

6.6.4 Procedure

For orthonasal smelling of wine vapor-phase stimuli via squeeze bottles, the alcoholic wine stimulus was prepared by placing 5mL of Cabernet Sauvignon wine into a squeeze bottle (See Section 2.5.2). The dealcoholized wine stimulus was prepared by placing 5mL of Rouge wine into a squeeze bottle (See Section 2.5.2).

For orthonasal smelling of wine vapor-phase stimuli via wine glasses, the alcoholic wine stimulus was prepared by placing 30mL of Cabernet Sauvignon wine into a wine glass and covering it with a plastic petri dish (See Section 3.5.3). The dealcoholized wine stimulus was prepared by placing 30mL of Rouge wine into a wine glass and covering it with a plastic petri dish (See Section 3.5.3).

All stimuli were stored at 5.5°C. For sample preparation, storage, and evaluation locations, see Section 2.6.5.

For wine evaluations, each participant was presented with a tray which contained an empty squeeze bottle, a covered wine glass with 30mL of distilled water, a nose clip, squeeze bottles containing wine stimuli, and wine glasses containing wine stimuli (See Figure 6.1 for tray layout). The participant was told that he or she would be asked to smell wine using orthonasal smelling. Each participant was asked whether or not he or she had ever heard of orthonasal smelling. Regardless of whether or not the participant had heard of orthonasal smelling, the method was defined. Orthonasal smelling was described as inhaling through the nose.

(A)

(B)

Figure 6.1: Tray Layout for Orthonasal Wine Vapor-phase Stimuli Triangle Tests via Squeeze Bottles and Wine Glasses. (A) Layout when squeeze bottle triangle test is first. (B) Layout when wine glass triangle test is first.

For wine vapor-phase stimuli evaluations, discrimination testing was conducted via triangle tests. For orthonasal evaluations via squeeze bottles, each participant received 2 squeeze bottles with the Cabernet Sauvignon wine stimulus and 1 squeeze bottle with the Rouge wine stimulus or vice versa. All possible combinations of the wine stimuli were presented in a random, balanced order. The objective for each participant was to select the different stimulus out of the three.

For orthonasal evaluations via wine glasses, each participant received 2 wine glasses with the Cabernet Sauvignon wine stimulus and 1 wine glass with the Rouge wine stimulus or vice versa. All possible combinations of the wine stimuli were presented in a random, balanced order. The objective for each participant was to select the different stimulus out of the three. It should be mentioned that the order of evaluation methods (i.e. squeeze bottle and wine glass) used was randomized across all participants.

Since the objective for each participant regarding orthonasal evaluations via squeeze bottles and wine glasses was to select the different stimulus out of the three, each participant was told that the objective for the experiment was to select the wine sample that was different out of 3 wine samples. The participant was told that the empty squeeze bottle and wine glass with water on the tray would be used to practice before actual wine evaluations. The method (i.e. squeeze bottle or wine glass) practiced first was dictated by the randomly selected evaluation method order. The experimenter provided directions verbally followed by a non-verbal demonstration for the first specified method. Once the experimenter presented directions and a non-verbal demonstration, the participant demonstrated the method. Any participant questions were answered, and the participant proceeded with wine vapor-phase stimuli evaluation. Participants were allowed to re-smell wine stimuli if needed. Once the first evaluation was complete, the described procedure was repeated for the remaining evaluation method. Each participant evaluated wine vapor-phase stimuli via squeeze bottles and wine glasses 1 time.

6.7 DATA ANALYSIS

Inferential statistics were applied to collected data. A normal approximation to the binomial was made via calculated z-scores to determine whether wine vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail could be discriminated via 118.29mL low-density polyethylene squeeze bottles and wine glasses. A z-score was also calculated to determine whether the correct response rates for wine vapor-phase stimuli evaluations via squeeze bottles and wine glasses were similar.

6.8 RESULTS

Out of a total of 30 participants, 20 participants gave correct responses for orthonasal smelling via squeeze bottles while 23 participants gave correct responses for orthonasal smelling via wine glasses (See Table A.7). Calculated z-scores were determined to be 3.679 ($p < 2.326 \times 10^{-4}$) for orthonasal smelling via squeeze bottles and 4.841 ($p < 3.4 \times 10^{-6}$) for orthonasal smelling via wine glasses. As a result, there was sufficient evidence to conclude that wine vapor-phase stimuli discriminations via squeeze bottles and wine glasses were not due to chance. A calculated z-score of -0.865 ($p < 0.1949$) was calculated for the proportion of correct responses from squeeze bottle evaluations and wine glass evaluations. As a result, no significant difference resulted between correct response rates.

6.9 DISCUSSION

Since discrimination occurred between the vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail via squeeze bottles and wine glasses, a 118.29mL low-density polyethylene squeeze bottle can be used to administer wine vapor-phase stimuli. Although the correct response rate for wine vapor-phase stimuli evaluations via squeeze bottles was less than the correct response rate for wine vapor-phase stimuli evaluations via wine glasses, no significant difference was found between the correct response rates for wine vapor-phase stimuli evaluations regarding the two vapor-phase stimuli delivery methods (squeeze bottles and wine glasses).

The correct response rate for females was the same for orthonasal wine vapor-phase stimuli evaluations via squeeze bottles and wine glasses. While the correct response rate for males was similar for orthonasal evaluations via squeeze bottles and wine glasses, males provided less correct responses using squeeze bottles. Females provided more correct responses than males for orthonasal wine vapor-phase stimuli evaluations via squeeze bottles and wine glasses.

6.10 CONCLUSION

Vapor-phase stimuli provided by an alcoholic and dealcoholized version of a wine bottled for retail could be discriminated via 118.29mL low-density polyethylene squeeze bottles with 24mm flip-top caps and wine glasses. Similar correct response rates for wine vapor-phase stimuli evaluations via squeeze bottles and wine glasses signifies that a 118.29mL low-density polyethylene squeeze bottle may be used to investigate human perceptions of wine vapor-phase stimuli.

CHAPTER 7

ASSESSMENT OF EFFECTS OF ETHANOL CONCENTRATION ON WINE VAPOR-PHASE STIMULI PERCEPTION

7.1 INTRODUCTION

Specific volatile interactions have been examined in binary mixtures and model wine solutions. Binary supra-threshold mixtures of woody and fruity attributes were homogenous with a woody attribute dominance in iso-intense mixtures (Atanasova and others 2005). In complex mixtures, woody attributes were also found to reduce fruity and floral attributes (Le Berre and others 2007).

Ethanol's impact on odorant volatility has been studied in model wine solutions, yet limited research has been conducted to investigate, perceptually, how ethanol affects vapor-phase stimuli provided by real wines. Low ethanol concentrations reportedly enhanced odorant volatility (Le Berre and others 2007). An ethanol concentration of 10% abv increased the odorant detection threshold of ethyl isobutanoate (Guth and Sies 2002). In addition, Grosch (2001) reported enhancement of fruity and floral attribute intensities at lower ethanol concentrations such as 7% abv. The hypothetical explanation for such behavior was that decreasing ethanol content causes the partial pressure of volatiles to increase. Such behavior may explain high floral and fruity attribute intensities at ethanol concentrations below 11% in Germany Riesling (Jackson 2009). However, Le Berre and others (2007) found that a higher ethanol concentration (12% abv) enhanced the intensity of perceived fruity attributes in a model wine solution containing whiskey lactone and isoamyl acetate.

Since ethanol impact on odorant volatility was observed to be different in model wine solutions versus real wines. Further research should be conducted to investigate ethanol's impact on perceived intensity of wine vapor-phase stimuli provided by wines with various ethanol concentrations.

7.2 OBJECTIVE

Research was conducted to investigate how ethanol concentration affects human perception of vapor-phase stimuli provided by alcoholic and dealcoholized wines.

7.3 HYPOTHESIS

An increase in ethanol concentration would yield a decrease in perceived wine vapor-phase stimuli intensities for fruity and floral qualitative descriptor attributes.

7.4 PARTICIPANTS

Participants for the study were recruited on Cornell University's campus using SUSAN (See Section 2.4), recruitment posters (See Figure A.5), and departmental campus emails. All participants had to be at least 21 years old, a wine drinker, healthy, neither pregnant nor lactating, and an American English communicator. Prior to any evaluation, each potential participant was questioned as to whether or not he or she was experiencing nasal congestion. If a potential participant indicated that he or she was congested or exemplified nasal congestion symptoms such as a runny or stuffy nose, he or she was not allowed to evaluate wine samples. The potential participant was asked to reschedule his or her appointment. Once a potential participant indicated that he or she was not experiencing nasal congestion, he or she signed a consent form approved by the IRBHP. All information provided via SUSAN, recruitment posters, and departmental campus emails was approved by Cornell University's IRBHP.

This study contained two groups: a Chardonnay Wine Group and a Rouge Wine Group. After each potential participant signed up for the study, he or she was questioned as to the type of wine that he or she drank the most. Participant response options were red wine, white wine, or both red and white wine equally. Participants who drank mostly white wine were unknowingly assigned to the Chardonnay Wine Group, and participants who drank mostly red wine were unknowingly assigned to the Rouge Wine Group. Participants who drank both red and white wine equally were assigned to the wine group with the least number of participants by the arrival of his or her evaluation day. The Chardonnay Wine Group (Group 1) contained 30 participants (22 females, 8 males). The ages of participants ranged from 21 to 29 years of age (Mean age = 21.7 years of age, SD = 1.66 years). The Rouge Wine Group (Group 2) was composed of 27 participants (16 females, 11 males). The ages of the participants ranged from 21 to 43 years of age (Mean age = 24.6 years of age, SD = 6.3 years).

7.5 MATERIALS

7.5.1 Stimuli

Nineteen qualitative descriptor attribute terms used for the Chardonnay Wine Group included: apple, pear, apricot, peach, lemon, orange, banana, pineapple, mango, coconut, butterscotch, vanilla, wood, smoke, toasted, caramel, butter, floral, and alcohol. Stimuli used as reference odors for the qualitative descriptor attribute terms consisted of: apple juice (Ocean Spray® Cranberries, Inc, Lakeville-Middleboro, MA), pear flavor (natural flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), apricot flavor (natural flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), peach flavor (artificial flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), lemon flavor (QAI Certified Organic, alcohol-free, Frontier™ Natural Products Co-op, Norway, IA), orange flavor (QAI Certified Organic, KSA Certified, Frontier™ Natural Products Co-op, Norway, IA), banana flavor (alcohol-free, Frontier™ Natural Products Co-op, Norway, IA), pineapple flavor (artificial flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), mango flavor (natural flavor with water and polypropylene glycol, Faerie's Finest, Hawaiian Gardens, CA), coconut flavor (artificial flavor with water and propylene glycol, Faeries' Finest, Hawaiian Gardens, CA), butterscotch flavor (KSA Certified Kosher-Dairy, Frontier™ Natural Products Co-op, Norway, IA), vanilla flavor (QAI Certified Organic, KSA Certified, Frontier™ Natural Products Co-op, Norway, IA), Oak Essence (LD Carlson Company, Kent, OH), liquid smoke (Reese® Hickory Liquid Smoke, Worlds Finer Foods, Inc., Bloomfield, NJ), toast (toasted Great Value™ 100% whole wheat bread), caramel flavor (natural flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), butter flavor (KSA Certified Kosher-Dairy, Frontier™ Natural Products Co-op, Norway, IA), linalool (≥ 97%, F.C.C-F.G, Nicht Direktem Sonnenlicht Aussetzen) and ethanol (Everclear®, 95% abv grain alcohol, Luxco®, Inc., St. Louis, MO). Specified concentrations of each odor stimulus can be seen in Table 7.1).

Sixteen qualitative descriptor attribute terms used for the Rouge Wine Group included: blackberry, strawberry, cherry, bell pepper, asparagus, olive, ginger, black pepper, vanilla, smoke, toasted, wood, earth, sweat, leather, alcohol. Stimuli used as reference odors for the qualitative descriptor attribute terms consisted of: blackberry flavor (Cook's™ Flavoring Company, Paso Robles, CA), strawberry flavor (KSA Certified, Frontier™ Natural Products Co-op, Norway IA), cherry flavor (KSA Certified, Frontier™ Natural Products Co-op, Norway, IA), bell pepper (Tops® Market, LLC, Depew NY), juice of canned asparagus (Tops® Tender Green Asparagus Spears Cut, Tops® Market, LLC, Depew NY), juice of canned olives (Great Value® Pimiento Stuffed Manzanilla Olives, Walmart Stores, Inc., Bentonville, AR), ginger flavor (natural flavor with water and propylene glycol, Faerie's Finest, Hawaiian Gardens, CA), ground black pepper (5th® Season Ground Black Pepper, Han-Dee Pak, Inc., Cockeysville, MD), vanilla flavor (QAI Certified

Organic, KSA Certified, Frontier™ Natural Products Co-op, Norway, IA), liquid smoke (Reese® Hickory Liquid Smoke, Worlds Finer Foods, Inc., Bloomfield, NJ), toast (toasted Great Value™ 100% whole wheat bread), Oak Essence (LD Carlson Company, Kent, OH), juice of canned garbanzo beans (Market Pantry™, Target Corporation, Minneapolis, MN) and mushrooms (Tops® Mushrooms, Tops® Market, LLC, Depew NY), Valeric Acid (99+%), F.C.C.-grade, CAS # 109-52-4, Sigma-Aldrich®, St. Louis, MO), leather belt (Faded Glory, Walmart Stores, Inc., Bentonville, AR), and ethanol (Everclear®, 95% abv grain alcohol, Luxco®, Inc., St. Louis, MO). Specified concentrations of each odor stimulus can be seen in Table 7.1).

Table 7.1: Reference Odor Quantities for Qualitative Descriptor Attribute Terms for Chardonnay and Rouge Wines.

Qualitative Descriptor Terms	Reference Stimulus	Quantity
Alcohol	Everclear®	200µL
Apple	Apple juice	5mL
Apricot	Apricot Flavor Extract	100µL
Asparagus	Juice of canned asparagus	500µL
Banana	Banana Flavor Extract	200µL
Bell Pepper	Bell Pepper	6g
Black Pepper	Ground Black Pepper in Water	0.1g of black pepper/ 7mL of water
Blackberry	Blackberry flavor	700µL
Butter	Butter Flavor	100µL
Butterscotch	Butterscotch Flavor Extract	300µL
Caramel	Caramel flavor	600µL
Cherry	Cherry flavor	150µL
Coconut	Coconut flavor	200µL
Earth	Humus and Mushroom juices	300µL of humus juice, 400µL of mushroom juice
Floral	Linalool	100µL
Ginger	Ginger flavor	100µL
Leather	Soaked leather (5cm x 2cm)	2.3g of leather in 5mL of water
Lemon	Lemon Flavor Extract	300µL
Mango	Mango flavor	400µL
Olive	canned olive juice	800µL
Orange	Orange Flavor Extract	400µL

Peach	Peach Flavor	150µL
Pear	Pear Flavor Extract	100µL
Pineapple	Pineapple flavor	100µL
Smoke	Liquid Smoke	100µL
Strawberry	Strawberry Flavor Extract	300µL
Sweat	Valeric Acid	1 drop
Toasted	Toast	3.9g of toasted bread
Vanilla	Vanilla Flavor Extract	700µL
Wood	Oak Essence	300µL

The wines used for the study were created using Ariel Rouge concentrate (35.19%) and Ariel Chardonnay concentrate (35.45%) provided by J. Lohr Vineyards and Wines from its reverse osmosis process. The two concentrates were analyzed at the Cornell University Wine Analysis Laboratory and were confirmed to have an ethanol concentration <0.5% abv (See Tables A.8 and A.9 for wine concentrate analysis results). Five wine concentrations were created for each type of wine concentrate: < 0.5% abv, 3.75% abv, 7% abv, 10.25 % abv, and 13.5% abv. Each concentration was created by adding the appropriate quantities of distilled water and Everclear®.

7.5.2 Squeeze Bottle Delivery Container

See Section 2.5.2 for details regarding squeeze bottles. Squeeze bottles used for wine vapor-phase stimuli evaluations were labeled as described in Section 3.5.2. Squeeze bottles used for reference odors were labeled with corresponding qualitative descriptive terms. Descriptor terms were selected based on wine aroma profile descriptions provided by J. Lohr Vineyards and Wines (Chardonnay; Rouge) and terms used to describe the types of wines (i.e. Chardonnay) in the literature (LaMar). A list of qualitative descriptor terms can be seen in Table 7.1.

7.5.3 Nose Clips

See Section 2.5.3 for details regarding nose clips.

7.6 METHODS

7.6.1 Participant Training

Participants were trained how to use a squeeze bottle for retronasal smelling and orthonasal smelling. Details for retronasal smelling and orthonasal smelling training procedures can be found in Section 2.6.1.

7.6.2 Participant Instructions for Retronasal Smelling

See Section 2.6.3 for retronasal smelling instructions.

7.6.3 Participant Instructions for Orthonasal Smelling

See Section 2.6.4 for orthonasal smelling instructions.

7.6.4 Procedure

Details for wine stimuli preparations can be found in Section 2.5.1. Reference odor squeeze bottles were prepared by placing the specified quantity of each odor stimulus (See Table 7.1) in a squeeze bottle (See section 7.5.2) labeled with the corresponding qualitative descriptor term. All stimuli were stored at 5.5°C. For sample preparation, storage, and evaluation locations, see Section 2.6.5.

Each participant was presented with a tray which contained an empty squeeze bottle and a nose clip and received reference odor squeeze bottles each labeled with a term. The reference squeeze bottles were arranged in an arch shape around the tray by the experimenter (See Figure 7.1 for tray layout). The participant was told that he or she would be asked to smell wine using 2 methods of smell: retronasal and orthonasal smelling. Each participant was asked whether or not he or she had ever heard of retronasal and orthonasal smelling. Regardless of whether or not the participant had heard of retronasal and orthonasal smelling, the 2 methods were defined. Retronasal smelling was described as inhaling through the mouth and exhaling through the nose. Orthonasal smelling was described as inhaling through the nose.

Figure 7.1: Tray Layout for Wine Vapor-phase Stimuli Evaluations Using Citation Frequencies via Squeeze Bottles.

Participants were told that the empty squeeze bottle on the tray would be used to practice retronasal and orthonasal smelling and that each of the reference squeeze bottles in the arch around the tray contained a reference odor describing the term on the squeeze bottle label.

Participants were also told that for each wine sample, they would be asked to smell it using retronasal or orthonasal smelling and select between 1 and 4 terms from a list that best described what he or she smelled in the wine sample. Participants were told that the provided reference odors would appear as response options in the list of descriptor terms.

A citation frequency-based method was used for wine evaluations. Instead of reference odor training, participants received reference odor exposure. Participants were instructed to smell the reference squeeze bottles first before any wines were presented. Participants were instructed how to smell the reference squeeze bottles orthonasally using the empty squeeze bottle (See Section 2.6.4). Participants were told that they would be allowed to smell the reference odors throughout all wine evaluations. Once the reference odors were smelled, participants received a ballot sheet (See Figure A.6) which contained directions and listed coded wine samples vertically and response terms horizontally. Participants were reminded that for each wine sample they would have to select between 1 and 4 terms that best described what was smelled in the wine sample. It was explained that selected terms should be indicated by placing an "X" or marking in the appropriate space for selected terms.

Retronasal evaluations were always conducted before orthonasal evaluations. So, each participant was told that the retronasal smelling method would be used for the first 5 samples (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv). Participant training for the retronasal smelling method was conducted using the empty squeeze bottle (See Section 2.6.3). After training, the experimenter provided the participant with the first wine sample to be evaluated. Once the participant finished evaluating the first sample, there was a 5 second break before the next sample was presented. After retronasal evaluations were completed, the experimenter explained that the second 5 samples would be smelled using the orthonasal smelling method. Training for the orthonasal smelling method was conducted using the empty squeeze bottle (See Section 2.6.4). Once the training was completed, the experimenter handed the participant the first sample. After the participant evaluated the sample, there was a 5 second break before the next sample was presented. Retronasal and orthonasal smelling wine evaluations were replicated in the same order. There was a 1-minute break during the transition between evaluation methods (i.e. retronasal smelling and orthonasal smelling). For each set of 5 samples, wines were unknowingly evaluated in an ascending order starting with the lowest ethanol concentration.

After wine evaluations were completed, each participant was questioned about how often he or she drank wine. If the participant belonged to the Chardonnay Wine Group, he or she was questioned about how often he or she drank white wine. Participants who belonged to the Rouge Wine Group were questioned about how often they drank red wine.

Each participant received $6 at the end of his or her session as compensation for participation.

7.7 Data Analysis

Inferential statistics were applied to collected data. It should be mentioned that data from repeated measures were analyzed. A contingency table analysis, categorical response analysis, and correspondence analysis were conducted using JMP® 9 software (SAS®, Cary, NC). The contingency table analysis produced a contingency table from which a chi-square value was calculated to test for homogeneity among wine samples. A Fisher's Exact test statistic was calculated using SPSS® Statistics 19 (IBM® Corporation, Armonk, NY). The contingency table analysis also produced a mosaic plot exhibiting a visual representation of wine response rates. Response rates represent ratios for each qualitative descriptor attribute response frequency count in relation to the total frequency count including all qualitative descriptor attributes for a given wine. A categorical response analysis, which analyzes data representing multiple responses by identification, was conducted. Each response level was investigated for significance. Linear regression was also used to express variance attributed to ethanol and convey the linear relationship between ethanol concentration and each qualitative descriptor attribute category via Microsoft® Office Excel 2007 (Microsoft® Corporation, Radmond, WA). The correspondence analysis produced a graphical display of the wine-response space indicating wines and response levels in close proximity. Hierarchical clusters were subsequently produced from the graphical display of the wine-response space.

7.8 Results

A contingency table with frequency counts for each response level (qualitative descriptor attributes) and cell Chi-square values can be seen for Chardonnay wine evaluated retronasally in Figure A.6. Out of 620 observations, 72 degrees of freedom were associated with the model. According to the calculated Pearson Chi-square test statistic, 58.924, and the Fisher's Exact test statistic, 59.593, qualitative descriptor attribute response probabilities were similar across the 5 wine samples.

Response probabilities for qualitative descriptor attributes can be seen in Figure 7.2 for Chardonnay wines evaluated retronasally. Higher response probabilities for apple, alcohol, vanilla, and apricot were found for <0.5% abv to 10.25% abv. High response probabilities for alcohol and vanilla were found at 13.5% abv. The response probability for alcohol was fairly constant and the highest at 13.5% abv. The response probability for apple significantly decreased at 13.5% abv. The response probability for butterscotch increased drastically for 3.75% abv and remained fairly constant for subsequent wine samples. A significant Chi-square value was only found for the apple qualitative descriptor attribute (See Figure 7.3).

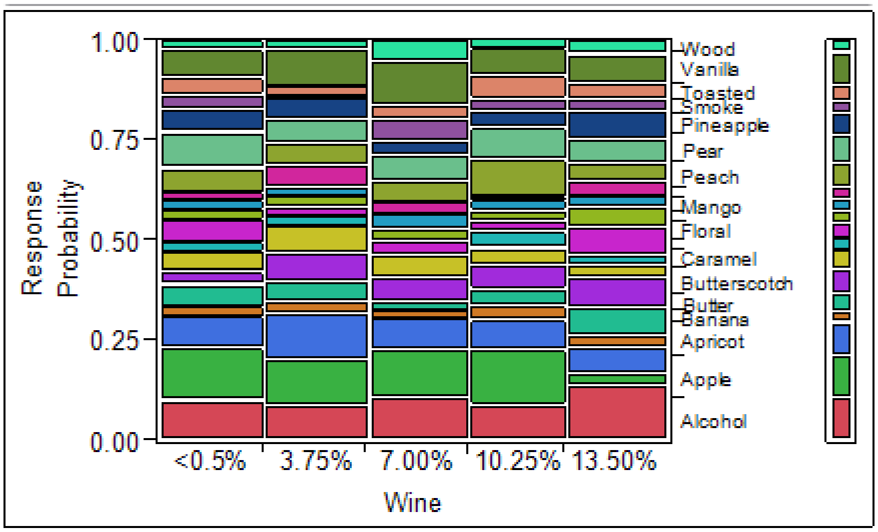


Figure 7.2: Retronasal Qualitative Descriptor Attribute Response Probabilities for Chardonnay Wines.

Response	ChiSquare	Prob>ChiSq
Alcohol	1.5095	0.8250
Apple	10.6889	0.0303*
Apricot	2.6182	0.6236
Banana	1.0270	0.9057
Butter	2.7452	0.6013
Butterscotch	2.5421	0.6371
Caramel	2.4172	0.6595
Coconut	7.2070	0.1253
Floral	6.0293	0.1970
Lemon	1.6364	0.8022
Mango	0.8527	0.9312
Orange	6.5878	0.1593
Peach	2.4654	0.6508
Pear	1.2508	0.8697
Pineapple	1.8192	0.7690
Smoke	5.2443	0.2631
Toasted	3.0959	0.5419
Vanilla	2.3547	0.6708
Wood	2.4338	0.6565

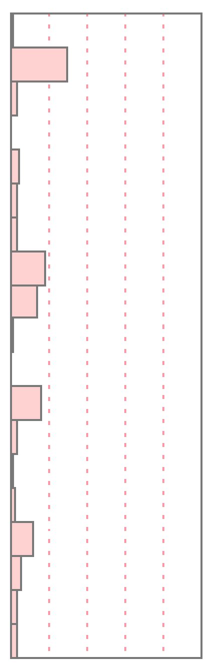


Figure 7.3: Chi-square Values for Individual Qualitative Descriptor Attribute Responses Regarding Retronasal Chardonnay Wine Evaluations.

The 2-dimensional plot automatically produced from the Correspondence Analysis can be seen in Figure 7.4. Approximately 90% of the variance can be explained by 3 components. Component 1 accounts for 37.2% of variance; Component 2 accounts for 27.6% of variance; and Component 3, which is not shown in the 2-dimensional plot, accounts for 25% of variance. Component 1 separates 3.75% abv and 13.5% abv from <0.5% abv, 7% abv, and 10.25% abv by some quality level. Component 2 appears to be mostly related to response level. The 3 components were used to cluster related wines and response levels (See Figure A.7 for clusters). Apple, pear, peach, coconut, and toasted attributes characterized <0.5% abv and 10.25% abv. Apricot, orange, caramel, floral, alcohol, lemon, banana, pineapple, butter, and butterscotch attributes characterized 3.75% abv and 13.5% abv. Mango, wood, vanilla, and smoke attributes characterized 7% abv.

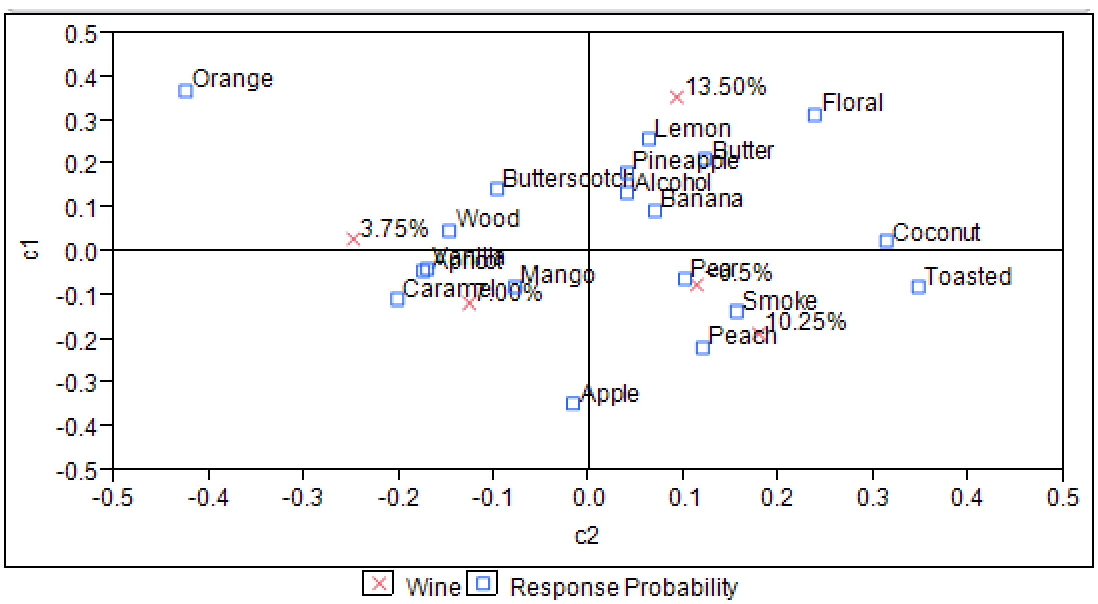


Figure 7.4: Two-dimensional Correspondence Analysis Plot for Chardonnay Wines and Retronasal Qualitative Descriptor Attributes.

The 19 qualitative descriptor attributes can be grouped into 5 categories: fruit, caramelized, wood, floral, and alcohol. Fruit, caramelized, wood, and floral categories were based on first-tier terms of the wine aroma wheel (Noble and others 1987). Alcohol, which is a third-tier term on the wine aroma wheel (Noble and others 1987), was used to represent the alcohol category. Qualitative descriptor attribute terms were assigned to the fruit, caramelized, and wood categories based on third-tier terms of the wine aroma wheel (Noble and others 1987). Apple, pear, apricot, peach, lemon, orange, banana, pineapple, mango, and coconut were assigned to the fruit category (See Table A.10 and Table A.11 for qualitative descriptor category response frequencies). Butterscotch, caramel, and butter were assigned to the caramelized category. Toasted, smoke, vanilla, and wood were assigned to the wood category. Floral was assigned to the floral category, and alcohol was assigned to the alcohol category. In the event that a specific qualitative descriptor attribute term was not found on the wine aroma wheel, the term was categorized based on its definition. For example, coconut is defined as a fruit. So, it would be assigned to the fruit category not the floral category.

An increase in the response rate for the wood category resulted with an increase in floral and alcohol category response rates retronasally (See Figure A.8 for linear regression). Fruit and caramelized category response rates showed an inverse response pattern (whether response rates increased or decreased) in relation to floral, wood, and alcohol category response rates. The caramelized category response rate changed at higher ethanol concentrations (10.25% abv and 13.5% abv) resulting with an increase in response rate at 13.5% abv.

In linear regression, the linear relationship between variables (Correlation) is indicative by r-square values. R-square values convey model fit - “how well the model fits the data” (StatSoft). For conducted research, r-square values for specific qualitative descriptor attributes specify how much variance can be attributed to solely change in ethanol concentration (See Figure A.8 for r-square values). Less than 2% of variance was caused by a change in ethanol concentration for caramelized, wood, and floral categories. Higher r-square values were found for fruit and alcohol categories. Approximately 58% of variance for the fruit category and 23.56% of variance for the alcohol category could be explained by a change in ethanol concentration.

A contingency table with frequency counts for each response level (qualitative descriptor attributes) and cell Chi-square values can be seen for Chardonnay wine evaluated orthonasally in Figure A.9. Out of 718 observations, 72 degrees of freedom are associated with the model. According to the Pearson Chi-square test statistic, 73.198, and the Fisher's Exact Test statistic, 72.253, qualitative descriptor attribute response probabilities were similar across the 5 wine samples.

Response probabilities for qualitative descriptor attributes can be seen in Figure 7.5 for Chardonnay wines evaluated orthonasally. All wine samples had higher response probabilities for alcohol and apple when compared to other qualitative descriptor attribute terms. Response probabilities for alcohol started off low and significantly increased. The response probabilities for lemon and floral were highest at 3.75% abv. Orange character increased while peach and pear character decreased at 7% abv. For all other wine samples, peach character was high and orange character was relatively low. Vanilla character was lowest at 10.25% abv. A significant Chi-square value was only found for the alcohol qualitative descriptor attribute (See Figure 7.6).

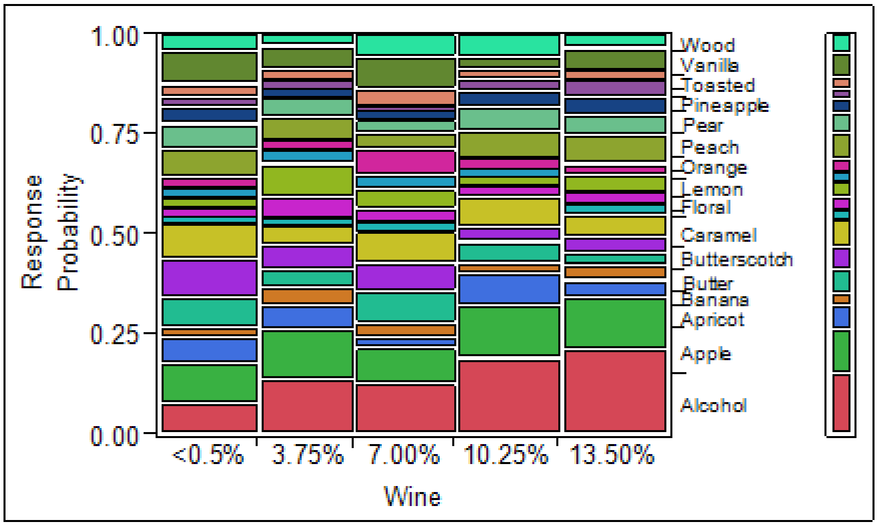


Figure 7.5: Orthonasal Qualitative Descriptor Attribute Response Probabilities for Chardonnay Wines.

Response	ChiSquare	Prob>ChiSq
Alcohol	12.6607	0.0131*
Apple	1.9348	0.7478
Apricot	4.4366	0.3501
Banana	0.5770	0.9656
Butter	3.3166	0.5063
Butterscotch	6.6337	0.1566
Caramel	2.1053	0.7164
Coconut	7.2200	0.1247
Floral	2.4163	0.6597
Lemon	6.1181	0.1905
Mango	8.1513	0.0862
Orange	4.7155	0.3178
Peach	2.1646	0.7055
Pear	1.5704	0.8141
Pineapple	2.9564	0.5651
Smoke	4.8460	0.3035
Toasted	1.9149	0.7514
Vanilla	3.5567	0.4693
Wood	2.1059	0.7163

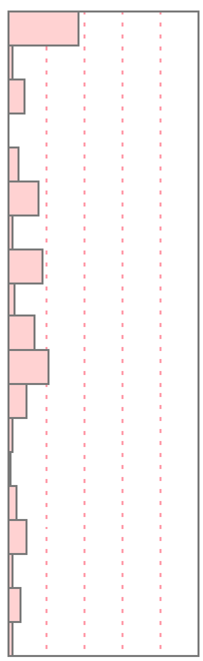


Figure 7.6: Chi-square Values for Individual Qualitative Descriptor Attribute Responses Regarding Orthonasal Chardonnay Wine Evaluations.

The 2-dimensional plot automatically produced from the Correspondence Analysis can be seen in Figure 7.7. Approximately 87% of the variance can be explained by 3 components. Component 1 accounts for 46% of variance; Component 2 accounts for 23 % of variance; and Component 3, which is not shown in the 2-dimensional plot, accounts for 17.7 % of variance. Component 1 separates <0.05% abv, 3.75% abv, and 7% abv from 10.25% abv and 13.5% abv by some quality level. Component 2 is mostly related to response level. The 3 components were used to cluster related wines and response levels (See Figure A.10 for clusters). Butter, butterscotch, caramel, wood, vanilla, toasted, and orange characterized <0.5% abv and 7% abv. Floral, banana, lemon, and mango characterized 3.75% abv. Apple, pear, apricot, pineapple, alcohol, and smoke characterized 10.25% abv and 13.5% abv.

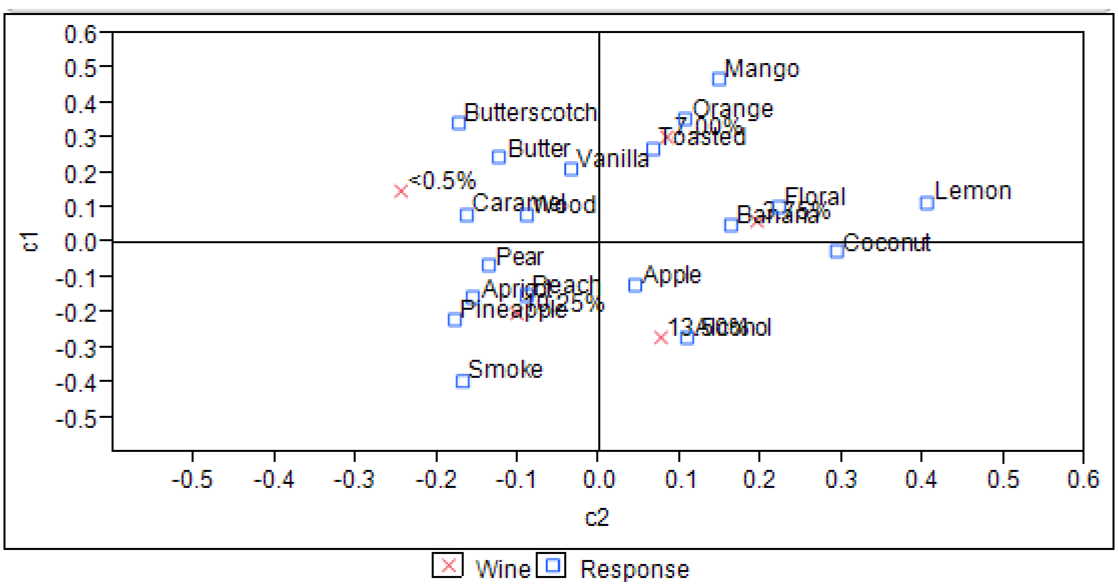


Figure 7.7: Two-dimensional Correspondence Analysis Plot for Chardonnay Wines and Orthonasal Qualitative Descriptor Attributes.

An increase in the alcohol category response rate yielded increases in floral and fruit category response rates retronasally (See Figure A.11 for linear regression). However, additions of ethanol at 10.25% abv did not produce an increase in the floral category response rate. Caramelized and woody category response rates demonstrated an inverse pattern in relation to fruit, floral, and alcohol category response rates. The pattern for the woody category response rate changed at 13.5% abv.

Less than 4% of variance for the wood and floral categories was caused by a change in ethanol concentration (See Figure A.11 for r-square values). Higher r-square values were found for fruit, caramelized, and alcohol categories. Approximately 19% of variance for the fruit category and 46.7% of variance for the caramelized category was due to ethanol concentration. The caramelized category response rate demonstrated a reciprocal pattern for retronasal and orthonasal smelling. If the caramelized response rate increased retronasally, it would decrease orthonasally except at 10.25% abv. Floral and alcohol displayed the same behavior until 10.25% abv was attained.

Ten percent of participants drank white wine on less than 3 occasions in the past 3 months. Thirty-eight percent of participants drank white wine between 4 and 11 times while 52% of participants drank white wine on 12 or more occasions in the past 3 months.

A contingency table with frequency counts for each response level (qualitative descriptor attributes) and cell Chi-square values can be seen for Rouge wine evaluated retronasally in Figure A.12. Out of 603 observations, 60 degrees of freedom are associated with the model. According to the Pearson Chi-square test statistic, 53.385, and the Fisher's Exact Test statistic, 53.579, qualitative descriptor attribute response probabilities were similar across the 5 wine samples.

Response probabilities for qualitative descriptor attributes can be seen in Figure 7.8. All wines had higher response probabilities for alcohol, blackberry, and cherry, and to a lesser extent vanilla, strawberry, and wood attributes. Response probabilities for blackberry and cherry remained fairly constant for most ethanol concentrations. Earth and leather attributes increased at 10.25% abv. A significant Chi-square value was only found for the ginger qualitative descriptor attribute (See Figure 7.9).

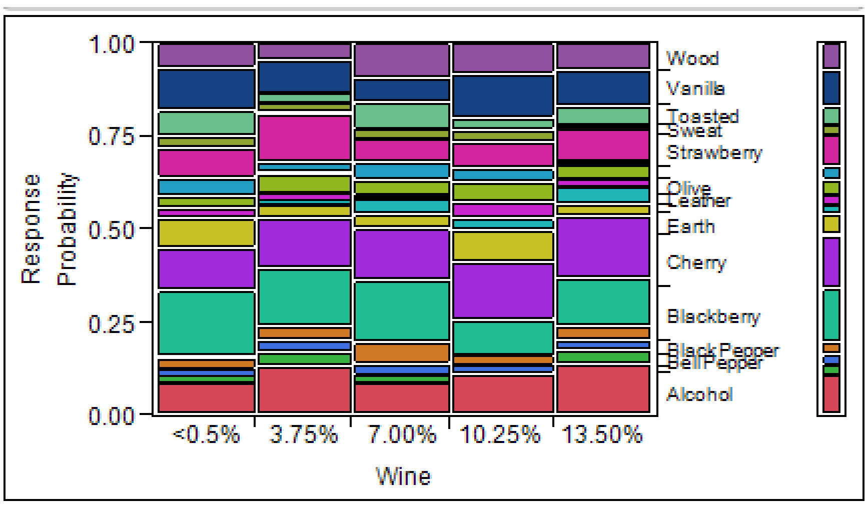


Figure 7.8: Retronasal Qualitative Descriptor Attribute Response Probabilities for Rouge Wines.

Response	ChiSquare	Prob>ChiSq
Alcohol	2.2488	0.6901
Asparagus	6.7146	0.1518
Bell Pepper	1.0270	0.9057
Black Pepper	2.3622	0.6695
Blackberry	3.7420	0.4420
Cherry	1.6735	0.7955
Earth	5.0318	0.2841
Ginger	11.4650	0.0218*
Leather	4.8086	0.3075
Olive	1.6950	0.7916
Smoke	4.5475	0.3370
Strawberry	3.3584	0.4997
Sweat	2.4057	0.6616
Toasted	3.7695	0.4381
Vanilla	2.6088	0.6253
Wood	2.6704	0.6144

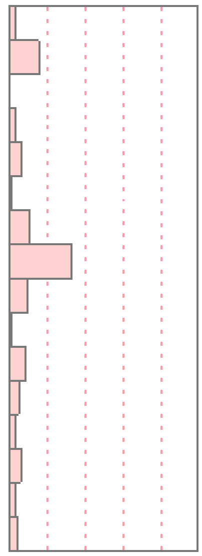


Figure 7.9: Chi-square Values for Individual Qualitative Descriptor Attribute Responses Regarding Retronasal Rouge Wine Evaluations.

The 2-dimensional plot automatically produced from the Correspondence Analysis can be seen in Figure 7.10. Approximately 93% of the variance can be explained by 3 components. Component 1 accounts for 38.8% of the variance; Component 2 accounts for 29.1% of the variance; and Component 3, which is not shown in the 2-dimensional plot, accounts for 25.1% of variance. Component 1 is related mostly to response level while Component 2 separates <0.5% abv, 3.75% abv, and 7% abv from 10.25% abv and 13.5% abv by some quality level. The three components were used to cluster related wines and response levels (See Figure A.13 for clusters). Blackberry, smoke, earth, sweat, toasted, wood, and black pepper characterized <0.5% abv and 7% abv. Strawberry and Asparagus characterized 3.75% abv. Alcohol, leather, cherry, bell pepper, olive, and vanilla characterized 10.25 %abv and 13.5% abv. Ginger was grouped by itself.

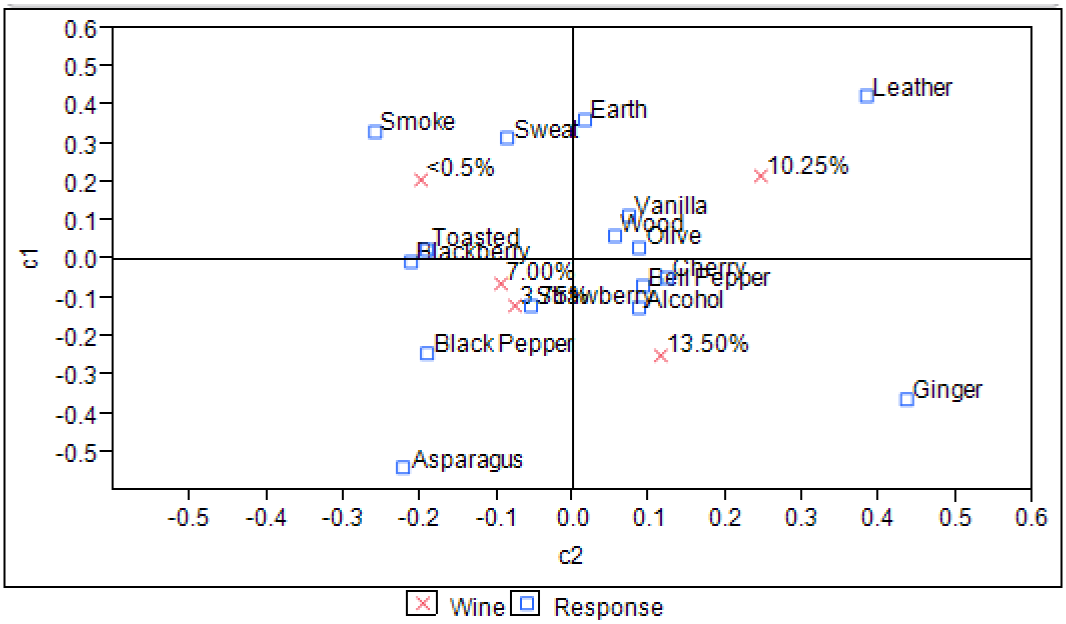


Figure 7.10: Two-dimensional Correspondence Analysis Plot for Rouge Wines and Retronasal Qualitative Descriptor Attributes.

The 16 qualitative descriptor attribute terms can be grouped into 7 categories. Five categories, earth; wood; spice; vegetative; and fruit, were based on first-tier terms of the wine aroma wheel (Noble and others 1987). Alcohol, which is a third-tier term on the wine aroma wheel (Noble and others 1987), was used to represent the alcohol category. The animal category was derived from Campo and others' (2008) qualitative descriptor attribute list. Qualitative descriptor attribute terms were assigned to the 7 categories based on third-tier terms of the wine aroma wheel (Noble and others 1987) (See Table A.12 and Table A.13 for qualitative descriptor attribute category response frequencies) and, in the case of animal attributes, Campo and others' (2008) qualitative descriptor attribute list. Thus, sweat and leather were assigned to the animal category. Earth was assigned to the earth category. Toasted, smoke, vanilla, and wood were assigned to wood category. Ginger and black pepper were assigned to the Spice category. Asparagus, bell pepper, and olive were assigned to the vegetative category. Blackberry, strawberry, and cherry were assigned to the fruit category, and alcohol was assigned to the alcohol category. In the event that a qualitative descriptor attribute term was not listed in the wine aroma wheel or the qualitative descriptor attribute list by Campo and others (2008), it was categorized based on its definition and similarity to other grouped qualitative descriptor attribute terms in a category. For example, the term "toasted" would be placed in the wood category along with terms such as smoke, oak, burnt, and vanilla instead of the fruit category with terms like cherry and strawberry.

Fruit, vegetative, and alcohol category response rates had similar response patterns until 10.25% abv was attained retronasally (See Figure A.14 for linear regression). The only ethanol concentration where the animal category response rate increased and the spice category response rate decreased was 10.25% abv. Fruit and wood category response rates showed inverse patterns.

R-square values regarding a specific qualitative descriptor attribute as a function of ethanol concentration indicate how much variance can be attributed to solely ethanol (See Figure A.14 for r-square values). For retronasal smelling, less than 5% of variance for vegetative, wood, and animal categories was caused by ethanol concentration. Relatively higher r-square values were observed for fruit, spice, earth, and alcohol categories. Less than 20% of variance was attributed to ethanol concentration for the fruit and earth categories. Approximately 48% of variance for the spice category was caused by a change in ethanol concentration. About 32% of variance for the alcohol category could be accounted for by ethanol concentration. Alcohol had similar response patterns retronasally and orthonasally except at 3.75% abv.

A contingency table with frequency counts for each response level (qualitative descriptor attributes) and cell Chi-square values can be seen for Rouge wine evaluated orthonasally in Figure A.15. Out of 686 observations, 60 degrees of freedom are associated with the model. According to the Pearson Chi-square test statistic, 62.947, and the Fisher's Exact Test statistic, 62.195, qualitative descriptor attribute response probabilities were similar across the 5 wine samples.

Response probabilities for qualitative descriptor attributes can be seen in Figure 7.11 for Rouge wines evaluated orthonasally. Higher response probabilities were observed for alcohol, blackberry, cherry, earth, and wood. Response probabilities for bell pepper remained fairly constant from 3.75% abv to 13.5% abv, except at 7% abv. Response probabilities for alcohol remained fairly constant. Cherry and blackberry character was lowest at 3.75% abv. In addition, asparagus was relatively high for 3.75% abv when compared with the remaining 4 wine samples. At 13.5% abv, the response probability for black pepper increased while the response probabilities for earth and olive decreased. A significant Chi-square value was only found for the bell pepper and wood qualitative descriptor attributes (See Figure 7.12). It should be mentioned that asparagus fell short of having a significant Chi-square value at alpha = 0.05.

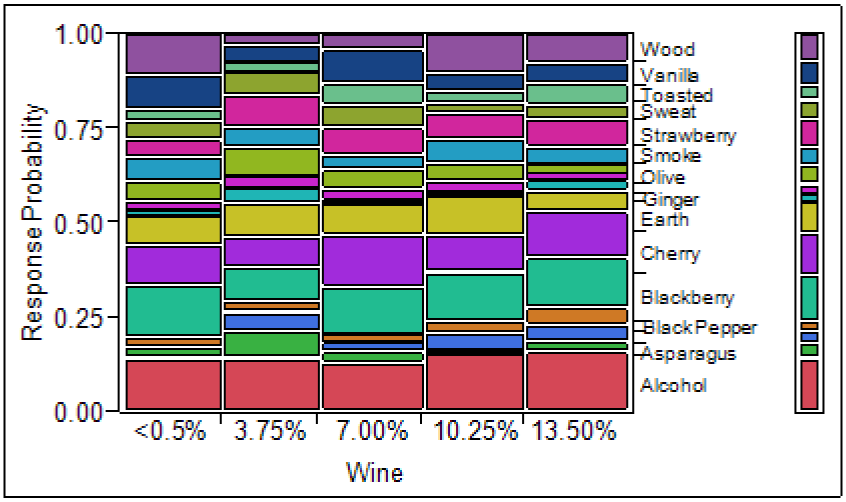


Figure 7.11: Orthonasal Qualitative Descriptor Attribute Response Probabilities for Rouge Wines.

Response	ChiSquare	Prob>ChiSq
Alcohol	0.5415	0.9693
Asparagus	9.1242	0.0581
Bell Pepper	11.1367	0.0251*
Black Pepper	2.0930	0.7187
Blackberry	2.0403	0.7283
Cherry	3.0625	0.5474
Earth	1.7275	0.7857
Ginger	7.7482	0.1013
Leather	1.5257	0.8221
Olive	4.8599	0.3020
Smoke	1.2671	0.8669
Strawberry	1.7832	0.7756
Sweat	3.1768	0.5287
Toasted	4.2490	0.3734
Vanilla	3.5402	0.4718
Wood	10.1048	0.0387*

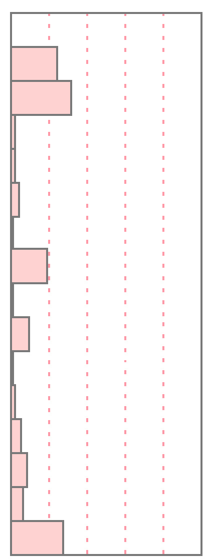


Figure 7.12: Chi-square Values for Individual Qualitative Descriptor Attribute Responses Regarding Orthonasal Rouge Wine Evaluations.

The 2-dimensional plot automatically produced from the Correspondence Analysis is shown in Figure 7.13. Three components were used to create hierarchical clusters. Approximately 89% of variance can be explained by 3 components.

Component 1 accounts for 48.7% of variance; Component 2 accounts for 20.9% of variance; and Component 3, which is not shown in the 2-dimensional plot, accounts for 19% of the variance. The 3 components were used to cluster related wines and response levels (See Figure A.16 for clusters). Earth, smoke, wood, black pepper, and ginger attributes characterized <0.5% abv, 10.25% abv, and 13.5% abv. Asparagus, olive, bell pepper, and ginger characterized 3.75% abv. Cherry, toasted, leather, sweat, and vanilla characterized 7% abv.

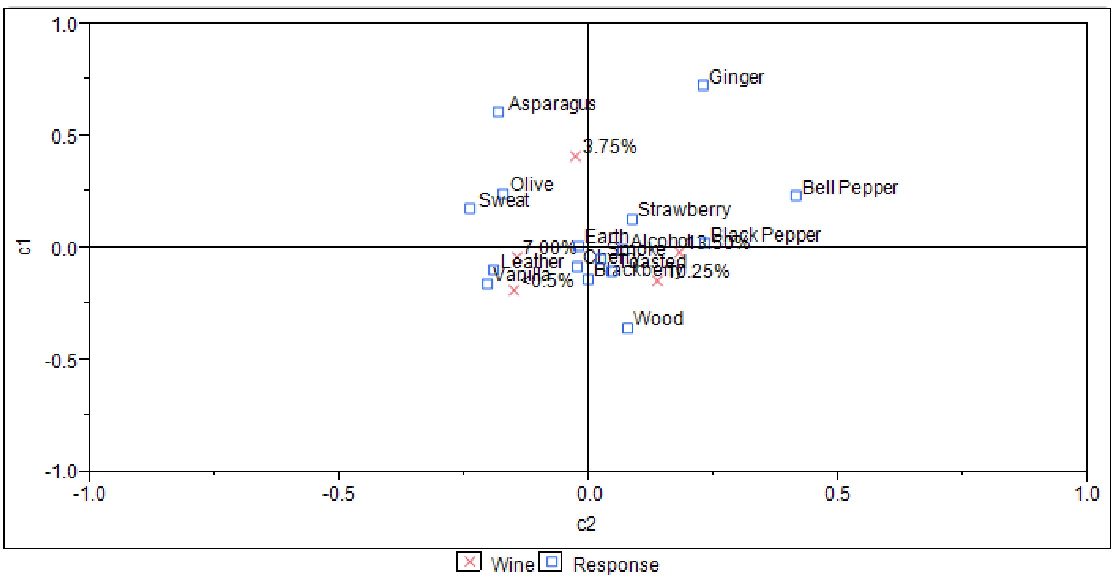


Figure 7.13: Two-dimensional Correspondence Analysis Plot for Rouge Wines and Orthonasal Qualitative Descriptor Attributes.

As for qualitative descriptor categories for orthonasal smelling, an increase in the alcohol category response rate yielded a decrease in the fruit category response rate except at the highest ethanol concentration (13.5% abv) (See Figure A.17 for linear regression). Spice and vegetative category response patterns were similar until a concentration of 10.25% abv was reached.

Less than 9% of variance for vegetative, wood, spice, and earth categories was attributed to a change in ethanol concentration (See Figure A.17 for r-square values). Fruit, animal, and alcohol categories had relatively higher r-square values. Roughly 34 % of variance for the fruit category and 43% of variance for the earth category could be accounted for by ethanol. Approximately 59% of variance for the alcohol category was attributed to ethanol concentration. Animal, earth, and fruit categories showed inverse response patterns regarding retronasal and orthonasal smelling.

Sixteen percent of participants drank red wine on less than 3 occasions in the past 3 months. Thirty-six percent of participants drank red wine between 4 and 11 times while 48% of participants drank red wine on 12 or more occasions in the past 3 months.

7.9 DISCUSSION

The basic profile for Chardonnay wine vapor-phase stimuli consisted of: apple, pear, peach, apricot, butterscotch, caramel, and alcohol character. It was surprising and unexpected that Chardonnay wines would be perceptually similar. This implies that the extent of ethanol's impact on vapor-phase stimuli perceptions in real wines may be minimal especially from a consumer perspective. While there were no significant differences in qualitative descriptor attribute response rates for Chardonnay wines, ethanol impact on vapor-phase stimuli perceptions was observed. For retronasal smelling, initial peach character transitioned to woody and yellow fruits such as apricot, peach, and mango to more tropical and caramel character as ethanol concentration increased. For orthonasal smelling, an increase in ethanol concentration yielded floral and citrus character. Although woody character was found across each ethanol concentration, tree fruits such as apple and pear, yellow fruits such as apricot and peach, and alcohol dominated higher ethanol concentrations.

Inverse response patterns of fruit and caramelized category response rates in relation to wood, floral, and alcohol category response rates indicate that alcohol could suppress fruit odor intensity retronasally. Although woody character can mask fruit character, at low fruit odor intensities wood has no influence (Grosch 2001). As Le Berre and others (2007) stated, a synergy effect of ethanol with fruit character may not hold for low alcohol concentrations. Obviously, the concentration of vapor-phase stimuli retronasally is lower than the orthonasal concentration (Linforth and others 2002). Since the caramelized category response rate increased at higher ethanol concentrations, alcohol could possibly enhance caramel character retronasally.

Grosch found that additions of ethanol to concentrations below 10% could increase odorant volatility (2001). This may hold true for floral character. At 10.25% abv, additions of ethanol did not produce an increase in the floral category response rate. However, higher ethanol concentrations did increase the response rate for the fruit category. Le Berre and others (2007) found that fruity odor intensity increased in the presence of 12% ethanol for a wine solution containing whiskey lactone and isoamyl acetate. Inverse response patterns for animal, floral, and alcohol categories support Lasekan and others findings regarding palm wine (2007). They found that dominant characteristics retronasally were the minor characteristics orthonasally. However, the fruit category showed the same response rate pattern retronasally and orthonasally until a concentration of 13.5% abv was reached. If the fruit category response rate increased retronasally, it would also increase orthonasally. The wood category response rate had the same pattern retronasally and orthonasally as well.

Low r-square values for caramelized, wood, and floral categories retronasally and wood and floral categories orthonasally indicate that another factor(s) besides ethanol concentration could have impacted response rates. For retronasal smelling, it is possible that lower activation of the olfactory system caused difficutly in vapor-phase stimuli recognitions which produced lower r-square values. For orthonasal smelling, a relatively higher r-square value for the caramelized category is indicative that ethanol concentration was a key factor affecting response rate. Ethanol concentration was the primary factor affecting the alcohol category response rate which was expected.

Regarding hierarchical clusters (See Figure A.7 and Figure A.10) produced for wines and response levels from the 2-dimensional correspondence analysis plot, the sequence of some of the most visible types of qualitative descriptor attributes (i.e. caramel and floral) located closest to a given wine retronasally were in a reversed order orthonasally (See Table 7.2).

The basic profile for Rouge wine vapor-phase stimuli consisted of blackberry, cherry, strawberry, vanilla, wood, and alcohol. It was surprising and unexpected that Rouge wines would be perceptually similar. This implies that the extent of ethanol's impact on vapor-phase stimuli perceptions in real wines may be minimal especially from a consumer perspective. Although there was no significant difference in qualitative descriptor attribute response rates across the 5 wine samples, ethanol impact on perceived vapor-phase stimuli was observed. As ethanol concentration increased for retronasal smelling, fruity character increased then disappeared. At 7% abv woody character appeared. As ethanol concentration continually increased, leather character emerged and then some fruit, vegetative, and alcohol character emerged at the highest ethanol concentration.

As for orthonasal smelling, earth and wood character was found for the lowest ethanol concentration. As ethanol concentration increased, vegetative, wood, and microbiological character emerged with little fruit. Fruit and alcohol character was observed at the highest ethanol concentration.

Even though Rouge wine response patterns were not as pronounced as response patterns for Chardonnay wine, ethanol could suppress odorant volatility of fruit attributes orthonasally. Not to mention, the alcohol category had similar response patterns retronasally and orthonasally except at 3.75% abv. Inverse response patterns were observed for fruit, earth, and animal categories regarding retronasal and orthonasal smelling. Less pronounced response patterns in Rouge wine could be due to the types of volatiles present (i.e. fruit, spice, vegetative, etc.) and the non-volatile composition. Non-volatile components in wine can impact odorant volatility (Jackson 2009).

Low r-square values for vegetative, wood, and animal categories retronasally and vegetative, wood, spice, and earth categories orthonasally indicate that another factor(s) besides ethanol concentration could have impacted response rates. For retronasal smelling, it is possible that lower activation of the olfactory system caused difficutly in vapor-phase stimuli recognitions which produced lower r-square values. For orthonasal smelling, a relatively higher r-square value for the alcohol category is indicative that ethanol concentration was a key factor affecting response rate which was to be expected.

Regarding hierarchical clusters (See Figure A.13 and A.16) produced for wines and response levels from the 2-dimensional correspondence analysis plot, the sequence of some of the most visible types of qualitative descriptor attributes (i.e. leather and earth) located closest to a given wine retronasally were in a reversed order orthonasally (See Table 7.3).

Table 7.2: Most Visible Descriptors from Hierarchical Clusters for Chardonnay Wines.

Retronasal		Orthonasal	
Wine	Descriptor	Wine	Descriptor
<0.5%	Fruit	<0.5%	Caramel
3.75%	Fruit	3.75%	Floral, Fruit
7%	Wood	7%	Wood
10.25%	Fruit	10.25%	Fruit
13.50%	Fruit, Caramel, Floral, Alcohol	13.50%	Fruit, Alcohol

Table 7.3: Most Visible Descriptors for Hierarchical Clusters Rouge Wines.

Retronasal		Orthonasal	
Wine	Descriptor	Wine	Descriptor
<0.5%	Earth, Wood, Fruit, Animal	<0.5%	Animal, Wood
3.75%	Fruit, Vegetative	3.75%	Vegetative
7%	Wood, Spice	7%	Fruit
10.25%	Animal	10.25%	Earth, Wood, Alcohol
13.50%	Vegetative, Alcohol	13.50%	Fruit, Spice, Wood, Vegetative

About a 6.5% abv difference was needed to produce increases in alcohol category response rates retronasally for Chardonnay wine and at 3.75% abv orthonasally. For Rouge wine, a 6.5% abv difference was needed to produce an increase in the alcohol category response rate at 3.75% retronasally. Orthonasally, alcohol category response rates remained fairly similar.

7.10 CONCLUSION

Ethanol enhances perceived floral and wood odor intensities retronasally but fruit and floral odor intensities orthonasally in Chardonnay wine. Ethanol enhances perceived fruit, spice, and vegetative odor intensities retronasally but earth, spice, and vegetative odors orthonasally in Rouge wine. The two routes of vapor-phase stimuli delivery (i.e. retronasal and orthonasal) produce inverse patterns of qualitative descriptor attributes for perceived vapor-phase stimuli provided by wine. Such patterns are more pronounced in Chardonnay wine than Rouge wine. As a result, retronasal and orthonasal qualitative descriptions for wine vapor-phase stimuli are not equivalent.

Animal and earth odors in Rouge wine could suppress synergistic effects of alcohol on vegetative and fruit odors retronasally. The type of vapor-phase stimuli (i.e. fruit or spice) modified by ethanol could depend on specific ethanol concentration. Understanding the impact of ethanol on vapor-phase stimuli in real wine can aid production of wines with specific desired aroma profiles and improve consumer acceptability of alcohol-removed and low alcohol content wines.

Recognizing that qualitative descriptions differ orthonasally and retronasally entails that orthonasal wine evaluations should not be used to predict wine aroma profiles or investigate volatile interactions for food/ beverage products.

CONCLUSION

As climatic changes impact grape wine production and quality, wine producers must be knowledgeable about non-volatile interactions with volatiles and volatile interactions with other volatiles. Understanding such interactions can aid in the production of specialized wines with targeted wine aroma profiles. In addition, the production of quality wine under less than optimal conditions and quality improvements for dealcoholized and low alcohol content wines may be attained.

In the event that wine adjustments are necessary to create a balanced wine or compensate for quality issues in wine, wine producers would have insight to know how such adjustments impact wine attributes such as aroma, flavor, and taste.

Since ethanol is a key wine component that can affect odorant volatility, understanding ethanol impact on volatile perceptions is vital. To investigate ethanol impact and other volatile interactions without gustatory input, a glass delivery container such as a wine glass is not appropriate. A delivery container that permits retronasal and orthonasal vapor-phase stimuli evaluations such as a 118.29mL low-density polyethylene squeeze bottle with 24mm flip-top cap should be used. While low-density polyethylene was not confirmed to alter wine vapor-phase stimuli perceptually, odorant scalping and migration should be investigated analytically to determine effects on wine volatile concentrations.

Although the appropriateness of descriptive analysis techniques for qualitative vapor-phase stimuli evaluations has been debated, consumer perceptions should be integrated more in conveying qualitative information for food/ beverage products such as wine. Trained participants and untrained participants/ consumers perceptions are not always equivalent (Roberts and Vickers 1994). Methodologies that merge the gap between unspecific qualitative information obtained by untrained participants/ consumers in discrimination tests and specific qualitative information obtained by trained participants are needed. Such methodologies should allow qualitative information to be obtained from consumers easily. A potential concept basis for such methodologies is citation frequencies. Instead of extensively training participants/ consumers to standardize responses, qualitative attribute references may be provided to give participants a field of reference on which to base judgments. Selection of attribute references would be a crucial component.

Since inverse response patterns for qualitative descriptor attributes for wine presented retronasally and orthonasally were observed for Chardonnay and Rouge wines, orthonasal wine perceptions may not be an appropriate predictor for wine aroma profiles. Retronasal evaluations may be more appropriate to determine wine aroma profiles and conduct wine aroma profile evaluations. Further research should be conducted to investigate the impact of ethanol on other types of wines since wine composition could affect vapor-phase stimuli perceptions via non-volatile and volatile interactions.

APPENDIX

Figure A.1: Recruitment Poster Used to Obtain Participants.

(A)

Complete the following sequence of procedures for the given stimulus bottle(s). Please do not look into bottle(s). Breathe normally. Please do not sniff or breathe unusually deep.

Oral-cavity-only

Instructions:

Put on your nose clip, exhaling through your mouth. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top in your mouth, and squeeze bottle 2 times. Remove flipped up portion of top from your mouth and close it. Breathe normally through your mouth with nose clip in place until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

Evaluation Questions:

1) Sample # __________

2) Is there a smell?

3) If there is a smell, describe the smell using as many descriptive words as possible. Please be as specific as possible.

4) Comments:

(B)

Retronasal

Instructions:

Inhale. Put on your nose clip. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top in your mouth, and squeeze bottle **2** times. Remove flipped up portion of top from your mouth and close it. Keep your mouth **CLOSED** and remove nose clip. Breathe normally through your nose until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

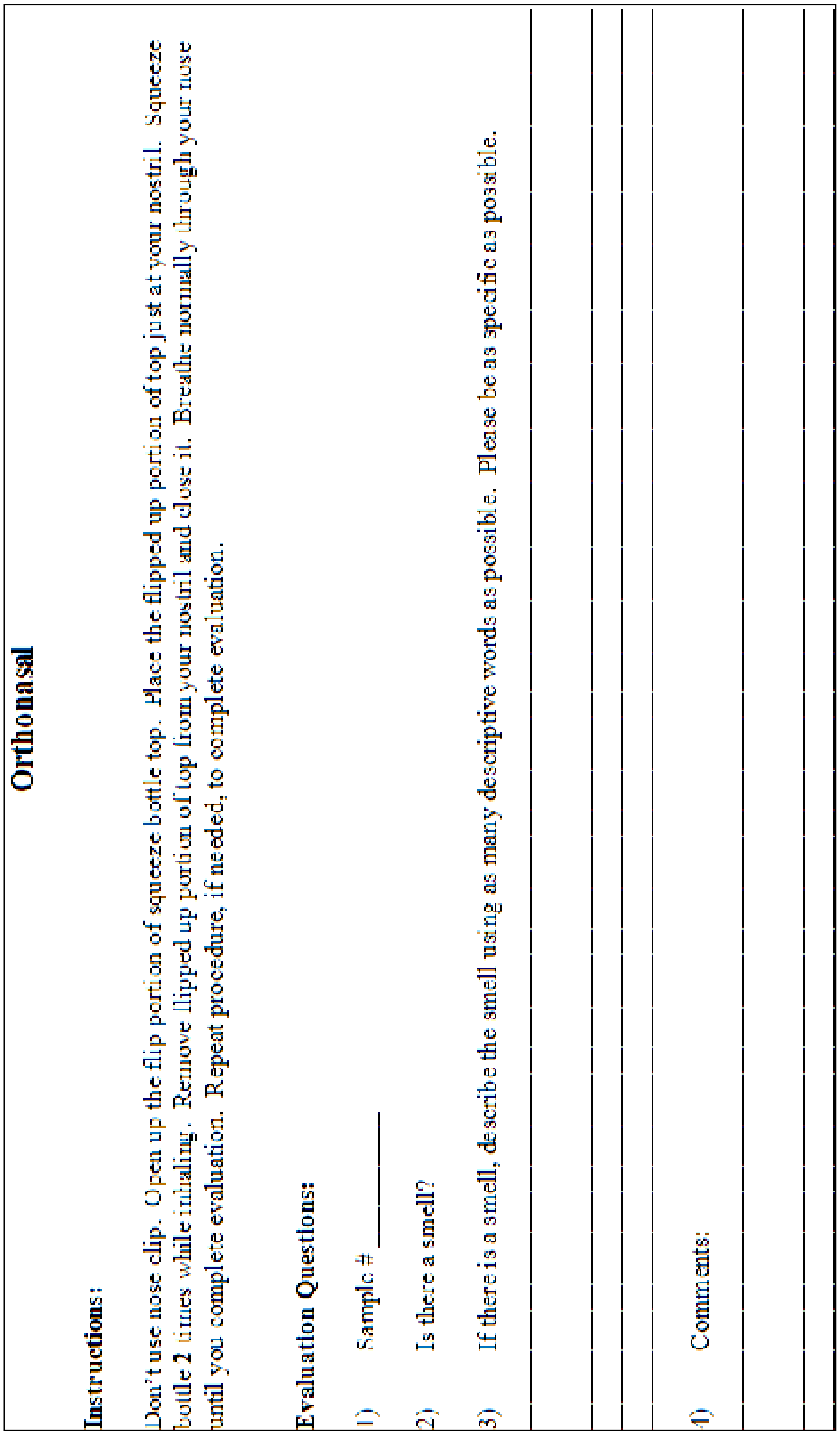
Evaluation Questions:

1) Sample # __________

2) Is there a smell?

3) If there is a smell, describe the smell using as many descriptive words as possible. Please be as specific as possible.

4) Comments:



Orthonasal

Instructions:

Don't use nose clip. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top just at your nostril. Squeeze bottle **2** times while inhaling. Remove flipped up portion of top from your nostril and close it. Breathe normally through your nose until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

Evaluation Questions:

1) Sample # ________

2) Is there a smell?

3) If there is a smell, describe the smell using as many descriptive words as possible. Please be as specific as possible.

4) Comments:

(C)

Figure A.2: Ballot 1 for Obtaining Qualitative Wine Descriptions of Chardonnay and Merlot Wines. (A) OCO. (B) Retronasal Smelling. (C) Orthonasal Smelling.

Complete the following sequence of procedures for the given stimulus bottle(s). Please do not look into bottle(s). Breathe normally. Please do not sniff or breathe unusually deep.

Oral-cavity-only

Instructions:

Put on your nose clip and exhale through your mouth. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top in your mouth, and squeeze bottle 2 times. Remove flipped up portion of top from your mouth and close it. Breathe normally through your mouth with nose clip in place until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

Evaluation Questions:

1) Sample # __________

2) Is there a smell? __________________

3) If there is a smell…
   Do you smell **fruit**? ____________ If so, what kind of fruit? ____________________________________
   Do you smell **spices**? ___________ If so, what kind of spices? ____________________________________
   Do you smell **floral**? ___________ If so, what kind of floral? ____________________________________
   Do you smell **vegetables**? _______ If so, what kind of vegetables? ________________________________
   Do you smell **nuts**? If so, what kind of nuts?
   Do you smell **alcohol**? __________ Describe smell. ____
   Do you smell **wood**? ____________ Describe smell. ____
   Do you smell **caramel**? _________ Describe smell. ____

4) If you smell anything or experience anything **not** previously mentioned, please describe below.

____
____
____

(A)

(B)

Retronasal

Instructions:

Inhale. Put on your nose clip. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top in your mouth, and squeeze bottle **2** times. Remove flipped up portion of top from your mouth and close it. Keep your mouth **CLOSED** and remove nose clip. Breathe normally through your nose until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

Evaluation Questions:

1) Sample # __________

2) Is there a smell? __________________

3) If there is a smell…

Do you smell **fruit**? If so, what kind of fruit?
Do you smell **spices**? ___________ If so, what kind of spices? ______________________________
Do you smell **floral**? ___________ If so, what kind of floral? ______________________________
Do you smell **vegetables**? _______ If so, what kind of vegetables? ____________________________
Do you smell **nuts**? If so, what kind of nuts?
Do you smell **alcohol**? __________ Describe smell. ______________________________
Do you smell **wood**? ____________ Describe smell. ______________________________
Do you smell **caramel**? _________ Describe smell. ______________________________

4) If you smell anything or experience anything **not** previously mentioned, please describe below.

____
____
____
____

Orthonasal

Instructions:

Don't use nose clip. Open up the flip portion of squeeze bottle top. Place the flipped up portion of top just at your nostril. Squeeze bottle 2 times while inhaling. Remove flipped up portion of top from your nostril and close it. Breathe normally through your nose until you complete evaluation. Repeat procedure, if needed, to complete evaluation.

Evaluation Questions:

1) Sample # ________

2) Is there a smell? ________

3) If there is a smell…

Do you smell **fruit**? ________	If so, what kind of fruit? ________
Do you smell **spices**? ________	If so, what kind of spices? ________
Do you smell **floral**? ________	If so, what kind of floral? ________
Do you smell **vegetables**? ________	If so, what kind of vegetables? ________
Do you smell **nuts**? ________	If so, what kind of nuts? ________
Do you smell **alcohol**? ________	Describe smell. ________
Do you smell **wood**? ________	Describe smell. ________
Do you smell **caramel**? ________	Describe smell. ________

4) If you smell anything or experience anything **not** previously mentioned, please describe below.

____

____

____

____

(C)

Figure A.3: Ballot 2 for Obtaining Qualitative Wine Descriptions of Chardonnay and Merlot Wines. (A) OCO. (B) Retronasal Smelling. (C) Orthonasal Smelling.

Consumer Form

Please complete the following questionnaire by selecting the response that represents your attitude for given statements or questions. You may select your response by placing an "X" in the corresponding box.

1) I am familiar with grape juice.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

2) I am familiar with red wines.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

3) I am familiar with white wines.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

4) I am familiar with non-alcoholic (less than 0.5% alcohol) wines.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

5) How often do you drink red grape juice?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

6) How often do you drink white grape juice?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

7) How often do you drink red wines?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

8) How often do you drink white wines?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

(A)

9) How often do you drink red non-alcoholic wines?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

10) How often do you drink white non-alcoholic wines?

- ☐ Very Frequently
- ☐ Frequently
- ☐ Occasionally
- ☐ Rarely
- ☐ Never

(B)

Figure A.4: Consumer Form Used to Determine Participant Familiarity and Consumption Frequency for Grape Juice, Wine, and Dealcoholized (Non-Alcoholic) Wine. (A) Front of Form. (B) Back of Form.

Table A.1: Participant Responses for OCO, Retronasal Smelling, and Orthonasal Smelling of Chardonnay Wine.

Panelist Number	Gender	Age	OCO		Retronasal Smelling		Orthonasal Smelling	
			Ballot 1	Ballot 2	Ballot 1	Ballot 2	Ballot 1	Ballot 2
1	M	29	0	0	0	0	1	1
2	M	26	0	0	1	1	1	1
3	F	21	0	0	1	1	1	1
4	F	21	0	0	1	1	1	1
5	F	21	0	0	*	*	1	1
6	M	21	0	*	*	*	1	1
7	M	21	1	0	0	0	1	1
8	F	21	1	0	0	1	1	1
9	F	22	0	0	0	0	1	1
10	F	21	0	0	0	0	1	1
11	F	25	0	0	1	1	1	1
12	M	21	0	0	0	1	1	1
13	F	21	0	0	1	1	1	1
14	M	21	0	0	1	1	1	1
15	F	25	0	0	1	1	1	1
16	F	21	0	0	0	1	1	1
17	F	21	0	0	1	1	1	1
18	M	22	0	0	0	1	1	1
19	F	21	0	0	0	0	1	1
20	F	21	0	0	0	0	1	1
21	M	24	0	0	1	1	1	1
22	F	21	0	0	1	1	1	1
23	M	32	1	0	1	0	1	1
24	M	21	0	0	1	1	1	1
25	F	21	0	0	0	0	1	1
26	F	21	0	0	1	1	1	1
27	M	22	0	0	0	0	1	1
28	F	21	0	0	1	1	1	1
29	F	21	1	0	1	1	1	1
30	M	21	0	0	1	1	1	1
31	M	21	0	1	1	1	1	1
32	M	21	0	0	1	1	1	1
33	F	21	1	0	0	1	1	1
Total Response Counts			5	1	18	22	33	33

For gender, "M" represents male, and "F" represents female. For columns, "1" indicates the wine stimulus was smelled, "0" indicates that a wine stimulus was not smelled, and an asterisk (*****) represents an inconclusive response. Inconclusive responses were considered to be "0".

Table A.2: Participant Responses for OCO, Retronasal Smelling, and Orthonasal Smelling of Merlot Wine.

Panelist Number	Gender	Age	OCO		Retronasal Smelling		Orthonasal Smelling	
			Ballot 1	Ballot 2	Ballot 1	Ballot 2	Ballot 1	Ballot 2
1	M	29	0	0	0	0	1	1
2	M	26	0	0	1	1	1	1
3	F	21	0	0	1	1	1	1
4	F	21	0	0	1	1	1	1
5	F	21	*	0	*	*	1	1
6	M	21	0	*	*	1	1	1
7	M	21	0	0	0	1	0	1
8	F	21	0	0	0	0	1	1
9	F	22	0	0	0	0	1	1
10	F	21	0	0	0	0	1	1
11	F	25	0	0	0	1	1	1
12	M	21	0	0	0	1	1	1
13	F	21	0	0	1	1	1	1
14	M	21	0	0	1	1	1	1
15	F	25	0	0	1	1	1	1
16	F	21	0	0	1	1	1	1
17	F	21	0	0	0	1	1	1
18	M	22	1	0	1	0	1	1
19	F	21	0	0	1	1	1	1
20	F	21	0	0	0	0	1	1
21	M	24	0	0	1	1	1	1
22	F	21	0	0	1	1	1	1
23	M	32	1	1	1	0	1	1
24	M	21	0	0	1	1	1	1
25	F	21	0	0	0	0	1	1
26	F	21	0	0	1	1	1	1
27	M	22	0	0	1	0	1	1
28	F	21	0	1	1	1	1	1
29	F	21	0	1	1	1	1	1
30	M	21	0	0	0	1	1	1
31	M	21	0	0	1	1	1	1
32	M	21	0	0	1	1	1	1
33	F	21	0	0	1	1	1	1
Total Response Counts			2	3	20	23	32	33

For gender, "M" represents male, and "F" represents female. For columns, "1" indicates the wine stimulus, was smelled, "0" indicates the wine stimulus was not smelled, and an asterisk (*****) represents an inconclusive response. Inconclusive responses were considered to be “0”.

Table A.3: Qualitative Descriptor Attribute Frequency Counts for Chardonnay and Merlot Wines.

Descriptors			Response Frequency Counts			
			Chardonnay Wine		Merlot Wine	
Tier 1	Tier 2	Tier 3	Ballot 1	Ballot 2	Ballot 1	Ballot 2
Fruity						
	Citrus	Citrus	2	2	3	3
		Orange	2	2	3	2
		Lemon	1	0	2	0
	Berry	Berry	1	1	1	2
		Strawberry	2	0	1	1
		Lychee	0	1	0	1
		Grape	3	7	5	11
	Tree	Cherry	3	1	1	2
		Apple	1	2	1	7
		Plum	0	1	1	1
		Peach	1	0	0	0
		Currant	0	0	0	1
		Apricot	0	0	0	1
		Tomato	0	0	0	1
	Tropical	Tropical	0	1	1	0
		Pineapple	0	1	0	0
		Pear	0	0	0	1
		Coconut	0	0	1	0
	Dried	Raisins	0	0	1	0
	Other	Fruity	3	2	5	0
		Dark fruit	1	0	0	0
		Fermented fruit	1	0	0	0
Vegetative		Vegetable	0	1	0	1
		Mint	2	2	0	1
		Carrots	0	1	0	1
		Cauliflower	0	1	0	0
		Celery	0	0	0	1
		Egg Plant	0	0	0	1
		Dark Green Veggies	0	0	0	1
		Wheat	1	0	0	0
Nutty		Nutty	2	1	1	0
		Almonds	1	2	1	0
		Peanuts	1	1	0	1
		Hazelnut	0	0	0	1
Sweet		Sweet	7	4	12	4
	Caramel	Caramel	3	12	0	12
		Butterscotch	1	0	1	0
		Syrup	1	1	0	1
		Butter	0	1	0	1
		Chocolate	7	3	3	3

		Sugar	0	2	1	0
	Other	Candy	1	3	0	1
		Doughnut	0	0	0	1
		Cake	1	0	0	0
		Pancake	1	0	0	0
Woody		Wood	0	3	2	4
	Resinous	Pine	0	0	0	1
		Oak	2	3	0	3
		Vanilla	2	3	1	0
	Burned	Roasted	1	0	1	0
		Coffee	8	2	5	1
		Smoke	1	0	0	0
Earthy		Earth	0	0	1	0
		Mineral	0	0	1	1
Chemical						
		Potent	0	0	1	0
		Leather	0	0	1	0
	Sulfur	Sulfur	1	1	0	1
	Pungent	Alcohol	4	18	2	23
		Vinegar	2	0	1	1
Pungent		Pungent	0	2	1	0
		Acidic	1	0	0	0
		Cool	1	0	0	0
Microbiological						
	Yeast	Yeast	1	0	1	1
		Bread	1	1	3	2
		Dough	3	0	1	0
	Lactic	Must	1	0	0	0
		Cheese	1	0	0	0
		Milk	0	0	0	1
		Sour	2	1	1	2
Floral		Floral	0	7	1	8
Spicy		Spice	1	3	0	6
		Rosemary	0	1	0	1
		Oregano	0	1	0	1
		Cinnamon	0	1	0	1
		Pepper	0	2	0	0
		Salty	0	1	0	0
Other		Fresh	1	0	0	0
		Artificial	1	1	0	0
		Rich	1	0	2	0
		Sharp	1	0	0	0
		Ripe	0	0	1	0
		Stale	0	0	2	0
		Bitter	0	0	1	0
		Tannins	0	0	1	0
		Gross	1	0	1	1
	Beverages	Wine	2	1	1	0
		Red Wine	5	3	3	3

Light/ White Wine	1	0	1	1
Brandy	0	1	0	0
Vodka	0	1	0	0
Sangria	0	0	1	0
Total Responses	96	113	83	128

Table A.4: Participant Responses for Retronasal and Orthonasal Triangle Tests Involving Cabernet Sauvignon Wine Incubated in Low-density Polyethylene and a Wine Glass.

Panelist Number	Gender	Age	Retronasal Smelling Responses	Orthonasal Smelling Responses
1	M	21	0	0
2	F	21	1	1
3	M	21	1	0
4	M	21	0	0
5	F	21	0	0
6	F	21	0	0
7	F	21	0	1
8	F	21	1	1
9	F	22	0	1
10	F	21	0	0
11	F	21	0	1
12	F	21	0	0
13	F	22	0	0
14	F	21	0	1
15	F	25	0	0
16	F	21	1	1
17	F	31	0	1
18	M	21	0	1
19	M	30	0	0
20	M	21	1	1
21	F	21	0	0
22	F	21	1	1
23	M	21	1	1
24	F	21	0	0
25	F	21	0	0
Total Correct Responses			7	12

For Gender, "M" represents male, and "F" represents female. For columns, "1" represents a correct response, and "0" represents an incorrect response.

Table A.5: Participant Responses for Retronasal and Orthonasal Triangle Tests Involving an Alcoholic and Dealcoholized Version of a Wine.

Panelist Number	Gender	Age	Retronasal Smelling Responses	Orthonasal Smelling Responses
1	21	M	1	0
2	21	F	1	1
3	21	F	0	0
4	21	F	0	1
5	21	F	0	0
6	21	M	1	0
7	23	F	1	0
8	21	M	0	0
9	22	F	1	1
10	22	F	0	1
11	22	F	0	0
12	21	F	0	0
13	21	M	0	0
14	21	F	1	0
15	21	F	1	0
16	23	M	0	1
17	21	M	1	0
18	26	M	0	1
19	23	M	1	1
20	21	M	0	0
21	21	F	1	0
22	24	M	0	0
23	21	M	0	1
24	22	F	1	0
25	23	F	1	1
26	21	F	0	0
27	21	F	1	0
28	21	F	0	1
29	21	M	0	0
30	22	F	0	1
31	22	F	0	0
32	21	F	0	1
33	21	F	1	1
Total Correct Responses			14	13

For Gender, "M" represents male, and "F" represents female. For columns, "1" represents a correct response, and "0" represents an incorrect response.

Table A.6: Participant Responses for Retronasal and Orthonasal Triangle Tests Involving Alcoholic and Dealcoholized Wines Bottled for Retail.

Panelist Number	Gender	Age	Retronasal Smelling Responses	Orthonasal Smelling Responses
1	57	F	0	1
2	52	F	1	0
3	35	F	1	0
4	21	F	1	1
5	21	M	0	1
6	21	F	1	1
7	21	M	1	1
8	23	F	0	1
9	21	F	1	1
10	21	M	1	1
11	36	M	1	0
12	21	M	1	1
13	21	M	1	1
14	21	F	0	1
15	21	F	1	1
16	21	F	0	1
17	21	F	1	1
18	21	M	1	1
19	21	F	1	1
20	26	F	0	0
21	23	F	1	1
22	21	F	0	0
23	22	F	1	1
24	23	M	1	0
25	21	M	1	1
26	27	F	0	1
27	22	M	1	1
28	21	M	1	1
29	21	F	1	1
30	21	F	0	0
31	21	F	1	1
32	21	M	0	1
33	21	M	0	0
Total Correct Responses			22	25

For Gender, "M" represents male, and "F" represents female. For columns, “1” represents a correct response, and "0" represents an incorrect response.

Table A.7: Participant Responses for Orthonasal Triangle Tests Involving Alcoholic and Dealcoholized Wines Bottled for Retail Presented in Squeeze Bottles and Wine Glasses.

Panelist Number	Gender	Age	Wine Glass Discrimination	Squeeze Bottle Discrimination
1	21	M	1	1
2	21	F	1	1
3	21	M	1	0
4	21	M	1	1
5	21	F	1	1
6	21	F	0	1
7	21	F	0	0
8	21	F	1	1
9	22	F	0	1
10	21	F	1	0
11	21	F	1	0
12	21	F	0	0
13	22	F	1	1
14	21	F	1	1
15	25	F	1	1
16	21	F	1	1
17	31	F	0	0
18	21	M	1	1
19	30	M	1	1
20	21	M	1	0
21	21	F	1	1
22	21	F	1	1
23	21	M	1	1
24	21	F	1	1
25	21	F	0	0
26	21	F	0	0
27	33	M	1	0
28	22	F	1	1
29	21	F	1	1
30	21	F	1	1
Total Correct Responses			23	20

For Gender, "M" represents male, and "F" represents female. For columns, "1" represents a correct response, and "0" represents an incorrect response.

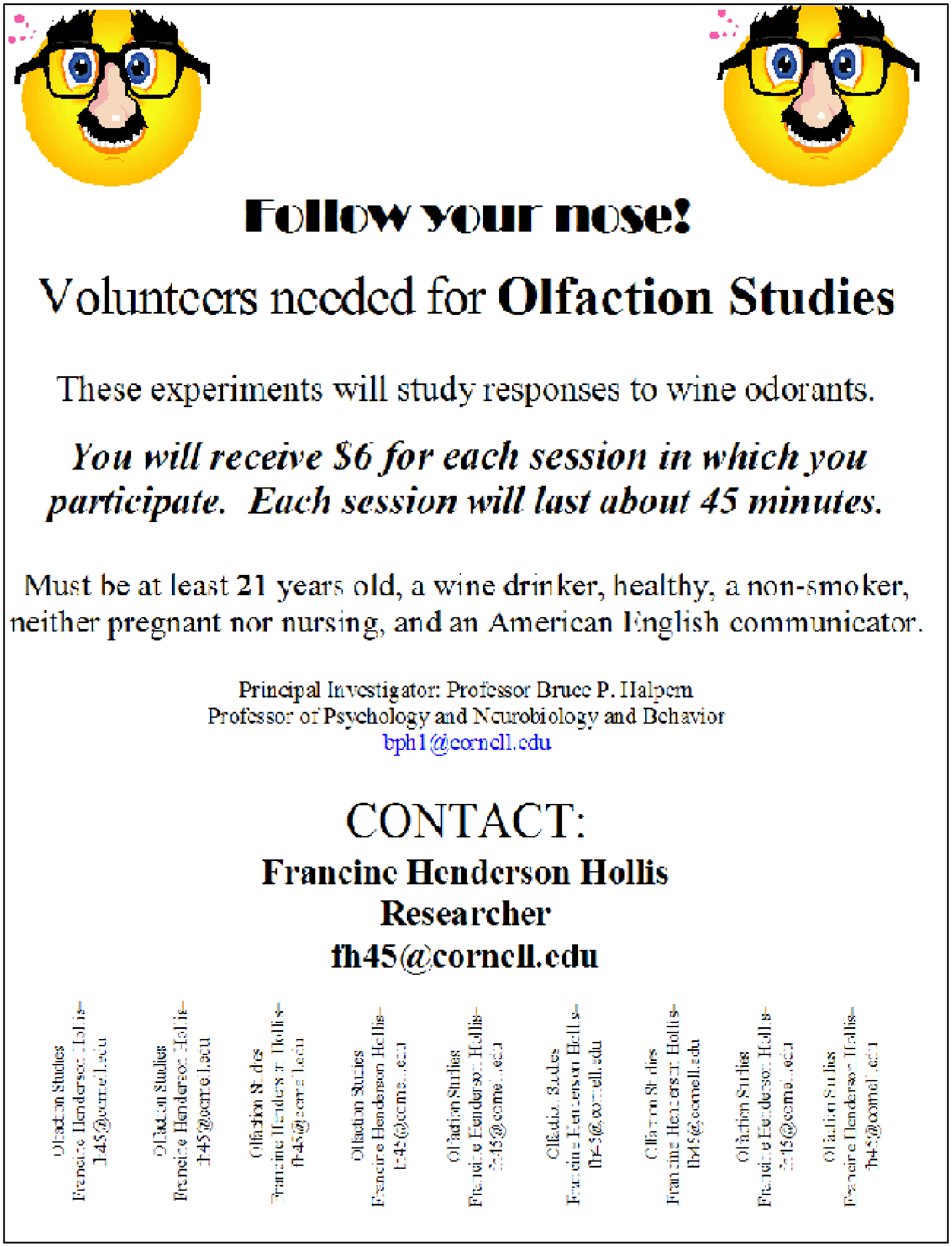


Figure A.5: Recruitment Poster Used to Obtain Wine Consumers.

Table A.8: Ariel Chardonnay Concentrate Analysis Results.

Analysis		Result
pH		3.1
Titratable Acidity		6.9 g/L
Glucose		2.7 g/L
Fructose		1.3 g/L
Residual Sugar		0.4 %w/v
Ethanol		<0.5 %w/v
Organic Acids:		
	Tartrate	2.0 g/L
	Malate	3.1 g/L
	Lactate	1.0 g/L
	Acetate	0.1 g/L
Free SO_2		20.3 mg/L
Total SO_2		187.4 mg/L

Table A.9: Ariel Rouge Concentrate Analysis Results.

Analysis		Result
pH		3.28
Titratable Acidity		13.5 g/L
Glucose		1.4 g/L
Fructose		5.0 g/L
Residual Sugar		0.6 %w/v
Ethanol		<0.5 %v/v
Organic Acids:		
	Tartrate	5.5 g/L
	Malate	2.1 g/L
	Lactate	3.5 g/L
	Acetate	0.1 g/L
Free SO_2		26.0 mg/L
Total SO_2		213.4 mg/L

Contingency Table

Wine	Response																			
Count Total % Col % Row % Cell Chi^2	Alcohol	Apple	Apricot	Banana	Butter	Butterscotch	Caramel	Coconut	Floral	Lemon	Mango	Orange	Peach	Pear	Pineapple	Smoke	Toasted	Vanilla	Wood	
<0.5%	13	17	10	3	7	4	7	2	8	3	3	2	8	12	7	5	5	9	3	128
	2.10	2.74	1.61	0.48	1.13	0.65	1.13	0.32	1.29	0.48	0.48	0.32	1.29	1.94	1.13	0.81	0.81	1.45	0.48	20.65
	19.70	25.76	19.23	17.65	24.14	11.11	21.88	15.38	29.63	15.79	17.65	11.11	21.05	26.67	22.58	23.81	21.74	17.31	16.67	
	10.16	13.28	7.81	2.34	5.47	3.13	5.47	1.56	6.25	2.34	2.34	1.56	6.25	9.38	5.47	3.91	3.91	7.03	2.34	
	0.0287	0.8356	0.0504	0.0740	0.1714	1.5850	0.0234	0.1743	1.0557	0.2170	0.0740	0.7925	0.0031	0.7903	0.0562	0.1019	0.0133	0.2806	0.1380	
3.75%	12	14	15	4	6	9	9	3	3	3	3	7	7	8	7	1	2	12	3	128
	1.94	2.26	2.42	0.65	0.97	1.45	1.45	0.48	0.48	0.48	0.48	1.13	1.13	1.29	1.13	0.16	0.32	1.94	0.48	20.65
	18.18	21.21	28.85	23.53	20.69	25.00	28.13	23.08	11.11	15.79	17.65	38.89	18.42	17.78	22.58	4.76	8.70	23.08	16.67	
	9.38	10.94	11.72	3.13	4.69	7.03	7.03	2.34	2.34	2.34	2.34	5.47	5.47	6.25	5.47	0.78	1.56	9.38	2.34	
	0.1940	0.0103	1.6940	0.0685	0.0000	0.3307	0.8672	0.0372	1.1888	0.2170	0.0740	2.9019	0.0910	0.1792	0.0562	2.5661	1.5908	0.1489	0.1380	
7.00%	13	15	10	2	3	7	7	0	4	4	5	3	7	8	4	7	4	14	6	123
	2.10	2.42	1.61	0.32	0.48	1.13	1.13	0.00	0.65	0.65	0.81	0.48	1.13	1.29	0.65	1.13	0.65	2.26	0.97	19.84
	19.70	22.73	19.23	11.76	10.34	19.44	21.88	0.00	14.81	21.05	29.41	16.67	18.42	17.78	12.90	33.33	17.39	26.92	33.33	
	10.57	12.20	8.13	1.63	2.44	5.69	5.69	0.00	3.25	3.25	4.07	2.44	5.69	6.50	3.25	5.69	3.25	11.38	4.88	
	0.0007	0.2776	0.0097	0.5586	1.3176	0.0028	0.0669	2.5790	0.3435	0.0141	0.7853	0.0913	0.0385	0.0963	0.7516	1.9276	0.0694	1.3155	1.6523	
10.25%	11	16	9	4	5	7	5	5	3	3	3	1	11	9	5	4	7	8	2	118
	1.77	2.58	1.45	0.65	0.81	1.13	0.81	0.81	0.48	0.48	0.48	0.16	1.77	1.45	0.81	0.65	1.13	1.29	0.32	19.03
	16.67	24.24	17.31	23.53	17.24	19.44	15.63	38.46	11.11	15.79	17.65	5.56	28.95	20.00	16.13	19.05	30.43	15.38	11.11	
	9.32	13.56	7.63	3.39	4.24	5.93	4.24	4.24	2.54	2.54	2.54	0.85	9.32	7.63	4.24	3.39	5.93	6.78	1.69	
	0.1941	0.9414	0.0813	0.1806	0.0489	0.0032	0.1952	2.5785	0.8901	0.1050	0.0171	1.7177	1.9629	0.0221	0.1373	0.0000	1.5712	0.3635	0.5934	
13.50%	17	4	8	4	8	9	4	3	9	6	3	5	5	8	8	4	5	9	4	123
	2.74	0.65	1.29	0.65	1.29	1.45	0.65	0.48	1.45	0.97	0.48	0.81	0.81	1.29	1.29	0.65	0.81	1.45	0.65	19.84
	25.76	6.06	15.38	23.53	27.59	25.00	12.50	23.08	33.33	31.58	17.65	27.78	13.16	17.78	25.81	19.05	21.74	17.31	22.22	
	13.82	3.25	6.50	3.25	6.50	7.32	3.25	2.44	7.32	4.88	2.44	4.07	4.07	6.50	6.50	3.25	4.07	7.32	3.25	
	1.1655	6.3155	0.5200	0.1167	0.8774	0.4834	0.8687	0.0687	2.4784	1.3201	0.0412	0.5719	0.8549	0.0963	0.5565	0.0066	0.0419	0.1679	0.0515	
	66	66	52	17	29	36	32	13	27	19	17	18	38	45	31	21	23	52	18	620
	10.65	10.65	8.39	2.74	4.68	5.81	5.16	2.10	4.35	3.06	2.74	2.90	6.13	7.26	5.00	3.39	3.71	8.39	2.90	

N	DF	-LogLike	RSquare (U)
620	72	31.979320	0.0182

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	63.959	0.7391
Pearson	58.924	0.8659

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Chi-Square Tests

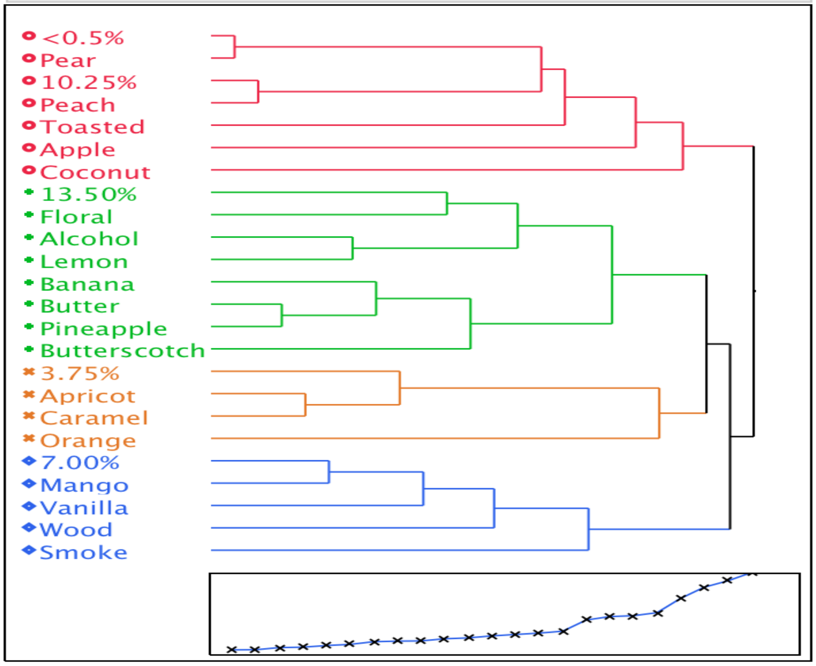
	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Pearson Chi-Square	58.924	72	.866	.870	.862	.879
Likelihood Ratio	63.959	72	.739	.816	.806	.826
Fisher's Exact Test	59.593			.829	.820	.839
N of Valid Cases	620					

Figure A.6: Contingency Table for Retronasal Qualitative Descriptor Attribute Responses for Chardonnay Wines.

Hierarchical Clustering

Method = Ward

Dendrogram



Clustering History

Number of Clusters	Distance	Leader	Joiner
23	0.212895002	<0.5%	Pear
22	0.221664064	10.25%	Peach
21	0.327929841	Butter	Pineapple
20	0.347974972	Apricot	Caramel
19	0.428180904	7.00%	Mango
18	0.485060603	Alcohol	Lemon
17	0.617909097	Banana	Butter
16	0.645407801	3.75%	Apricot
15	0.654780993	7.00%	Vanilla
14	0.762104516	13.50%	Floral
13	0.804731199	Banana	Butterscotch
12	0.903419996	7.00%	Wood
11	0.972001235	13.50%	Alcohol
10	1.039951429	<0.5%	10.25%
9	1.132521267	<0.5%	Toasted
8	1.683094900	7.00%	Smoke
7	1.853671627	13.50%	Banana
6	1.896472003	<0.5%	Apple
5	2.045097433	3.75%	Orange
4	2.747838889	<0.5%	Coconut
3	3.299064540	13.50%	3.75%
2	3.611786371	13.50%	7.00%
1	4.018750641	<0.5%	13.50%

Figure A.7: Hierarchical Clustering of Chardonnay Wines and Retronasal Qualitative Descriptor Attributes.

Table A.10: Retronasal Qualitative Descriptor Category Response Frequency Count for Chardonnay Wine.

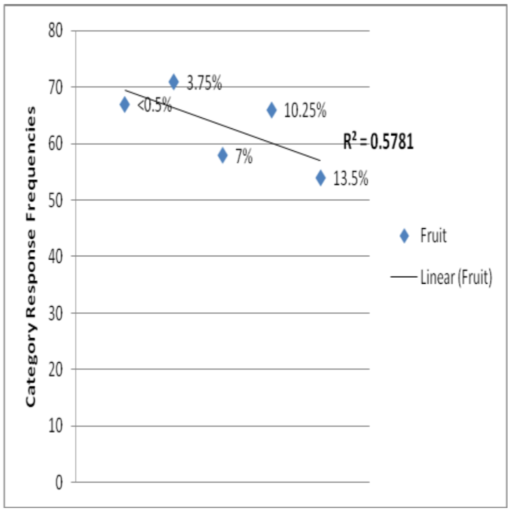
Descriptor Category	Descriptor Attribute	Wine				
		<0.5% abv	3.75% abv	7% abv	10.25% abv	13.5% abv
Fruit:						
	Apple	17	14	15	16	4
	Apricot	10	15	10	9	8
	Banana	3	4	2	4	4
	Coconut	2	3	0	5	3
	Lemon	3	3	4	3	6
	Mango	3	3	5	3	3
	Orange	2	7	3	1	5
	Peach	8	7	7	11	5
	Pear	12	8	8	9	8
	Pineapple	7	7	4	5	8
Total Frequency Count		67	71	58	66	54
Caramelized:						
	Butter	7	6	3	5	8
	Butterscotch	4	9	7	7	9
	Caramel	7	9	7	5	4
Total Frequency Count		18	24	17	17	21
Wood:						
	Smoke	5	1	7	4	4
	Toasted	5	2	4	7	5
	Vanilla	9	12	14	8	9
	Wood	3	3	6	2	4
Total Frequency Count		22	18	31	21	22
Floral:						
	Floral	8	3	4	3	9
Total Frequency Count		8	3	4	3	9
Alcohol:						
	Alcohol	13	12	13	11	17
Total Frequency Count		13	12	13	11	17

For each category, specific qualitative descriptor attribute response frequencies are listed.

Table A.11: Orthonasal Qualitative Descriptor Category Response Frequency Count for Chardonnay Wine.

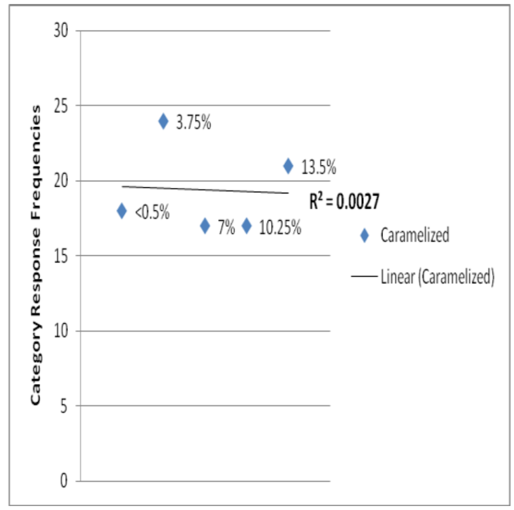
Descriptor Category	Descriptor Attribute	Wine				
		<0.5% abv	3.75% abv	7% abv	10.25% abv	13.5% abv
Fruit:						
	Apple	14	17	13	19	19
	Apricot	9	8	4	12	7
	Banana	4	6	5	4	5
	Coconut	2	2	3	0	5
	Lemon	4	11	7	3	7
	Mango	3	5	5	3	0
	Orange	4	3	9	3	4
	Peach	10	8	6	11	11
	Pear	9	7	5	9	7
	Pineapple	6	3	3	6	7
Total Frequency Count		65	70	60	70	72
Caramelized:						
	Butter	10	6	11	8	5
	Butterscotch	14	8	10	5	5
	Caramel	13	7	11	11	9
Total Frequency Count		37	21	32	24	19
Wood:						
	Smoke	4	2	1	4	6
	Toasted	4	4	7	4	3
	Vanilla	12	8	11	5	9
	Wood	6	4	8	8	5
Total Frequency Count		26	18	27	21	23
Floral:						
	Floral	3	7	5	5	3
Total Frequency Count		3	7	5	5	3
Alcohol:						
	Alcohol	12	19	18	29	32
Total Frequency Count		12	19	18	29	32

For each category, specific qualitative descriptor attribute response frequencies are listed.



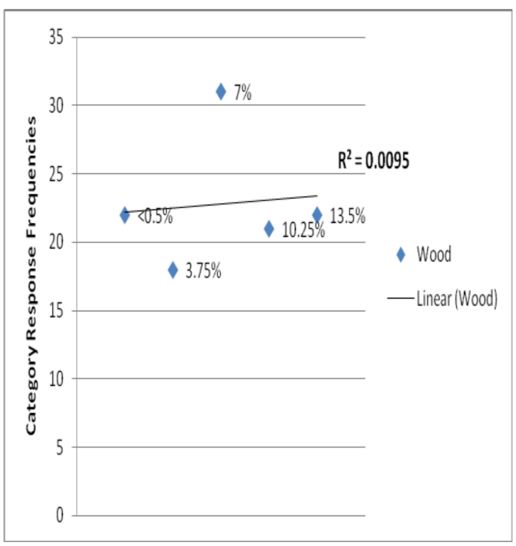
Category Response Frequencies
80
70
60
50
40
30
20
10
0
3.75%
<0.5%
10.25%
7%
13.5%
R² = 0.5781
Fruit
Linear (Fruit)

(A)



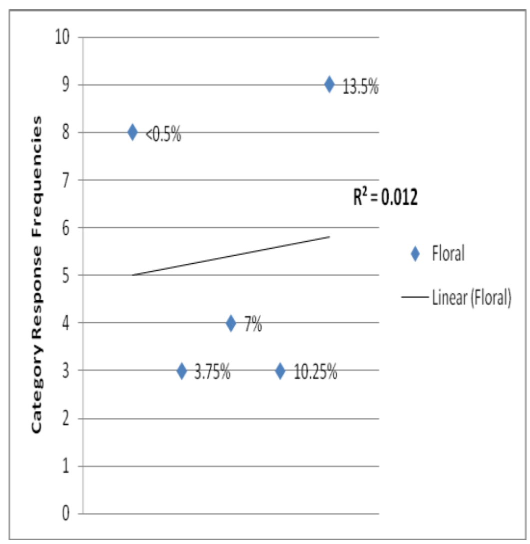
Category Response Frequencies
30
25
20
15
10
5
0
3.75%
13.5%
<0.5%
7%
10.25%
R² = 0.0027
Caramelized
Linear (Caramelized)

(B)



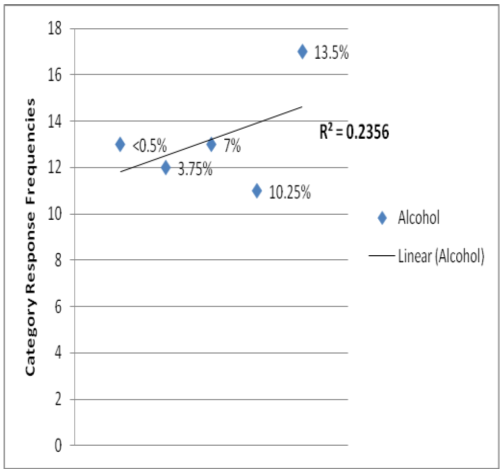
Category Response Frequencies
35
30
25
20
15
10
5
0
7%
R² = 0.0095
<0.5%
13.5%
10.25%
3.75%
Wood
Linear (Wood)

(C)



Category Response Frequencies
10
9
8
7
6
5
4
3
2
1
0
13.5%
<0.5%
R² = 0.012
Floral
Linear (Floral)
7%
3.75%
10.25%

(D)



(E)

Figure A.8: Linear Regression of Chardonnay Wines (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv) Regarding Retronasal Qualitative Descriptor Attribute Categories. (A) Fruit Category. (B) Caramelized Category. (C) Wood Category. (D) Floral Category. (E) Alcohol Category.

Contingency Table

Response

Wine	Count / Total % / Col % / Row % / Cell Chi^2	Alcohol	Apple	Apricot	Banana	Butter	Butterscotch	Caramel	Coconut	Floral	Lemon	Mango	Orange	Peach	Pear	Pineapple	Smoke	Toasted	Vanilla	Wood	
<0.5%	Count	12	14	9	4	10	14	13	2	3	4	3	4	10	9	6	4	4	12	6	143
	Total %	1.67	1.95	1.25	0.56	1.39	1.95	1.81	0.28	0.42	0.56	0.42	0.56	1.39	1.25	0.84	0.56	0.56	1.67	0.84	19.92
	Col %	10.91	17.07	22.50	16.67	25.00	33.33	25.49	16.67	13.04	12.50	18.75	17.39	21.74	24.32	24.00	23.53	18.18	26.67	19.35	
	Row %	8.39	9.79	6.29	2.80	6.99	9.79	9.09	1.40	2.10	2.80	2.10	2.80	6.99	6.29	4.20	2.80	2.80	8.39	4.20	
	Cell Chi^2	4.4810	0.3328	0.1341	0.1273	0.5190	3.7961	0.7955	0.0636	0.5455	0.8837	0.0109	0.0736	0.0767	0.3610	0.2093	0.1114	0.0332	1.0295	0.0049	
3.75%	Count	19	17	8	6	6	8	7	2	7	11	5	3	8	7	3	2	4	8	4	135
	Total %	2.65	2.37	1.11	0.84	0.84	1.11	0.97	0.28	0.97	1.53	0.70	0.42	1.11	0.97	0.42	0.28	0.56	1.11	0.56	18.80
	Col %	17.27	20.73	20.00	25.00	15.00	19.05	13.73	16.67	30.43	34.38	31.25	13.04	17.39	18.92	12.00	11.76	18.18	17.78	12.90	
	Row %	14.07	12.59	5.93	4.44	4.44	5.93	5.19	1.48	5.19	8.15	3.70	2.22	5.93	5.19	2.22	1.48	2.96	5.93	2.96	
	Cell Chi^2	0.1369	0.1624	0.0305	0.4903	0.3076	0.0013	0.6991	0.0291	1.6553	4.1274	1.3185	0.4057	0.0487	0.0003	0.6152	0.4478	0.0045	0.0251	0.5737	
7.00%	Count	18	13	4	5	11	10	11	3	5	7	5	9	6	5	3	1	7	11	8	142
	Total %	2.51	1.81	0.56	0.70	1.53	1.39	1.53	0.42	0.70	0.97	0.70	1.25	0.84	0.70	0.42	0.14	0.97	1.53	1.11	19.78
	Col %	16.36	15.85	10.00	20.83	27.50	23.81	21.57	25.00	21.74	21.88	31.25	39.13	13.04	13.51	12.00	5.88	31.82	24.44	25.81	
	Row %	12.68	9.15	2.82	3.52	7.75	7.04	7.75	2.11	3.52	4.93	3.52	6.34	4.23	3.52	2.11	0.70	4.93	7.75	5.63	
	Cell Chi^2	0.6481	0.6383	1.9334	0.0135	1.2063	0.3453	0.0828	0.1655	0.0448	0.0712	1.0649	4.3559	1.0546	0.7340	0.7646	1.6595	1.6128	0.4957	0.5698	
10.25%	Count	29	19	12	4	8	5	11	0	5	3	3	3	11	9	6	4	4	5	8	149
	Total %	4.04	2.65	1.67	0.56	1.11	0.70	1.53	0.00	0.70	0.42	0.42	0.42	1.53	1.25	0.84	0.56	0.56	0.70	1.11	20.75
	Col %	26.36	23.17	30.00	16.67	20.00	11.90	21.57	0.00	21.74	9.38	18.75	13.04	23.91	24.32	24.00	23.53	18.18	11.11	25.81	
	Row %	19.46	12.75	8.05	2.68	5.37	3.36	7.38	0.00	3.36	2.01	2.01	2.01	7.38	6.04	4.03	2.68	2.68	3.36	5.37	
	Cell Chi^2	1.6692	0.2312	1.6485	0.1930	0.0109	1.5842	0.0164	2.4903	0.0108	1.9960	0.0309	0.6586	0.2215	0.2275	0.1271	0.0632	0.0700	2.0155	0.3816	
13.50%	Count	32	19	7	5	5	5	9	5	3	7	0	4	11	7	7	6	3	9	5	149
	Total %	4.46	2.65	0.97	0.70	0.70	0.70	1.25	0.70	0.42	0.97	0.00	0.56	1.53	0.97	0.97	0.84	0.42	1.25	0.70	20.75
	Col %	29.09	23.17	17.50	20.83	12.50	11.90	17.65	41.67	13.04	21.88	0.00	17.39	23.91	18.92	28.00	35.29	13.64	20.00	16.13	
	Row %	21.48	12.75	4.70	3.36	3.36	3.36	6.04	3.36	2.01	4.70	0.00	2.68	7.38	4.70	4.70	4.03	2.01	6.04	3.36	
	Cell Chi^2	3.6859	0.2312	0.2039	0.0001	1.3126	1.5842	0.2369	2.5294	0.6586	0.0194	3.3203	0.1252	0.2215	0.0599	0.6329	1.7324	0.5368	0.0123	0.3193	
		110	82	40	24	40	42	51	12	23	32	16	23	46	37	25	17	22	45	31	718
		15.32	11.42	5.57	3.34	5.57	5.85	7.10	1.67	3.20	4.46	2.23	3.20	6.41	5.15	3.48	2.37	3.06	6.27	4.32	

N	DF	-LogLike	RSquare (U)
718	72	39.226871	0.0196

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	78.454	0.2817
Pearson	73.198	0.4385

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Chi-Square Tests

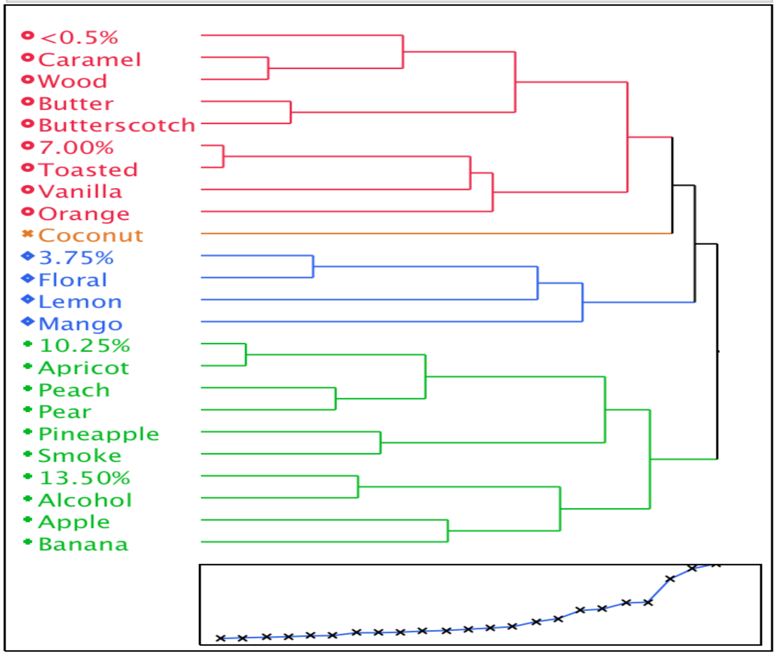
	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Pearson Chi-Square	73.198	72	.438	.440	.427	.452
Likelihood Ratio	78.454	72	.282	.386	.373	.398
Fisher's Exact Test	72.253			.419	.406	.431
N of Valid Cases	718					

Figure A.9: Contingency Table for Orthonasal Qualitative Descriptor Attribute Responses for Chardonnay Wines.

Hierarchical Clustering

Method = Ward

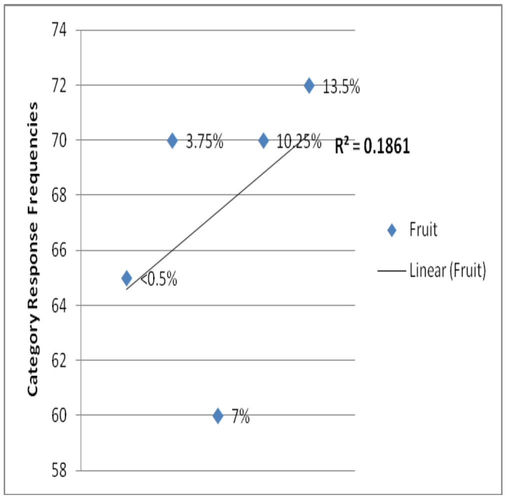
Dendrogram



Clustering History

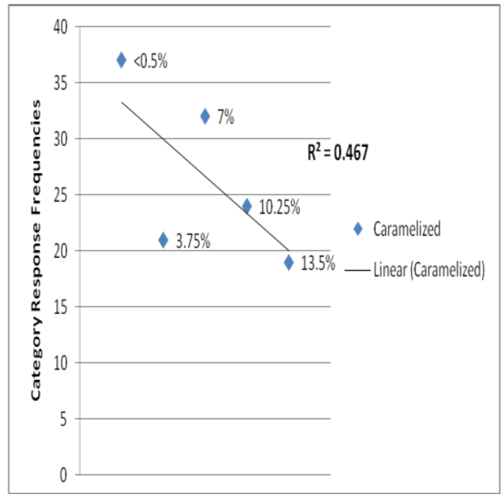
Number of Clusters	Distance	Leader	Joiner
23	0.306797954	7.00%	Toasted
22	0.338825418	10.25%	Apricot
21	0.366221742	Caramel	Wood
20	0.395707248	Butter	Butterscotch
19	0.437727052	3.75%	Floral
18	0.454010741	Peach	Pear
17	0.599319028	13.50%	Alcohol
16	0.602394769	Pineapple	Smoke
15	0.631616477	<0.5%	Caramel
14	0.685871397	10.25%	Peach
13	0.717066119	Apple	Banana
12	0.782700722	7.00%	Vanilla
11	0.848080565	7.00%	Orange
10	0.917575364	<0.5%	Butter
9	1.173318782	3.75%	Lemon
8	1.335235377	13.50%	Apple
7	1.760755198	3.75%	Mango
6	1.840872160	10.25%	Pineapple
5	2.152268284	<0.5%	7.00%
4	2.195245065	10.25%	13.50%
3	3.406693820	<0.5%	Coconut
2	3.941353464	<0.5%	3.75%
1	4.193261102	<0.5%	10.25%

Figure A.10: Hierarchical Clustering of Chardonnay Wines and Orthonasal Qualitative Descriptor Attributes.



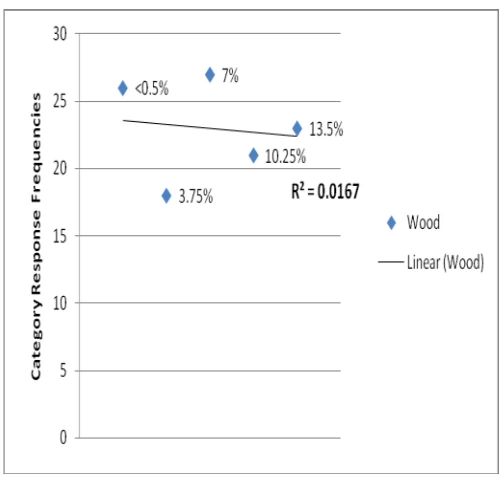
Category Response Frequencies
74
72
70
68
66
64
62
60
58
<0.5%
3.75%
7%
10.25%
13.5%
R² = 0.1861
Fruit
Linear (Fruit)

(A)



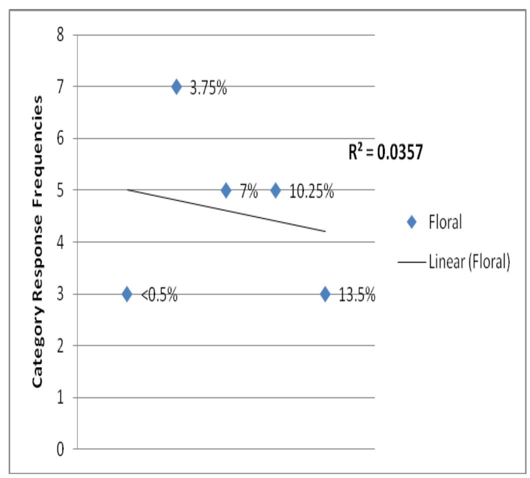
Category Response Frequencies
40
35
30
25
20
15
10
5
0
<0.5%
7%
10.25%
3.75%
13.5%
R² = 0.467
Caramelized
Linear (Caramelized)

(B)



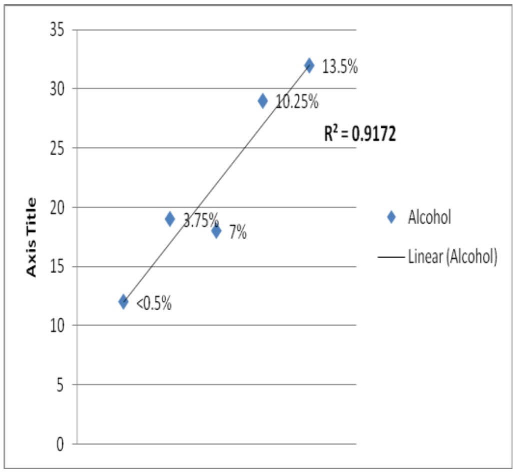
Category Response Frequencies
30
25
20
15
10
5
0
<0.5%
7%
13.5%
10.25%
3.75%
R² = 0.0167
Wood
Linear (Wood)

(C)



Category Response Frequencies
8
7
6
5
4
3
2
1
0
3.75%
R² = 0.0357
7%
10.25%
<0.5%
13.5%
Floral
Linear (Floral)

(D)



(E)

Figure A.11: Linear Regression of Chardonnay Wines (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv) Regarding Orthonasal Qualitative Descriptor Attribute Categories. (A) Fruit Category. (B) Caramelized Category. (C) Wood Category. (D) Floral Category. (E) Alcohol Category.

Contingency Table

Response

Wine: Count / Total % / Col % / Row % / Cell Chi^2	Alcohol	Asparagus	Bell Pepper	Black Pepper	Blackberry	Cherry	Earth	Ginger	Leather	Olive	Smoke	Strawberry	Sweat	Toasted	Vanilla	Wood	
<0.5%	11	2	2	4	22	14	10	0	3	4	6	10	4	8	14	8	122
	1.82	0.33	0.33	0.66	3.65	2.32	1.66	0.00	0.50	0.66	1.00	1.66	0.66	1.33	2.32	1.33	20.23
	15.94	16.67	11.76	18.18	25.29	16.28	29.41	0.00	21.43	14.81	31.58	18.52	26.67	27.59	23.33	19.05	
	9.02	1.64	1.64	3.28	18.03	11.48	8.20	0.00	2.46	3.28	4.92	8.20	3.28	6.56	11.48	6.56	
	0.6277	0.0754	0.6024	0.0457	1.0989	0.6643	1.4161	3.2371	0.0099	0.3916	1.2091	0.0784	0.3070	0.7752	0.2852	0.0291	
3.75%	16	4	4	5	18	16	5	1	2	7	3	16	3	3	11	5	119
	2.65	0.66	0.66	0.83	2.99	2.65	0.83	0.17	0.33	1.16	0.50	2.65	0.50	0.50	1.82	0.83	19.73
	23.19	33.33	23.53	22.73	20.69	18.60	14.71	6.25	14.29	25.93	15.79	29.63	20.00	10.34	18.33	11.90	
	13.45	3.36	3.36	4.20	15.13	13.45	4.20	0.84	1.68	5.88	2.52	13.45	2.52	2.52	9.24	4.20	
	0.4171	1.1245	0.1240	0.0998	0.0402	0.0556	0.4357	1.4742	0.2106	0.5244	0.1499	2.6791	0.0005	1.2956	0.0597	1.3048	
7.00%	11	2	4	6	20	16	5	5	1	5	5	8	3	8	8	11	118
	1.82	0.33	0.66	1.00	3.32	2.65	0.83	0.83	0.17	0.83	0.83	1.33	0.50	1.33	1.33	1.82	19.57
	15.94	16.67	23.53	27.27	22.99	18.60	14.71	31.25	7.14	18.52	26.32	14.81	20.00	27.59	13.33	26.19	
	9.32	1.69	3.39	5.08	16.95	13.56	4.24	4.24	0.85	4.24	4.24	6.78	2.54	6.78	6.78	9.32	
	0.4638	0.0516	0.1363	0.6672	0.5199	0.0409	0.4109	1.1157	1.1046	0.0152	0.4420	0.6237	0.0014	0.9526	1.1921	0.9411	
10.25%	14	0	4	2	12	20	10	4	6	7	4	9	4	4	15	10	125
	2.32	0.00	0.66	0.33	1.99	3.32	1.66	0.66	1.00	1.16	0.66	1.49	0.66	0.66	2.49	1.66	20.73
	20.29	0.00	23.53	9.09	13.79	23.26	29.41	25.00	42.86	25.93	21.05	16.67	26.67	13.79	25.00	23.81	
	11.20	0.00	3.20	1.60	9.60	16.00	8.00	3.20	4.80	5.60	3.20	7.20	3.20	3.20	12.00	8.00	
	0.0064	2.4876	0.0643	1.4376	2.0194	0.2647	1.2363	0.1407	3.3067	0.3517	0.0010	0.4300	0.2551	0.6731	0.5278	0.1922	
13.50%	17	4	3	5	15	20	4	6	2	4	1	11	1	6	12	8	119
	2.82	0.66	0.50	0.83	2.49	3.32	0.66	1.00	0.33	0.66	0.17	1.82	0.17	1.00	1.99	1.33	19.73
	24.64	33.33	17.65	22.73	17.24	23.26	11.76	37.50	14.29	14.81	5.26	20.37	6.67	20.69	20.00	19.05	
	14.29	3.36	2.52	4.20	12.61	16.81	3.36	5.04	1.68	3.36	0.84	9.24	0.84	5.04	10.08	6.72	
	0.8405	1.1245	0.0375	0.0998	0.2741	0.5403	1.0944	2.5588	0.2106	0.3312	2.0163	0.0111	1.2980	0.0134	0.0021	0.0100	
	69	12	17	22	87	86	34	16	14	27	19	54	15	29	60	42	603
	11.44	1.99	2.82	3.65	14.43	14.26	5.64	2.65	2.32	4.48	3.15	8.96	2.49	4.81	9.95	6.97	

N	DF	-LogLike	RSquare (U)
603	60	29.927474	0.0193

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	59.855	0.4810
Pearson	53.385	0.7143

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Chi-Square Tests

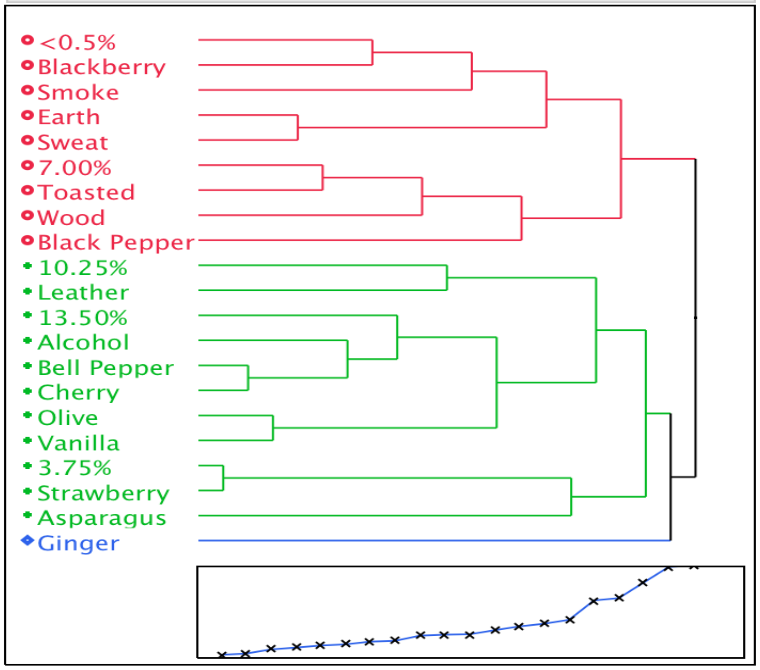
	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Pearson Chi-Square	53.385	60	.714	.721	.709	.732
Likelihood Ratio	59.855	60	.481	.603	.590	.616
Fisher's Exact Test	53.579			.672	.660	.684
N of Valid Cases	603					

Figure A.12: Contingency Table for Retronasal Qualitative Descriptor Attribute Responses for Rouge Wines.

Hierarchical Clustering

Method = Ward

Dendrogram



Clustering History

Number of Clusters	Distance	Leader	Joiner
20	0.095353855	3.75%	Strawberry
19	0.146566920	Bell Pepper	Cherry
18	0.316189469	Olive	Vanilla
17	0.393483339	Earth	Sweat
16	0.476634306	7.00%	Toasted
15	0.526069269	Alcohol	Bell Pepper
14	0.638405983	<0.5%	Blackberry
13	0.671776740	13.50%	Alcohol
12	0.884788879	7.00%	Wood
11	0.924516715	10.25%	Leather
10	0.941436049	<0.5%	Smoke
9	1.107971823	13.50%	Olive
8	1.264590300	7.00%	Black Pepper
7	1.375978122	<0.5%	Earth
6	1.537437846	3.75%	Asparagus
5	2.333702873	10.25%	13.50%
4	2.429958128	<0.5%	7.00%
3	3.072490259	10.25%	3.75%
2	3.709081297	10.25%	Ginger
1	3.767730618	<0.5%	10.25%

Figure A.13: Hierarchical Clustering of Rouge Wines and Retronasal Qualitative Descriptor Attributes.

Table A.12: Retronasal Qualitative Descriptor Category Response Frequency Count for Rouge Wine.

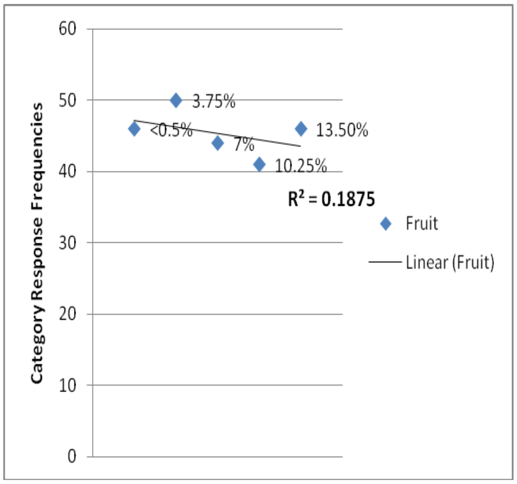
Descriptor Category	Descriptor Attribute	Wine				
		<0.5% abv	3.75% abv	7% abv	10.25% abv	13.5% abv
Fruit:						
	Blackberry	22	18	20	12	15
	Cherry	14	16	16	20	20
	Strawberry	10	16	8	9	11
Total Frequency Count		46	50	44	41	46
Vegetative:						
	Asparagus	2	4	2	0	4
	Bell Pepper	2	4	4	4	3
	Olive	4	7	5	7	4
Total Frequency Count		8	15	11	11	11
Wood:						
	Smoke	6	3	5	4	1
	Toasted	8	3	8	4	6
	Vanilla	14	11	8	15	12
	Wood	8	5	11	10	8
Total Frequency Count		36	22	32	33	27
Spice:						
	Black Pepper	4	5	6	2	5
	Ginger	0	1	5	4	6
Total Frequency Count		4	6	11	6	11
Earth						
	Earth	10	5	5	10	4
Total Frequency Count		10	5	5	10	4
Animal						
	Leather	3	2	1	6	2
	Sweat	4	3	3	4	1
Total Frequency Count		7	5	4	10	3
Alcohol						
	Alcohol	11	16	11	14	17
Total Frequency Count		11	16	11	14	17

For each category, specific qualitative descriptor attribute response frequencies are listed.

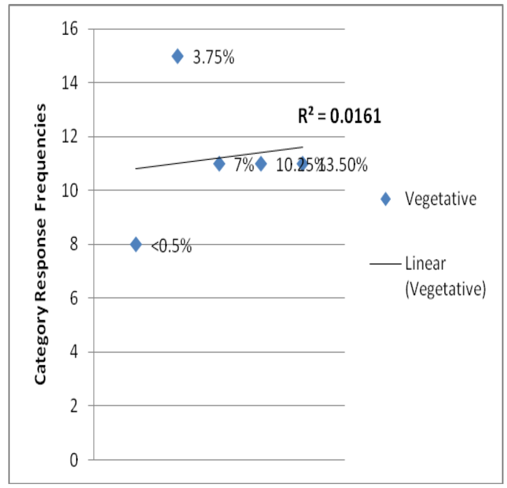
Table A.13: Orthonasal Qualitative Descriptor Category Response Frequency Count for Rouge Wine.

Descriptor Category	Descriptor Attribute	Wine				
		<0.5% abv	3.75% abv	7% abv	10.25% abv	13.5% abv
Fruit:						
	Blackberry	19	12	18	18	18
	Cherry	14	11	20	14	17
	Strawberry	6	11	10	10	10
Total Frequency Count		39	34	48	42	45
Vegetative:						
	Asparagus	4	10	4	1	4
	Bell Pepper	0	6	4	7	6
	Olive	7	11	7	7	3
Total Frequency Count		11	27	15	15	13
Wood:						
	Smoke	9	7	5	8	7
	Toasted	4	3	8	4	8
	Vanilla	12	6	12	7	8
	Wood	15	4	6	14	10
Total Frequency Count		40	20	31	33	33
Spice:						
	Black Pepper	4	4	2	4	6
	Ginger	1	6	1	1	4
Total Frequency Count		5	10	3	5	10
Earth						
	Earth	11	12	11	14	8
Total Frequency Count		11	12	11	14	8
Animal						
	Leather	4	3	5	4	2
	Sweat	7	9	9	4	5
Total Frequency Count		11	12	14	8	7
Alcohol						
	Alcohol	19	19	18	21	22
Total Frequency Count		19	19	18	21	22

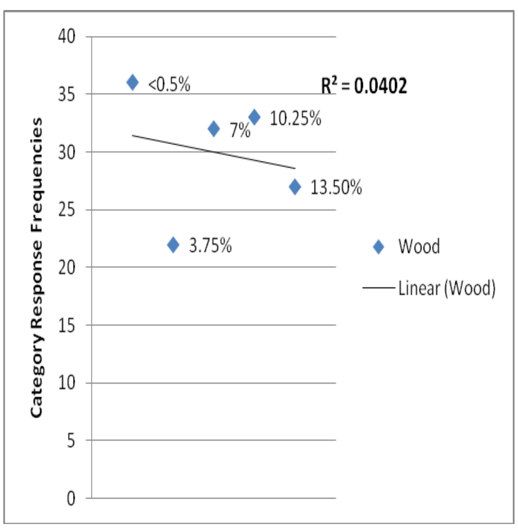
For each category, specific qualitative descriptor attribute response frequencies are listed.


Category Response Frequencies
60
50
40
30
20
10
0
3.75%
<0.5%
7%
13.50%
10.25%
R² = 0.1875
Fruit
Linear (Fruit)

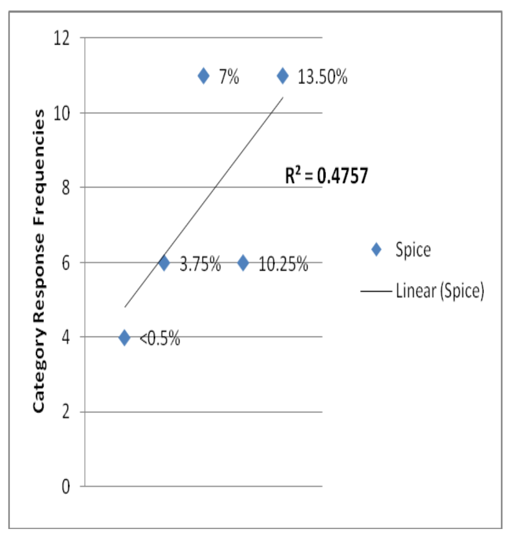
(A)


Category Response Frequencies
16
14
12
10
8
6
4
2
0
3.75%
R² = 0.0161
7%
10.25%
13.50%
<0.5%
Vegetative
Linear (Vegetative)

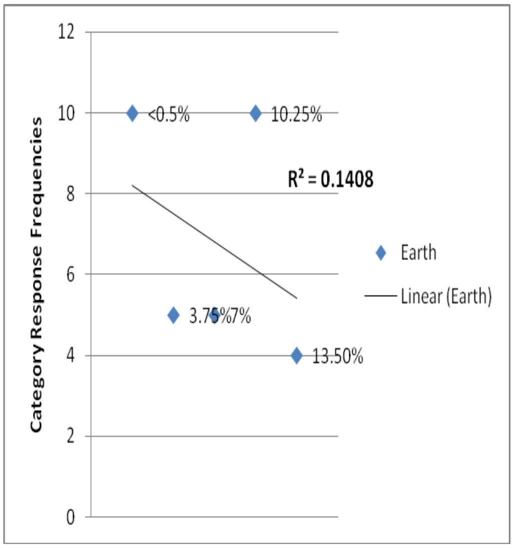
(B)


Category Response Frequencies
40
35
30
25
20
15
10
5
0
<0.5%
R² = 0.0402
7%
10.25%
13.50%
3.75%
Wood
Linear (Wood)

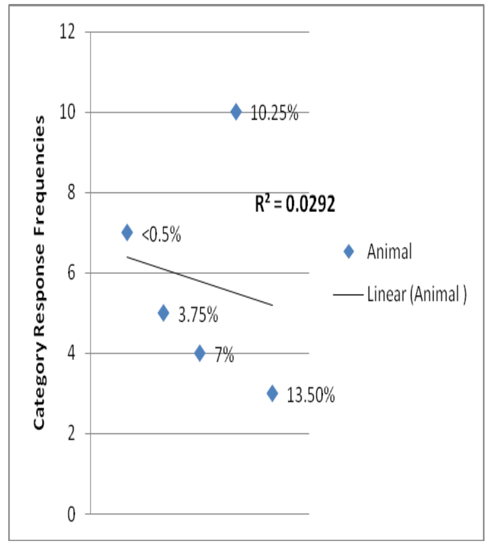
(C)


Category Response Frequencies
12
10
8
6
4
2
0
7%
13.50%
R² = 0.4757
3.75%
10.25%
<0.5%
Spice
Linear (Spice)

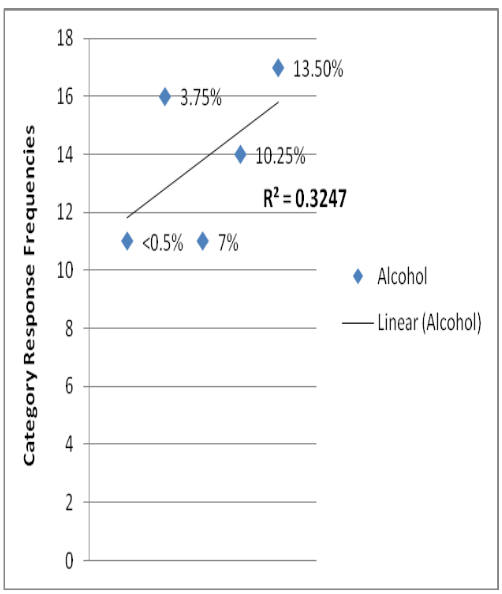
(D)



(E)



(F)



(G)

Figure A.14: Linear Regression of Rouge Wines (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv) Regarding Retronasal Qualitative Descriptor Attribute Categories. (A) Fruit Category. (B) Vegetative Category. (C) Wood Category. (D) Spice Category. (E) Earth Category. (F) Animal Category. (G) Alcohol Category.

Contingency Table

Wine	Count / Total % / Col % / Row % / Cell Chi^2	Alcohol	Asparagus	Bell Pepper	Black Pepper	Blackberry	Cherry	Earth	Ginger	Leather	Olive	Smoke	Strawberry	Sweat	Toasted	Vanilla	Wood	
<0.5%		19	4	0	4	19	14	11	1	4	7	9	6	7	4	12	15	136
		2.77	0.58	0.00	0.58	2.77	2.04	1.60	0.15	0.58	1.02	1.31	0.87	1.02	0.58	1.75	2.19	19.83
		19.19	17.39	0.00	20.00	22.35	18.42	19.64	7.69	22.22	20.00	25.00	12.77	20.59	14.81	26.67	30.61	
		13.97	2.94	0.00	2.94	13.97	10.29	8.09	0.74	2.94	5.15	6.62	4.41	5.15	2.94	8.82	11.03	
		0.0200	0.0687	4.5598	0.0003	0.2740	0.0756	0.0009	0.9653	0.0522	0.0005	0.4863	1.1814	0.0100	0.3419	1.0625	2.8761	
3.75%		19	10	6	4	12	11	12	6	3	11	7	11	9	3	6	4	134
		2.77	1.46	0.87	0.58	1.75	1.60	1.75	0.87	0.44	1.60	1.02	1.60	1.31	0.44	0.87	0.58	19.53
		19.19	43.48	26.09	20.00	14.12	14.47	21.43	46.15	16.67	31.43	19.44	23.40	26.47	11.11	13.33	8.16	
		14.18	7.46	4.48	2.99	8.96	8.21	8.96	4.48	2.24	8.21	5.22	8.21	6.72	2.24	4.48	2.99	
		0.0059	6.7510	0.5057	0.0022	1.2764	0.9961	0.1030	4.7162	0.0757	2.5352	0.0001	0.3605	0.8376	0.9805	0.8856	3.2431	
7.00%		18	4	4	2	18	20	11	1	5	7	5	10	9	8	12	6	140
		2.62	0.58	0.58	0.29	2.62	2.92	1.60	0.15	0.73	1.02	0.73	1.46	1.31	1.17	1.75	0.87	20.41
		18.18	17.39	17.39	10.00	21.18	26.32	19.64	7.69	27.78	20.00	13.89	21.28	26.47	29.63	26.67	12.24	
		12.86	2.86	2.86	1.43	12.86	14.29	7.86	0.71	3.57	5.00	3.57	7.14	6.43	5.71	8.57	4.29	
		0.2404	0.1026	0.1026	1.0616	0.0246	1.2997	0.0161	1.0300	0.4790	0.0029	0.7497	0.0174	0.6123	1.1250	0.8637	1.6000	
10.25%		21	1	7	4	18	14	14	1	4	7	8	10	4	4	7	14	138
		3.06	0.15	1.02	0.58	2.62	2.04	2.04	0.15	0.58	1.02	1.17	1.46	0.58	0.58	1.02	2.04	20.12
		21.21	4.35	30.43	20.00	21.18	18.42	25.00	7.69	22.22	20.00	22.22	21.28	11.76	14.81	15.56	28.57	
		15.22	0.72	5.07	2.90	13.04	10.14	10.14	0.72	2.90	5.07	5.80	7.25	2.90	2.90	5.07	10.14	
		0.0591	2.8430	1.2172	0.0001	0.0475	0.1086	0.6639	0.9975	0.0397	0.0002	0.0793	0.0314	1.1790	0.3773	0.4654	1.7412	
13.50%		22	4	6	6	18	17	8	4	2	3	7	10	5	8	8	10	138
		3.21	0.58	0.87	0.87	2.62	2.48	1.17	0.58	0.29	0.44	1.02	1.46	0.73	1.17	1.17	1.46	20.12
		22.22	17.39	26.09	30.00	21.18	22.37	14.29	30.77	11.11	8.57	19.44	21.28	14.71	29.63	17.78	20.41	
		15.94	2.90	4.35	4.35	13.04	12.32	5.80	2.90	1.45	2.17	5.07	7.25	3.62	5.80	5.80	7.25	
		0.2182	0.0849	0.4075	0.9711	0.0475	0.1916	0.9465	0.7333	0.7257	2.3191	0.0081	0.0314	0.4948	1.2146	0.1224	0.0021	
		99	23	23	20	85	76	56	13	18	35	36	47	34	27	45	49	686
		14.43	3.35	3.35	2.92	12.39	11.08	8.16	1.90	2.62	5.10	5.25	6.85	4.96	3.94	6.56	7.14	

(Response columns; Wine rows)

N	DF	-LogLike	RSquare (U)
686	60	33.914461	0.0189

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	67.829	0.2278
Pearson	62.947	0.3724

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Chi-Square Tests

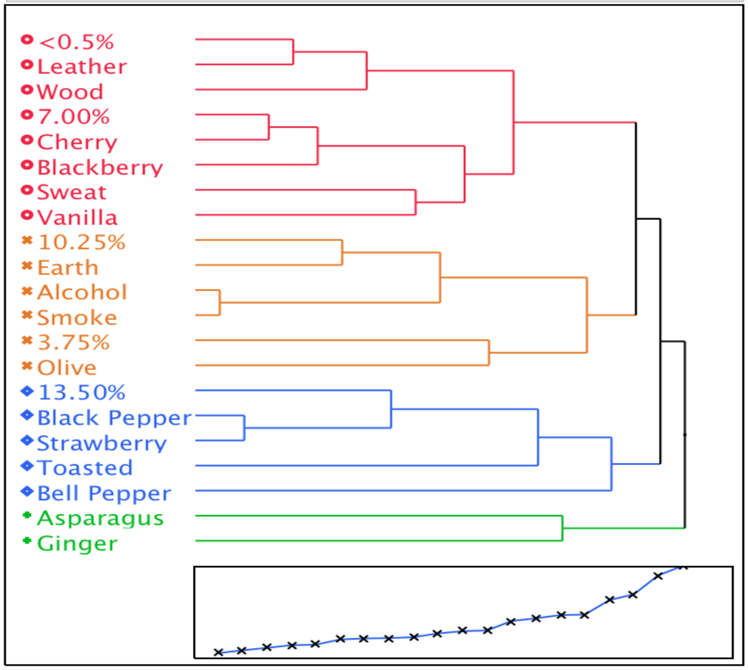
	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided) Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Pearson Chi-Square	62.947	60	.372	.370	.358	.383
Likelihood Ratio	67.829	60	.228	.310	.298	.322
Fisher's Exact Test	62.195			.355	.342	.367
N of Valid Cases	686					

Figure A.15: Contingency Table for Orthonasal Qualitative Descriptor Attribute Responses for Rouge Wines.

Hierarchical Clustering

Method = Ward

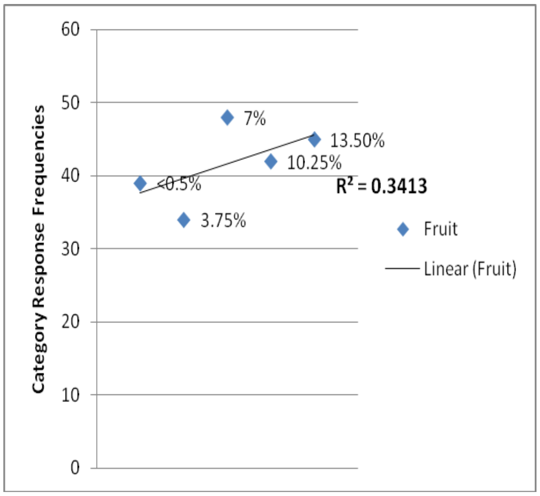
Dendrogram



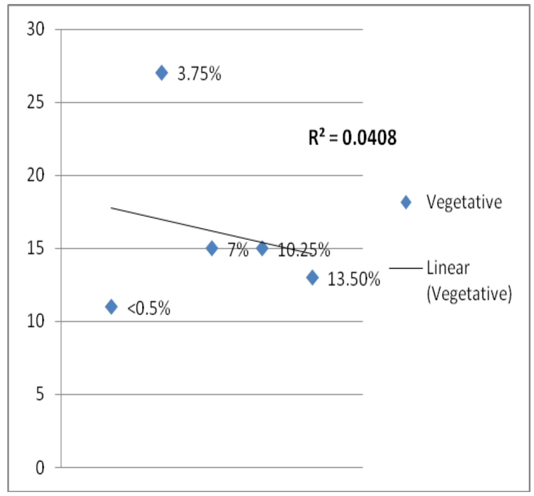
Clustering History

Number of Clusters	Distance	Leader	Joiner
20	0.183057999	Alcohol	Smoke
19	0.305441813	Black Pepper	Strawberry
18	0.408726750	7.00%	Cherry
17	0.524061394	<0.5%	Leather
16	0.546259195	7.00%	Blackberry
15	0.769043004	10.25%	Earth
14	0.813583474	<0.5%	Wood
13	0.828060152	13.50%	Black Pepper
12	0.868109892	Sweat	Vanilla
11	1.026586603	10.25%	Alcohol
10	1.124679017	7.00%	Sweat
9	1.154803232	3.75%	Olive
8	1.555734871	<0.5%	7.00%
7	1.674362129	13.50%	Toasted
6	1.811315118	Asparagus	Ginger
5	1.833082690	10.25%	3.75%
4	2.450326411	13.50%	Bell Pepper
3	2.698997611	<0.5%	10.25%
2	3.507912932	<0.5%	13.50%
1	3.915240235	<0.5%	Asparagus

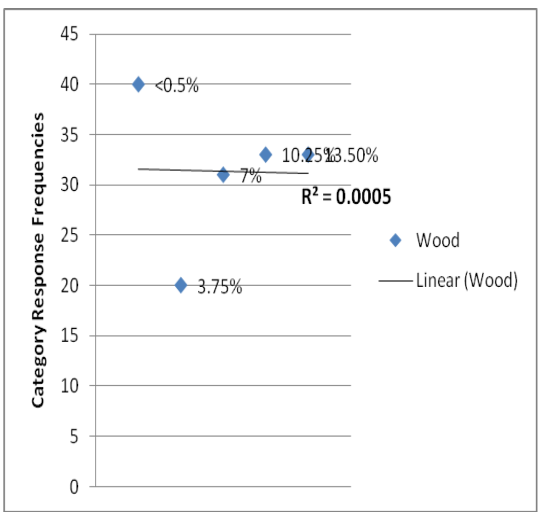
Figure A.16: Hierarchical Clustering of Rouge Wines and Orthonasal Qualitative Descriptor Attributes.


Category Response Frequencies
60
50
40
30
20
10
0
7%
13.50%
10.25%
<0.5%
3.75%
R² = 0.3413
Fruit
Linear (Fruit)

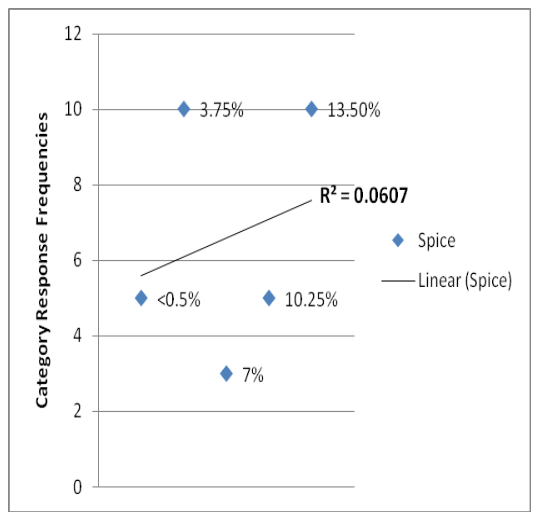
(A)


30
25
20
15
10
5
0
3.75%
R² = 0.0408
Vegetative
7%
10.25%
13.50%
<0.5%
Linear (Vegetative)

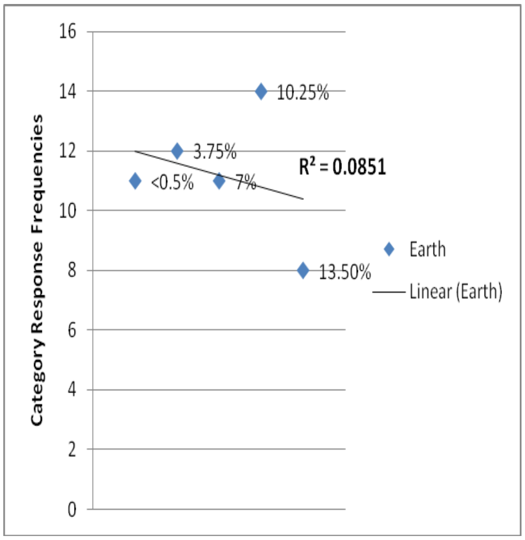
(B)


Category Response Frequencies
45
40
35
30
25
20
15
10
5
0
<0.5%
10.25%
13.50%
7%
R² = 0.0005
Wood
Linear (Wood)
3.75%

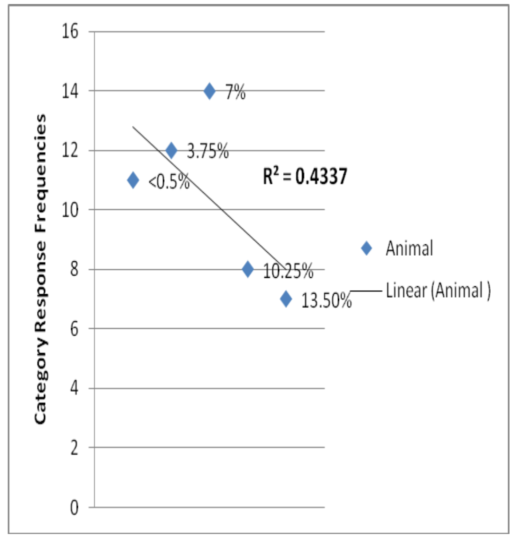
(C)


Category Response Frequencies
12
10
8
6
4
2
0
3.75%
13.50%
R² = 0.0607
Spice
Linear (Spice)
<0.5%
10.25%
7%

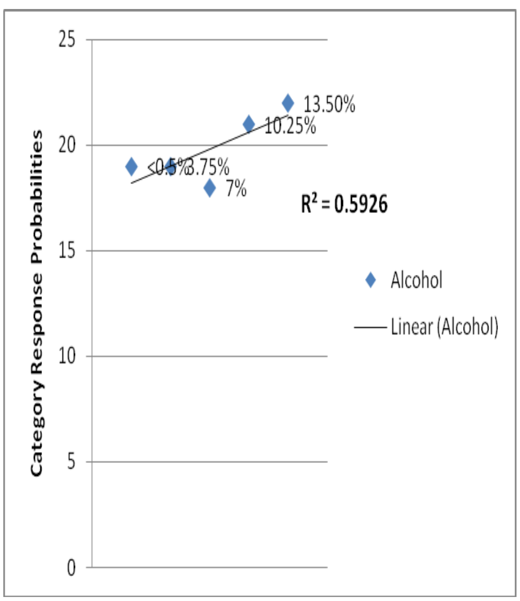
(D)



(E)



(F)



(G)

Figure A.17: Linear Regression of Rouge Wines (<0.5% abv, 3.75% abv, 7% abv, 10.25% abv, and 13.5% abv) Regarding Orthonasal Qualitative Descriptor Attribute Categories. (A) Fruit Category. (B) Vegetative Category. (C) Wood Category. (D) Spice Category. (E) Earth Category. (F) Animal Category. (G) Alcohol Category.

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