CREATING AND VALIDATING AN AROMA AND FLAVOR LEXICON FOR THE EVALUATION OF SPARKLING WINES.

by

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Abstract

Sparkling wines represent an important part of the full wine category. Currently, no lexicon exists that includes aroma, flavors and mouthfeel for sparkling wine. The objectives of this research were to: develop a aroma, flavor, basic taste and mouthfeel lexicon for sparkling wines, train a panel to use this lexicon, and validate the panel's performance. For lexicon development, 25 sparkling wines were selected from 132 by a team of sensory professionals and winemakers. The lexicon developed included 13 mouthfeel and taste, 48 aroma, and 48 flavor (aromatic) attributes (109 total attributes). For lexicon training, 22 experienced wine panelists participated in10, 3-hour sessions over two weeks. After training was complete, panel performance was validated with a practice phase and two studies. Analysis of panel discrimination (i.e. sample p-value) and within panel reproducibility (i.e. correlation of panelist with panel intensity) indicated that the new lexicon differentiated sparkling wines. Further, principal components analysis for studies two and three revealed grouping by wine type (e.g. brut, extra dry, etc.) again validating the new lexicon.

Table of Contents

List of Figures

List of Tables

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Dedication

This thesis is dedicated to the memory of my maternal grandfather Pépé Godefroy whose love, courage, and spirit have given me strength, and whose belief in me is realized through my success.

Chapter 1 - Descriptive Analysis Literature Review

Descriptive Analysis of Products

Descriptive analysis (DA) is a scientific method in which 8 to 12 trained panelists (i.e. a panel) identifies, categorizes, and determines the intensity of the sensory characteristics (i.e. appearance, aroma, flavor and texture of products). Descriptive analysis is used in the food and beverage industry for a wide range of purposes including new product development, shelf life determination, and quality assurance. Descriptive analysis is used in many other industries. Examples include cosmetics to describe the skin-feel of personal care products, the hand-feel of fabrics and paper products, or the sound of any product**.** Because descriptive analysis fingerprints product attributes, these results can help to detect superior quality varieties, improve agronomic aspects without decreasing organoleptic value and obtain new competitive materials for the market place (Del Castillo et al. 2008). In short, descriptive analysis can be a powerful tool as it can be used to ensure a product's characteristics are at the optimal levels / combination to maximize consumer acceptance, thus delivering product superiority.

It has been estimated that there are over 10,000 varieties of wines produced worldwide with California having more than 1,200 wineries. The characteristics of a wine are caused by an array of factors including: soil, climate, varietal, vinification processes, and the winemakers' expertise. Collectively, these factors are referred to as terroir. Variation in any of these factors can affect the characteristics and flavor profile of the wines, and all these factors create a wide range of aromas, colors, flavors, and mouthfeel. This is important because in wine subtle flavor differences may have an important impact on both consumer acceptance and price. Descriptive analysis has been particularly useful to examine certain effects of viticultural practices and process changes on final wine sensory properties (Lohitnavy et al. 2010).

Substantial research has been done using descriptive analysis to assess wines. Some of the research is more grape specific and emphasizes the sensory characteristics within each varietal. Chardonnay wines have been found to have tropical fruit, floral, and oaky aromas (De la Presa-Owens and Noble 1997), Zinfandels are characterized with aromas and flavors such as raspberries, berries, black pepper, and raisins (Noble, 1987). King et al. showed that Sauvignon Blancs have green characteristics associated with tropical fruits aromas (King et al. 2011). The

descriptive profiling of flavor attributes of white wines from different grape varieties helped Yildirim et al. (2007) to determine the effect of using different grape varieties on the sensory flavor characteristics of Turkish white wines. These are just a few examples of the many descriptive analysis studies done to better understand the factors related to wine characteristics from the grape varietals. Other research within the wine industry has focused on the practices that influence the sensory characteristics of the winemaking process. Sensory analysis is used to determine the ideal harvest time of the grapes showing that the harvest date discriminates the sensory profiles and the typicality of the wines (Cadot et al. 2012). Within the winemaking process, sensory evaluation is used to determine the best industry practices that can provide the optimum wines. As an example, the oxygen treatment of wine seems to have an effect on consumer preference that addresses their choice towards products with more olfactory complexity and less fruity notes (Paola Parpinello et al. 2011). Similarly, sensory analysis has been used to show that oak chips give rise to a different sensorial profile of wines depending on the point of addition. Higher intensities of woody, coconut, vanilla, and sweet spices descriptors were obtained when a large dose rate of chips was employed (Gómez García-Carpintero et al. 2012).

In the wine industry, certain "undesirable" flavors translate to a decrease in consumer acceptance. These flavors often are referred to as "off notes". In one study with Uruguayan Tannat wines, Varela and Gámbaro (2006) used quantitative descriptive analysis to determine that increases in yeasty, burned, and earthy aromas resulted in lower quality scores, while high intensities of dried fruit, phenolic, and berry aromas were desirable. The knowledge of these flavors and their interaction with other flavors is powerful as knowing the critical intensity for the "off note" and its interaction with other flavors may allow the "off note" to be blended below the intensity threshold or masked by another flavor. Knowing that bell pepper aromas which are often not desired in Cabernet Sauvignon can be masked by fruity aromas allow winemakers to blend "out" the perceived vegetative aromas with wines that are more fruity which could lead to better consumer acceptance of these wines (Hein et al. 2009). Ultimately, a vast amount of research on wines associated with descriptive analysis of the wines is meant to improve the quality of the wines to better meet consumer preferences. In their research, Lesschaeve and Findlay (2004) used wine descriptive analysis guided by consumer research proposing a strategy to target a wine style based on preference mapping outcomes.

Panel validation and reproducibility are key to ensuring panel success. As panel results are used to make product related decisions, these results need to be reliable and consistent over time. From a simple perspective, the validity of a DA panel can be defined as the extent to which DA results effectively categorize and rate the intensity of specific product characteristics. Using a wine example, does the complete profile of a Chardonnay accurately represent the specific characteristics of that wine? In this sense, panel validity is foundational to the method as it is the basis by which differences between or among products are determined. In practice, panel validation is usually done by measuring performance against established standards and / or comparing the results of one, often newer panel, to those of another, often more experienced panel. Reproducibility is critical as many DA projects (e.g. shelf life) require evaluation over a sustained period of time (e.g. months or years). The ability to effectively measure product differences over time is dependent on consistency of the panel's performance / accuracy. If a panel is inconsistent over time (i.e. poor reproducibility), the outcome is that true product differences over time may be missed due to the large variability in the results. Even worse, results conclude a "false" difference exists that actually is the result of either systematic errors in panel evaluation and / or high variability in panel results. Chambers et al. (2004) put it succinctly when they stated, "it is important that the panel functions like a finely tuned instrument."

The development of a solid sensory lexicon and panelist training are the basis of descriptive analysis. Depending on the needs and experience of an industry, the sensory panel may either be trained to use an already established lexicon or be part of the development of this lexicon. It's important to measure panelists' progress throughout the training to adapt the content of the training to remediate to any shortfalls if necessary. The ultimate goal of the training is to ensure that all panelists become finely tuned to evaluate the products. In their research, Chambers et al. (2004) found that training time improved panel performance by reducing variability in results, thus improving accuracy and precision. The length of training and lexicon development may vary depending on type of products. Training duration should not be fixed a priori. However, the panel should be trained until its performance can be judged as being satisfactory (Labbe et al, 2004). The authors explain that that training will create many benefits such as allowing assessors to become familiar with a vocabulary and to use it reliably, modifying mean profiles and making them reliable, improving discrimination and consensus within the panel. Significant training is

required before the panel becomes a reliable sensory instrument. It has been demonstrated that a trained panel can better differentiate products than an untrained panel, and the assessors on a trained panel show greater agreement than assessors on an untrained panel (Findlay et al. 2006).

Ensuring that a panel is a reliable tool to provide sensory measurement of products doesn't end with the completion of the training and lexicon development. Once a panel has been formed and trained, it must be validated and periodically monitored to ensure reliable results (Del Castillo et al. 2008). This is why typically a new panel in training needs to be validated to address any retraining needs before the panel can be operational. As for any good measuring tool, the sensitivity of a panel needs to be checked regularly to determine its ability to perform validly and consistently. In the case of a sensory panel, the individuals, as well as the panel as a whole need to be monitored. (Meilgard et al.2006). Evaluation of quality of ratings in sensory descriptive analysis is of vital importance because it relates to not only whether the ratings are acceptable, but also whether sensory analysis can provide reliable measurements (Bi, 2003). While many sensory studies vary in methodology and choice of statistical analyses to measure panel performance, they have one goal in common, measuring the validity of the panel. The results of any descriptive profiling are only as good as the performance of the panel. For this reason, examination of judge performance should be a routine part of the data analysis (King, et al. 2001). As one of many examples, in the sensory analysis of Spanish mandarin juices, Carbonell et al. (2007) measured the performance of the panel looking at several factors including but not limited to reproducibility of assessments of the same sample, interactions of panelists x samples, use of the full scales, and discrimination among samples. In conclusion, Carbonell et al. found that the panel performed satisfactorily, but some assessors needed more training. In the descriptive analysis of wine vinegar, Tesfaye et al (2010) developed a protocol to ensure that each panelist would follow certain steps that aim at providing more reproducible results. In their research on evaluation of the texture of dry beans, Del Castillo et al (2008) demonstrate that once the panel has been formed and trained, it must be validated and periodically monitored to ensure reliable results. They analyzed panelists' interactions with other factors during the tasting sessions to determine the aspects that need to be addressed in retraining to ensure a well-trained panel. Gawel et al. (2001) found that tasters can be trained to reproducibly discriminate and rate the intensities of astringent sub-qualities elicited by young dry

red wines. Whether evaluating juices, wines, dry beans, or any other product, and regardless of the type of statistical analyzes, the ultimate outcome of panel performance monitoring and panel validation is to determine whether or not a panel can be used to make a product decision and identify any attributes that the panel need to be retrained on.

Lexicon Development

Developing a lexicon for sensory testing of a product is a critical step in the research process (Chambers et al, 2005). The descriptive analysis process of any product typically starts with the development of a lexicon. The lexicon can be either provided to the panelists or developed with the panelists. A lexicon includes a list of sensory attributes that describe and defines the appearances, aromas, flavors, and textures characteristics of the products being tested. These attributes are the foundation of descriptive analysis as they define the sensory characteristics of the products being evaluated. For these reasons, it is necessary to have a lexicon to conduct descriptive analysis. When developing a sensory lexicon, it is necessary to provide panelists with a range of references and anchor points so products can be both evaluated qualitatively with descriptors and quantitatively with intensity ratings. A broad sample set helps to ensure that all potential variability within a product is represented (Civille et al. 2010). The goal of the lexicon is to provide panelists with a list of attributes that will ultimately enable them to differentiate products with use of relevant descriptors and appropriate intensity ratings. The lexicon can be developed for a multitude type of products in a broad range of food products, beverages, or even cosmetics.

Often lexicons are typically developed to fill a knowledge gaps by characterizing specific product attributes. There are many examples available such as the development and application of a lexicon to describe the flavor of pomegranate juice provides attribute descriptors, definitions and references that were lacking in literature on pomegranate (Koppel & Chambers, 2010). In the dairy industry, a lexicon for processed and imitation cheeses established a defined descriptive flavor language for products that can help cheese manufacturers understand the flavor profiles of different processed cheeses and imitation cheese-type products (Drake et al. 2010). In the Denmark meat industry, Byrne et al. developed a couple of lexicons relating to meat products, one lexicon specifically focuses on vocabulary for warmed-over flavors while another meat

lexicon focuses on warmed over flavor for chicken meats (Byrne et al. 1999). In the California agricultural industry, the development of an almond lexicon was developed to assess the sensory properties of almond varieties in terms of their range of appearance, aroma, flavor, and texture properties (Civille et al. 2010). In their research Dooley et al. (2009) provided a lip product lexicon that can benefit researchers and cosmetic companies in product development, quality control, and marketing. McDonnell et al. (2001) in Ireland developed a sensory vocabulary for the odor evaluation of distilled beverages. Regardless of the origin, the type of products being evaluated, or sensory focus (appearance, aroma, flavors, texture, or combination), all these lexicons provide panelists a well-defined vocabulary that will standardize the descriptive analysis process.

Many lexicons have been developed in the food and beverage industry for descriptive analysis. Some of these lexicons are small and / or limited to a specific type of products, while other lexicons have many attributes that can be applied to a wide range of product categories (e.g. coffee, tea, wine, beer, or spirits). These lexicons are sometimes presented in the format of sensory wheels serving two purposes. First, they provide a visual tool to facilitate learning of the attributes that comprise the lexicon. Second and more importantly, these wheels provide an effective framework by which to communicate the associations among the attributes. For example, groups of attributes can be given the same color; similar attributes can be listed next to each other, and opposite attributes can be listed opposite each other (e.g. “3” and “9” on a clock). In several cases, sensory specialists have developed wheels that provide a visual tool for these complex sensory lexicons. Lawless et al. (2012) provided a brief history of descriptive lexicons in wheel form that have been developed for wine by Noble et al (1984), beer by Clapperton (1976) et al. and more recently spirits among others. The wine aroma wheel was developed by Ann Noble at The University of California at Davis and is modeled after similar tools used by the beer and scotch whiskey industries (Baldy, 2004). Some variants of these wheels are used to educate consumers about product flavors and other properties.

Applications to Wines

Wine is a unique product category largely because of the wide range of product characteristics present including appearance, aroma, flavors, and mouthfeel. Wines are produced

all over the world. Wines grown in European countries such as France, Italy, Spain, or Greece are often referred as "Old World" wines while the rest of the wines produced in countries such as the United States, South Americas, New Zealand, Australia, and South Africa are typically referred to as "New World" wines. A result of global wine production, there is a vast array of wine available to consumers. Wines are broken down into major types such as reds, whites, blushes / rosés, sparkling wines, as well as fortified wines. Red, white, and rosés wines are often characterized according to the varietals from which they are made. Chardonnay, Sauvignon Blanc, and Pinot Gris are some examples of varietals for white wines. Cabernet sauvignon, Merlot, Syrah are some examples for red wines. White Grenache, White Merlot, White Zinfandel are also varietal examples for blush wines. In contrast sparkling wines are typically classified relative to their production method such as the standard (Champagne), or bulk (Charmat). Fortified wines are wines in which the alcohol content has been increased by the addition of wine, spirits, or brandy. Examples of fortified wines include Port, Sherry, and Madeira. In addition to their type, varietal, or vinification processes, wines are produced in many parts of the world. Within each of these types of wines, there are additional distinctions like geographical areas and varietals (types of grapes) that have a direct result on the sensory characteristics of the wines. All these factors combine to create the vast diversity in wines.

There are many sensory aspects to describe the complexity of wine including appearance, aroma and flavor, basic tastes, texture, and aftertaste. Appearance includes the color of the wines, with hue denoting its shade or tints and depth referring to its relative brightness, (Jackson, 2002) and may also include the clarity (absence of haze), viscosity (resistance to flow), as well as effervescence mostly for sparkling wines. Aroma and flavors are key components of wine. The range of flavors encountered in wines is expansive. Noble's original wine wheel (1984) illustrate this wide range of attributes that can be found in wines with a broad range of categories such as fruity, floral, caramel, herbaceous / vegetative, woody, chemical, earthy. Within each of these categories, Noble provides a detailed list of subcategories with more detailed specific attributes within each category. Some categories may seem more relevant to most people describing more commonly used terms such as fruit, green, caramel, and floral. However other categories that are relevant to describe wine may appear to be less so to someone who is not familiar with wine descriptors such as woody, earthy, and chemical. The fruit section has many tangible descriptors such as citrus (lemon, grapefruit), berry (blackberry, raspberry), tropical (pineapple, banana), etc.

The same applies to the herbaceous section with subcategories such as fresh green (cut grass, bell pepper) or dried green (hay, tea, tobacco). However, there are several more categories available such as woody, caramel, earthy, chemical. Woody includes resinous (cedar), burned (smokey, coffee), the chemical category is subdivided into petroleum (diesel, plastic), sulfur (burnt match, skunk), and pungent (ethanol, acetic acid).

Basic tastes are limited to five sensations: sweet, sour, bitter, salty, and umami (Pritchard, 2005). Mostly, sweet, sour, and bitter tastes are experienced in wine although salty may be more common in sparkling wines. The balance of basic tastes is important because it affects consumer preferences. Slight structural changes in many sweet and bitter-tasting compounds can change their taste quality from sweet to bitter, or vice versa. Glucose and fructose are the primary sources of sweet sensations in wine, with fructose being sweeter. Additionally the perception of sweetness may be enhanced by the presence of glycerol and ethanol (Jackson, 2002). Some of the most common mouthfeel descriptors in wines are astringency, alcohol burn, and carbonation. Pickering and Demiglio (2008) describe wine mouthfeel as a group of sensations characterized by a tactile response in the mouth, for which polyphenolic compounds (tannins) are the main elicitors in red wines. These authors further explain that white wines also elicit a wide range of taste and mouthfeel sensations, some of which may be different from those experienced in red wine. Some of the mouthfeel described in their research refer to viscosity, rating the thickness of the wine, as well as irritation, referring to the burning sensation caused by the alcohol from warm to numbing.

Due to the complexity of the wines, it's necessary to have a relevant and specific lexicon. Many lexicons have been created. Often these lexicons are specific to a varietal or wine region. Examples of these types of research include the descriptive analysis of red wines from different grape cultivars in Turkey (Yildirim et al. 2007), and the desirable levels of sensory properties in Sauvignon Blanc (King et al. 2011). A limitation of these lexicons is that they are restricted to specific subsets of wine and have limited use beyond these subsets. The value of a lexicon is enhanced when it can be used for a wide range of wines. The benefits of a universal wine lexicon include the ability to enhance knowledge through common language and the increased understanding of wines through more specific comparisons. In the wine industry Noble is well known for providing wine experts with a wine aroma terminology known as the wine wheel. Noble's wheel (1984) provides an organized list of wine aromas grouped in types such as fruity,

vegetative, woody, chemical, etc. The wine wheel is cited in many sensory publications as well as widely used in many winery tasting rooms. It's a useful tool that enables professional as well as amateurs to better describe wine. Lawless and Heymann (1999) describe the wine wheel as a system for arranging common wine aroma characteristics. While the wine aroma wheel is a valuable tool to describe the key aromas in wines, it does not describe mouthfeel. Gawel et al. (2000) created a red wine mouthfeel wheel that solely assists wine tasters in their interpretation and use of terminology relating to "in mouth" sensations produced by red wines. Similarly, Pickering and Demiglio (2008) developed a white wine mouthfeel as a lexicon for describing the oral sensations elicited by white wines.

Descriptive analysis of sparkling wines is even more complex than that of still, and it is well understood in the wine industry that sensory characteristics in still wines are different than that of sparkling wines. Sparkling wines can be made from three different methods: bottle fermentation, also known as the traditional French Méthode Champenoise; transfer process, a variation of bottle fermentation: or the Charmat method, a bulk process with fermentation in a tank (Baldy, 2004). The basic difference between still wines and sparkling wines is that sparkling wines contain large amounts of dissolved carbon dioxide gas, which bubbles up and forms a layer of foam. However, the difference is not limited to the perception of carbonation. Sparkling wines also differ from still wines in aromas and flavors as a result of the fermentation. Sparkling wines clearly have a different aroma / favor than still wines. Noble explains that her original wine wheel (1984) provides a list of analytical, specific terms to describe aroma notes that are most frequently encountered in table wines, but further explains that a second word list was developed later for sparkling wines to describe the unique aromas arising from the secondary fermentation that forms the carbon dioxide or bubbles. That list of aromas was found useful in developing the foundation of a sparkling ballot, as it provides terms that are more relevant to sparkling wines such as fresh yeast or vegemite. Torrens et al. found that the sensory profile of sparkling wine is more complex than that of still wine, with toasty, lactic, sweet, and yeasty notes (2010). In summary, key flavors / aromas differences exist between some sparkling and still wines with the predominant differences related to unique fermentation like flavors such as yeasty and vegemite.

The presence of carbonation in sparkling wine is definitely a noticeable key difference between still and sparkling wines. However, carbonation is not solely limited to the perception of

bubbles, or flavors resulting from the fermentation. Carbonation has an impact on other perceptions such as sweetness and sourness or burning. There is evidence that effervescence and foam directly influences the consumer preference for a specific sparkling wine. (Pozo-Bayón et al. 2009). In their research on carbonation interactions with sweetness and sourness, Yau and McDaniel (1992) explained that in addition to the classic sensations of taste and smell, the sensations from thermal, mechanical, and common chemical stimuli play an important role in food and beverage perception. In earlier research, they (Yau and Mc Daniel, 1991) described carbonation as complex, introducing mouthfeel components such as tingle, bite, burn, and numbing. They also found sometimes pain is reported at high carbonation levels (Yau and Mc Daniel, 1991). The final definition of carbonation perception, 'overall perception in the whole mouth including both bubbling feeling and pain perception', was decided through discussion (Yau and Mc Daniel, 1991). Bubbles formed in the glass are also responsible for the foam ring, or the collar on the liquid surface, which is another important characteristic of sparkling wines. Bubble size may also affect flavor release and mouthfeel. Unfortunately, there are no experimental results to verify this hypothesis (Liger-Belair et al. 1999). The importance of the sour / sweet balance on wine quality is well known (Martin, 2002). The author explains that sweetness has an important contribution to the total taste intensity of sparkling wines. Martin (2002) concluded that investigating the influence of carbonation and the contribution of the trigeminal system would be useful to more fully understand perceptual interactions in sparkling wines. Therefore, the effect of carbonation in sparkling wines is intertwined with all sensory aspects of the wine.

The effect of carbonation on the appearance of sparkling wines is important to both product characteristics and consumer acceptance. In their 2004 research, Hidalgo et al. noted that for consumers, special attention was paid, not only to the color, but also to the observation of foam characteristics. In this research, the authors concluded that many consumers consider appearance one of the most important characteristics of a sparkling wine. In their research, Hidalgo et al. (2004) measured visually the foam quality and effervescence with a panel of eight trained tasters. The attributes assessed were the initial quantity of foam formed, whether the foam covered the whole surface of the wine, the presence of a foam collar on the surface of the wine, the size of the bubbles, and the effervescence. García et al. (2009) explained that foam is the first characteristic that is observed by the consumer after the wine is poured into the glass, so

sparkling wine foam is one of the most important quality parameters of sparkling wines. All of this research emphasizes the importance of foaming in sparkling wine. Further, this research highlights the importance of effectively measuring all characteristics of bubbles (e.g. appearance) and the value of a descriptive panel to meet these needs.

Only limited research exists regarding the evaluation of carbonation in sparkling wines using descriptive analysis. Pickering and Demiglio's (2008) white wine mouthfeel wheel includes a thorough list of descriptors with a few attributes directed toward carbonation relating to foam. Pickering and Demiglio explained that mouthfeel has not been well studied, possibly due to the absence of a commonly accepted definition and difficulties in measuring the typically subtle sensation it encompasses. They further emphasized that some chosen terms used in the mouthfeel wheel are compound in nature and / or contain a hedonic component, and perhaps confound a common understanding of some attributes. The terms referring to sparkling wines the authors cite are mostly foam and mousse attributes (meringue, whipped cream, dessert mousse), relating to the dynamic feeling of expansion. The authors justifiably explain that their actual utility in assisting with describing and discriminating sparkling wines remains to be determined. While the sensory references provided in Pickering and Demeglio's research, such as whipped cream, illustrate the concept of foam, unfortunately they do not provide realistic anchor points. It may be more suitable when feasible to use liquid references to provide anchor points that replicate the sensation perceived in sparkling wines when training a sparkling descriptive panel.
Torrens et al. (2008) did some sensory work on sparkling Cava wines, classifying wines fermented by different yeast strains. However, while providing some valuable information to classify the wines fermented by different yeast strains on sensory characteristics of Cava wines with 10 attributes such as floral, fruit type, chemical, and lactic, these findings used discriminant analysis rather than full descriptive analysis. Vannier et al. (1999) originally found that analyzed chemical components in sparkling wines are poorly correlated to sensory properties; as a result they developed a strategy based on sensory analysis of Champagne wines, in order to define a quality control program using the fixed choice technique. This type of research provides valuable information and foundation on characteristics of sparkling wines. The authors concluded that the next step would be to organize a quantitative training using calibration solutions, which would be composed of external references imitating some wine descriptors.

One of the challenges of training judges on how to evaluate sparkling wines is that these products cannot typically be spiked with flavor compounds. To establish approximate threshold recognition levels, testing was performed to obtain appropriate addition levels of each flavor (Hein et al, 2009). Typically when training a descriptive still wine panel, spiking a base wine with flavors is a common exercise and a fairly easy process that enables the panel leader to familiarize the panelists with flavors commonly encountered in wines that may be present at threshold levels. However, spiking sparkling will lower the carbonation in sparkling wines, as it's necessary to stir added flavors into the wine. Therefore, there is a tremendous advantage to train a panel to evaluate sparkling wines that has already been trained to evaluate still wines, as it may be easier to skip the spiked wines exercises. The still wine panelists will have a valuable former experience that should enable them to describe the aromas and flavors perceived in sparkling wines being provided external references such as biscuit, or vegemite without spiking these flavor compounds into the wine. Furthermore, there is a great advantage to use trained panelists who are familiar with providing anchor points for basic tastes and mouthfeel attributes such as burn or astringent without the interaction of carbonation.

Sensory characteristics of sparkling wines are unique because of the carbonation. However, the carbonation doesn't only change the mouthfeel part of the product; it also affects the perception of basic tastes and other mouthfeel, as well as creating some distinct flavors unique to the sparkling wine. Therefore, there is a need for a unique lexicon that is relevant to the unique category of sparkling wines.

Objectives of this Research

The objective of this research project was to develop a sparkling wine lexicon that includes aromas, flavors, basic tastes, and mouthfeel. As a result of the lexicon development, a sparkling wine ballot and sparkling wine wheel were created. A group of 22 experienced still wine judges were trained to evaluate sparkling wines. The panelists were trained over a course of 10 sessions in a two-week period. Upon completion of training, panelists' data was validated with sparkling wine evaluation. The data collected from the descriptive panel was analyzed by Principal Component Analysis. The performance of the individual panelists was evaluated measuring

correlations and repeatability. Each panelist was provided individual feedback on their performance.

Chapter 2 - Creating and Validating an Aroma and Flavor Lexicon for the Evaluation of Sparkling Wines.

Abstract

Sparkling wines represent an important part of the full wine category. Currently, no lexicon exists that includes aroma, flavors, and mouthfeel for sparkling wine. The objectives of this research were to:1) develop an aroma, flavor, taste and mouthfeel lexicon for sparkling wines, 2) train a panel to use this lexicon on white sparkling wines, which represent the majority of sparkling wines, and validate the panel's performance with white sparkling wines. For lexicon development, 25 sparkling wines were selected from 132 by a team of sensory professionals and winemakers. The lexicon developed included 13 mouthfeel and taste, 48 aroma, and 48 flavor (aromatic) attributes (109 total attributes). For lexicon training, 22 experienced wine panelists participated in 10, 3-hour sessions over two weeks. After training was complete, panel performance was validated with a practice phase and two studies. Analysis of panel discrimination (i.e. sample p-value) and within panel reproducibility (i.e. correlation of panelist with panel intensity) indicated that the new lexicon differentiated sparkling wines consistently. Further, principal components analysis for studies two and three revealed grouping by wine type (e.g. brut, extra dry, etc.) again validating the new lexicon.

Practical Applications

This study provides a lexicon and references that can be used to train a descriptive panel in evaluating the aromas, flavors, tastes and mouthfeel of sparkling wines.

Keywords

Descriptive analysis, sparkling wines, lexicon, and validation.

Introduction

The basic difference between still and sparkling wines is effervescence. Specifically, effervescence is the process of bubbling as gas escapes. Sparkling wines contain large amounts of dissolved carbon dioxide gas, which bubbles up and forms a layer of foam. These wines can be made from three methods: French Méthode Champenoise, transfer process, or the Charmat method (Baldy, 2004) and are produced throughout the world (e.g. California, France, and Australia).

In addition to effervescence, sparkling wines also differ from non-sparkling wines in aromas and flavors as a result of the fermentation. Torrens et al. (2010) found that the sensory profile of sparkling wine is more complex that non-sparkling wines, with toasty, lactic, sweet, and yeasty notes. In other research, that author (Torrens et al. 2008) differentiated Spanish Cava sparkling wines by specific flavor attributes such as floral, chemical, and lactic. In summary, descriptive analysis of sparkling wines is more complex than non-sparkling wines with key flavor and aroma differences existing, such as yeasty and vegemite flavors (De La Presa-Owens, et al., 1998).

Limited research exists regarding the use of descriptive analysis to evaluate sparkling wines. Pickering and Demiglio's (2008) white wine mouthfeel wheel includes some foam attributes (e.g. meringue, whipped cream, dessert mousse). These authors noted that mouthfeel has not been well studied. One limitation of this study is that the sensory references they provided, such as whipped cream, illustrate the concept of foam, but do not provide realistic anchor points.

Developing a lexicon for sensory testing of a product is a critical step in the research process (Chambers et al, 2005). The descriptive sensory analysis process of any product typically starts with the development of a lexicon. The lexicon can be provided either to the panelists or developed with the panelists. A lexicon includes a list of sensory attributes that describes and defines the appearances, aromas, flavors, and textures characteristics of the products being tested. These attributes are the foundation of descriptive analysis, as they define the sensory characteristics of the products being evaluated. Thus, it is necessary to have a lexicon to conduct descriptive analysis. When developing a sensory lexicon, it is necessary to provide panelists with a range of references and anchor points so products can be both evaluated qualitatively with descriptors and quantitatively with intensity ratings. A broad sample set helps to ensure that all potential variability within a product is represented (Civille et al. 2010; Lawless and Civille,

2013). The goal of the lexicon is to provide panelists with a list of attributes that will ultimately enable them to differentiate products with use of relevant descriptors and appropriate intensity ratings. For example, Dooley et al. (2009) provided a lip product lexicon that can benefit researchers and cosmetic companies in product development, quality control, and marketing. McDonnell et al. (2001) developed a sensory vocabulary for the odor evaluation of distilled beverages in Ireland. Regardless of the origin, the type of products being evaluated, or sensory focus (appearance, aroma, flavors, texture, or combination), all these lexicons provide panelists a well-defined vocabulary that will standardize the descriptive analysis process.

Many lexicons have been developed in the food and beverage industry for descriptive analysis. For example, lexicons for fruit and vegetable products (Chambers et al., 2012; Koch et al., 2012; Leksrisompong, et al., 2012; Suwonshichon et al., 2012; Koppel and Chambers, 2010), grains (Bett-Garber et al., 2012; Vázquez-Araújo et al., 2011), nuts (Miller et al, 2013; Vázquez-Araújo et al., 2012, Civille et al., 2010;), meat (Maughan et al., 2012; Adhikari et al. 2011) and spices and condiments (Cherdchu et al., 2013; Lawless et al., 2012) have been published in recent years. These lexicons may be presented in a wheel format to better visualize the sensory attributes. Some of these wheels are small or limited to a specific type of products such as wine (Noble et al., 1984) or beer (Clapperton et al., 1976) while other lexicons have many attributes that can be applied to a wide range of product categories (Lawless et al., 2012). These sensory wheels serve two purposes. First, they provide a visual tool to facilitate learning of the attributes that comprise the lexicon. Second, and more importantly, these wheels provide an effective framework by which to communicate the associations among the attributes. For example, groups of attributes can be given the same color; similar attributes can be listed next to each other, and opposite attributes can be listed opposite each other (e.g. “3” and “9” on a clock). In several cases, sensory specialists have developed wheels that provide a visual tool for these complex sensory lexicons. Lawless et al., (2012) provided a brief history of descriptive lexicons in wheel form that have been developed for wine by beer by and more recently spirits among others. Some variants of these wheels are used to educate consumers about product flavors and other properties. Wheels are less useful as actual panel tools and do not provide definition or reference information although they serve as a foundation tool for the ballot development and understanding.

Panel validation and reproducibility are key to ensuring panel success (Chambers and Smith, 1993). Because panel results are used to make product related decisions, these results need to be reliable and consistent over time. From a simple perspective, the validity of a descriptive analysis (DA) panel can be defined as the extent to which DA results effectively categorize and rate the intensity of specific product characteristics. Using a wine example, does the complete profile of a Chardonnay accurately represent the specific characteristics of that wine? In this sense, panel validity is foundational to the method because it is the basis by which differences among products are determined. In practice, panel validation is usually done by measuring performance against established standards or comparing the results of one, often newer panel, to those of another, often more experienced panel. Reproducibility is critical as many DA studies (e.g. shelf- life) require evaluation over a sustained period of time (e.g. months or years). The ability to effectively measure product differences over time is dependent on consistency of the panel's performance. If a panel is inconsistent over time (i.e. poor reproducibility), the outcome is that true product differences over time may be missed due to the large variability in the results. Even worse, results may conclude a "false" difference exists that actually is the result of either systematic errors in panel evaluation or high variability in panel results.

Extensive research has been done in the area of panel performance (Tomic et al., 2007, Rossi, 2001 and Castura et al. 2005). The ability of a panel to find product differences is often referred to as discrimination. Although, discrimination can be presented in numerous ways (e.g. F plot, p-value plot, p*****MSE plot), showing the sample p-value from the ANOVA (model: attribute=sample panelist sample*panelist) is an effective and concise way to present these results. Within panel repeatability is another important performance metric. This metric measures the consistency of individual panelists to evaluate the same attribute/product combinations consistently. This metric can be evaluated by calculating the standard deviation of a panelist's repetitions for a given product combination. Agreement is another important metric. It refers to the consistency of a panelist average evaluation with the panel average. This can be measured using the correlation of each panelist vs. the panel average. Additionally, reproducibility over time represents the ability of a panel to provide the same scores for the same product at different times. Chambers et al. (2004), put it succinctly when they stated, "it is important that the panel functions like a finely tuned instrument."

Sparkling wines represent an important part of the full wine category. Currently, no lexicon exists that includes aroma, flavors, and mouthfeel for sparkling wine. The objectives of this research were to:1) develop an aroma, flavor, taste and mouthfeel lexicon for sparkling wines, 2) train a panel to use this lexicon on white sparkling wines, which represent the majority of sparkling wines, and validate the panel's performance with white sparkling wines.

Materials and Methods

Lexicon Development

A team of eight winemakers and sensory scientists screened 132 white sparkling wines. The original 132 wines were from 10 different countries with 43 distinct appellations within a large price range from economy wines (<$4.99) to luxury wines ($270.00). Characteristics of the sparkling products such as alcohol level (5.0 to 13.5% v/v), residual sugar (0.1-15.1g/100ml), and carbonation levels (296-1473mg/100ml) varied too. Only sparkling white wines were chosen because they represent the vast majority of sparkling wines. However, the professionals remained cognizant of the fact that the lexicon would need to include some terms appropriate for red and rosé sparkling wines. The tastings allowed sensory professionals to discuss the sensory attributes encountered. During this screening, external references were provided and used during the discussion of key attributes and lexicon development. Ultimately, screening enabled the descriptive panel leader to develop the lexicon, finalize the references, and create a sparkling wine evaluation ballot.

Over seven, 2-hour sessions, these individuals created the lexicon by informal evaluation. The lexicon included 13 mouthfeel and taste, 48 aroma and 48 flavor attributes (109 total attributes). The attributes selected for the lexicon included some that would likely be appropriate only for red or rosé sparkling wines. Those attributes are included in the lexicon, but were not validated using the further studies in the project.

Products for Further Testing

For the practice phase and Studies 1 and 2, samples were selected that represented a wide range of potential attributes. Samples information for the practice phase, Study 1 and Study 2

are presented in Tables 1-3. Some samples from the practice phase were included in Study 1 (n= 13) or Study 2 (n=9), but vintage or bottling date varied between the studies.

Sensory Panel / Subjects

Twenty-two non-smoking panelists, (18 females and 4 males) ages 27 to 64 were trained to use the new sparkling wine lexicon. Twenty-one panelists participated in the practice phase, and eighteen in Study 1 and Study 2. All panelists had over 200 hours of training, at least two years' experience evaluating still wines, and were members of the E&J Gallo Sensory Wine Panel. Panelists were trained to use the newly developed sparkling wine lexicon over two weeks in 10 sessions lasting 3 hours each.

Use of Lexicon for Evaluation of Samples

At the end of lexicon training, the panel evaluated 25 wines (Table 1) using the new lexicon. For this evaluation only one observation was collected by each panelist for each product (i.e. no replication) because the focus of the project was on learning and using the lexicon.

After lexicon training was complete the new lexicon was used to evaluate sparkling wines for two category reviews (i.e. studies 1 and 2). In Study 1, 20 sparkling wines were evaluated and in Study 2, 16 sparkling wines were evaluated (Tables 2 and 3). For each of these studies, two observations were collected by each panelist for each product. Between the practice phase and Study 2, the panel performed seven small sparkling wines projects each with less than 10 wines.

Instrumental Analysis

Residual Sugar:

Residual sugars were determined using enzyme-base methodology for the quantitation of glucose and fructose, commonly referred to as residual sugars (RS). Test results determined by this procedure represent the combined amount of glucose and fructose content and expressed in g/100 mL or percent values. The presence of D-glucose and D-fructose initiates a series of enzymatic reactions which produce nicotinamide-a-adenine dinucleotide phosphate

(NADPH). The amount of NADPH formed in these reactions is stoichiometric with the amount of glucose and fructose. The formation of NADPH is measured as an increase in the absorbance at 340 nm.

Ethanol determination: Alcohol determinations were determined using gas chromatography equipped with flame ionization detection. Results are expressed in % alcohol on a volume/volume basis. The limit of quantitation is 0.05% (v/v) with and level of uncertainty of +/-0.14% (v/v) at 14% (v/v).

Carbonation:

Carbon Dioxide ($CO_{2)}$ determination is based on absolute pressure and temperature using an Anton Paar CarboQC instrument. The sample is measured at two different volume expansions (10% and 30%) and the CO_2 content is calculated with a factor that accounts for dissolved air or nitrogen. The minimum detection limit of the instrument is 10.0 mg/100 mL CO_2. Samples less than that will be reported as ND or < 10.0 mg/100 mL.

Sensory Evaluation Procedure

Testing was done at the E&J Gallo Winery sensory laboratory using a modified Spectrum^{TM} Method (Meilgaard et al. 2006) for data collection, which uses a 0-15 scale. Samples were checked before serving to ensure there were no sample problems such as corkage. Serving was done in random order for each individual panelists and a new bottle was opened for each serving. This means that in some cases only 1 or 2 glasses were served per bottle. Samples were coded with random three-digit numbers. Assessments were done in individual booths using INAO (Institut National d'Appellation d'Origine) black wine tasting glasses covered with petri dishes. The panel evaluated mouthfeel (including carbonation) first, then aromas and flavors. Each session began with a calibration sample and ended with a group discussion. Samples were presented in a balanced monadic sequential design with a compulsory two-minute break after each sample. Data were collected using (Sensory Information Management System) SIMS.

Data Analysis

Data was analyzed using SPSS version 19. Analysis of variance was not done on the practice phase data because there was only one observation per panelist per product. For the analysis of variance model of studies 1 and 2, sample, judge, order and all two-way interactions were included in the model. Because the studies are exploratory to develop a lexicon, $P \leq 0.10$ was used as the criterion for significance with a least significant difference post-hoc test used to determine significant differences. For all studies, the correlation of average panelist intensity for each product by panel average for that product was calculated for each attribute. This was done using Senpaq version 5.01. Panelists' intensity vs. panel correlations were analyzed for the practice phase and studies 1 and 2. Principal component analysis (PCA) was done and biplots were created with XLStat. Because of the number of attributes, when a pair of attributes was highly correlated ($r \geq 0.80$), one attribute (usually the attribute from the inner circle of the wheel) was removed prior to the PCA.

Results and Discussion

Lexicon Development and References

The sparking lexicon was based on a previously developed non-sparkling lexicon of 109 attributes. As many as 78 non-sparkling attributes were found to be relevant to the sparkling wine category and were kept in the sparkling wine lexicon. Attributes not present in sparkling wines were removed (e.g. wood shavings), and attributes present in sparkling wines were added (e.g. vegemite, bubble pain). Wine experts, in general have finer skills to discriminate, recognize, and describe different wines, attributing these differences to some knowledge of the product rather than to special sensory qualities (Zamora and Guirao, 2004). For lexicon development, 25 wines were selected out of an initial 132.

Within the fruit category, the terms bruised fruit and artificial fruits were added to the fruit section of the ballot. Several attributes found to be unique to sparkling wines were added to the lexicon, such as bread dough, stale beer, vegemite, cured meat, and vitamin. In contrast, some still wine attributes, such as eucalyptus, mint, and wood shavings, were found irrelevant to sparkling wines and were removed. Other attributes already included in the still wine ballot were grouped differently in a way that was found to be more logical to the sparkling wine ballot. Sherry was found to be a unique attribute for sparkling wines and was therefore included as a category, whereas in the still wine ballot, it's a subcategory of the chemical attributes. Similarly, a yeasty category was created including the terms bread dough and stale beer. In contrast, the yeasty term is part of the microbiological / animal category of the still wine ballot. Instead of an oaky / woody / nutty category in the still wine ballot, a toasted category was created for the sparkling ballot including the following descriptors: toasted bread, nutty, and smoky.

These attributes represent a variety of aroma and flavor notes, such as vegemite, biscuit, and sherry, that may result from the unique *Méthode Champenoise* (a secondary fermentation is accomplished by adding a mixture of sugar and yeast) winemaking process. Attributes such as dark and red fruit were found irrelevant to these sparkling white wines, but were kept in the lexicon for possible further screening of red sparkling wines in the future. Some terms (e.g. wood shavings) were removed due to a low likelihood of being present in sparkling wines.

An even greater emphasis was placed on the development of the mouthfeel attributes relating to carbonation as the original still wine ballot only includes the term spritz typically referring to occasional low presence of carbonation. Originally the terms bubble size, bubble pain, foam, and creamy were introduced. A wide range of carbonated soft drinks and beers were screened to find products that best mimic the mouthfeel encountered in sparkling wines. Guinness beer had low bubble pain, small bubbles, and a creamy / mousse feel. San Pellegrino water was found to have low foam with a middle range of pain, while Banquet Coors beer was found to have low pain with a medium amount of foam. The 7up soda had high pain and high foam, while Canada Dry Club soda had the highest pain level with a low amount of foam.

During training, changes were made to the serving protocol and lexicon. The serving protocol was revised to improve product consistency. Specifically, glasses were rinsed with the sparkling wine being evaluated prior to pouring for sample evaluation. Additionally, the original terms bubble size and pain were found to be highly correlated and redundant and were therefore collapsed into one attribute bubble pain. For this research, challenges in panel agreement were consistent over the panel. The mouthfeel attributes bubble pain and foamy were most problematic. For this reason, additional calibration exercises were focused on the entire panel.

Once the lexicon was finalized, a sparkling wine wheel (Figure 1) was designed which was based on Noble's Wine Aroma Wheel (1987) as well as Pickering and Demiglio's white wine mouthfeel wheel (2008). The sparkling wine wheel provides a visual summary of all the sensory attributes relating to sparkling wines including mouthfeel. The attributes on the wheel are grouped in 13 sections from fruit to mouthfeel. These sections represent a first tier level of information emphasizing a broad category of attributes. Within, each section of the wheel, there is a second tier that provides an actual list of attributes reflecting the lexicon developed during this research study. For example, the fruit section has several attributes such as citrus, tropical, tree fruit, etc. Within each attribute, a third tier level was added to provide specific examples (e.g. the citrus attribute is subdivided with examples such as lemon, grapefruit, orange, lime).

Panel Validation

Table 5 provides a breakdown of attributes not present, attributes with significant differences, and attributes present in two or fewer wines for lexicon practice phase, Study 1, and

Study 2. For studies 1 and 2, attribute averages by product with statistical grouping are given in Tables 6 and 7. These results clearly illustrate the panel's ability to discriminate, as significant product differences (i.e. $p \leq 0.1$) existed for all of the attributes present in each of the three data sets. Further, all three data sets had at least 14 "distinguishing" attributes which indicates that the lexicon includes characteristics that are largely unique to specific wines. The use of distinguishing attributes in lexicons is typical in descriptive analysis to help classify products. For example, in the development of a sensory lexicon for mangos, Suwonsichon et al. were able to differentiate amongst mango cultivars with key attributes (2012).

Table 8 presents the correlation of panelist intensity versus panel intensity by attribute for the practice phase, Study 1, and Study 2. Tomic et al. have noted that correlations are well suited to illustrate how each assessor uses the scale for each attribute compared to the panel average (2007). In the practice phase, Study 2, and Study 3, the average correlations of all attributes were 0.69, 0.87, and 0.87, respectively.

Figures 3 and 4 provide the sensory maps for studies 1 and 2, respectively. For Study 1, the first two principal components accounted for 66.8% of the variation in the sensory attributes. Principal component 1 differentiates between the sweet aromatics (caramelized, vanilla, honey), tropical, white floral and overall sweetness and creaminess, versus those associated with the citrus flavor, burning, and overall sourness and astringency. Principal component 2 separates samples according to products with off flavors such as stale beer, petroleum, and bruised fruit, versus products with more complex flavors such as toasted bread, vegemite flavor, and dried fruit. For Study 2, the first two principal components accounted for 70.2% of the variation in the sensory attributes. Similarly in Study 2 principal component 1 differentiates tropical, white floral and overall sweetness versus burning and bitter products. Principal component 2 in Study 2 also separates complex flavors such as toasted bread, bread dough, vegemite, and sherry, versus bruised fruit, and petroleum. For studies 1 and 2, principal component analyses for PC3 vs. PC4 were reviewed and found to not provide better differentiation as none of these principal components accounted for more than 14.4 % of the total variability.

Discussion

Panelists must be able to detect and describe the perceived sensory attributes of a sample (Meilgaard et al. 2006). As in Study 1 and 2, 65 and 60 attributes were significantly different at $p \leq 0.10$ respectively, these results showed clear differentiation among the wines. The results show that the panelists were able to distinguish between the sparkling wines on the basis of mouthfeel, basic taste, aroma, and flavor attributes. One major reason for the large number of significant differences was that both studies 2 and 3 covered a large "sensory space" and each included at least 16 sparkling wines. Least significant differences (lsd) indicate that the discrimination of the panel exceeded the total product differences. For example, lsd's were often less than 0.3 in attributes where the maximum intensity difference exceeded 1.0 unit. These results further show strong panel discrimination and validate the panel's performance.

Some attributes were distinguishing where they were present only in one or two wines, such as candy / artificial, white floral, sweaty / lactic, petroleum in Study 1, and similarly, salty, bruised fruit, candy / artificial, vegemite, sherry, and petroleum in Study 2. Many other attributes were present in less than half of the wines, such as citrus, tropical, dried fruit, bread dough, and stale beer, emphasizing the uniqueness of many wines. Some attributes, such as mouthfeel, basic tastes, tree fruit, and sweet aromatics, were present in almost every wine but at different levels. Other attributes not found in the products included in this study, such as red and dark fruit, as well as chemical, microbiological, and earthy were retained. The red and dark fruit would most likely be relevant to evaluation of red sparkling wines. The chemical, microbiological and earthy attributes often considered as defects, could be useful in the study of shelf-life of sparkling wines.

Overall the average correlations of panelist vs. panel intensity were moderate to strong and increased over time showing panel repeatability. However, the correlations were overall lower for mouthfeel versus basic tastes, aromas, and flavors. The lower correlations in mouthfeel emphasize the challenges with evaluating mouthfeel (bubble pain, creamy, and foam). While, the panelists were experienced with the evaluation of aromas and flavors of wines, they had little to no experience with attributes pertaining to carbonation. Moreover, carbonation is unstable, and

as found during training, carbonation may vary from one pour to the next due to un-stability of the products. A change in serving protocol during training, where each glass was rinsed with the sparkling wine being evaluated, helped increase panel performance over time. Additionally, greater emphasis was placed in the evaluation of mouthfeel during training and calibration exercises to improve results on evaluation of carbonation mouthfeel . The biggest improvement was seen in the evaluation of the foamy attribute where the correlation was originally at a 0.37 and over a year later at 0.82 showing an increase of 119% over time.

The biplots in Figures 3 and 4 further validate panel performance as different wine types grouped together. The locations on the maps were consistent, distinguishing characteristics of these types of sparkling wines. The trained panel validated that attributes could be used to describe the sparkling wines. The Moscatos and Spumantes, which are the sweeter wines with floral notes and higher sweet aromatic flavors, are grouped together (S2.1, S2.2 and M2.1). The large group of Bruts was divided in three main groupings. The panel was able to characterize the most complex Brut wines with flavors such as bread dough, toasted bread, and sherry (B2.2, B2.3, B2.5, B2.7, B2.8, B2.7, B2.8 and B2.9). In contrast, the Bruts with off-notes, such as bruised fruit and petroleum, were close to each other. Additionally, four more Bruts that were simpler, with neither the complex flavors nor the off notes, were in the center of the map. These four Bruts were also closer in style to the Proseccos (P2.1, and P2.2) and the Extra-Dry (E2.1). Additionally, there was only one Demi-Sec (D2.1) that had a unique profile with creamy mouthfeel, high honey flavor, dried fruit and toasted notes. As a result, this Demi-Sec wine was located halfway between the sweet wines and the complex wines. Similar trends were found in Study 2, where the Moscatos and Spumantes are in the same area, defined by high sweetness, tropical and floral flavors. The Brut with complex flavors are again located in a same area of the map with toasted, vegemite, and bread dough flavors. The Bruts with off-notes are also separated. While the wines are grouped in areas with similar characteristics, they are also apart from each other, emphasizing the uniqueness of each product with differences in intensities. On both principal component biplots, the sourness and sweetness are inversely related, showing that the panel is able to differentiate wines based on sweetness level. The panel is also able to differentiate based on alcohol level; wine B2.4 in Study 2, and B3.3 in Study 3, have the highest level of alcohol at 13.5% and they are located the closest to the burn attribute on the biplots.

Based on these two principal component biplots, the panel was able to differentiate the wines therefore validating the lexicon and the ability of the panel to differentiate products

Conclusion

A great emphasis in this research was placed on creating a lexicon and references that provide descriptors that cover a wide sensory space of sparkling white wines. Some of the attributes included in the lexicon, such as red fruit, dark fruit, spice, and rose, were not encountered in the evaluation of sparkling wines. Further research on the evaluation of sparkling red wines is recommended to validate these "un-used" attributes on the sparkling wine ballot. This was not judged necessary at the time of the research as the sparkling wine category is dominated by white products. While a wide range of sparkling white wines were chosen to define the sensory space of the product category, most wines chosen in this study were defect free. An extensive list of chemical attributes (e.g. alcohol / volatile acidity, sulfide, vitamin, Band-Aid, paper / cardboard), and earthy / moldy attributes were retained as they would be useful in the evaluation of over-aged sparkling wines. These attributes represent undesirable aromas and flavors in wines and were retained on the sparkling ballot as they would be useful to evaluate sparkling wines over time, especially in shelf-life studies and quality assurance processes.

Another opportunity for future research is to evaluate panel repeatability over time. This is important as sparkling wines are produced from agricultural products that have appreciable variability over time due to numerous sources. These sources include: temperature, weather, processing conditions, winemaking practices, region sourced, and changes in production. For this reason, effective measurement of panel repeatability over time is critical to effectively measure product differences.

In this research, a lexicon, references, and flavor wheel were developed for the evaluation of sparkling wines. Over three studies, panel performance with the new lexicon was validated with discrimination, correlation, and principal component analysis. This new lexicon effectively differentiated sparkling wine types, and may be helpful for scientists and winemakers for the future evaluation of sparkling wines.

Figures and Tables

Figure 1: Sparkling Wine Wheel

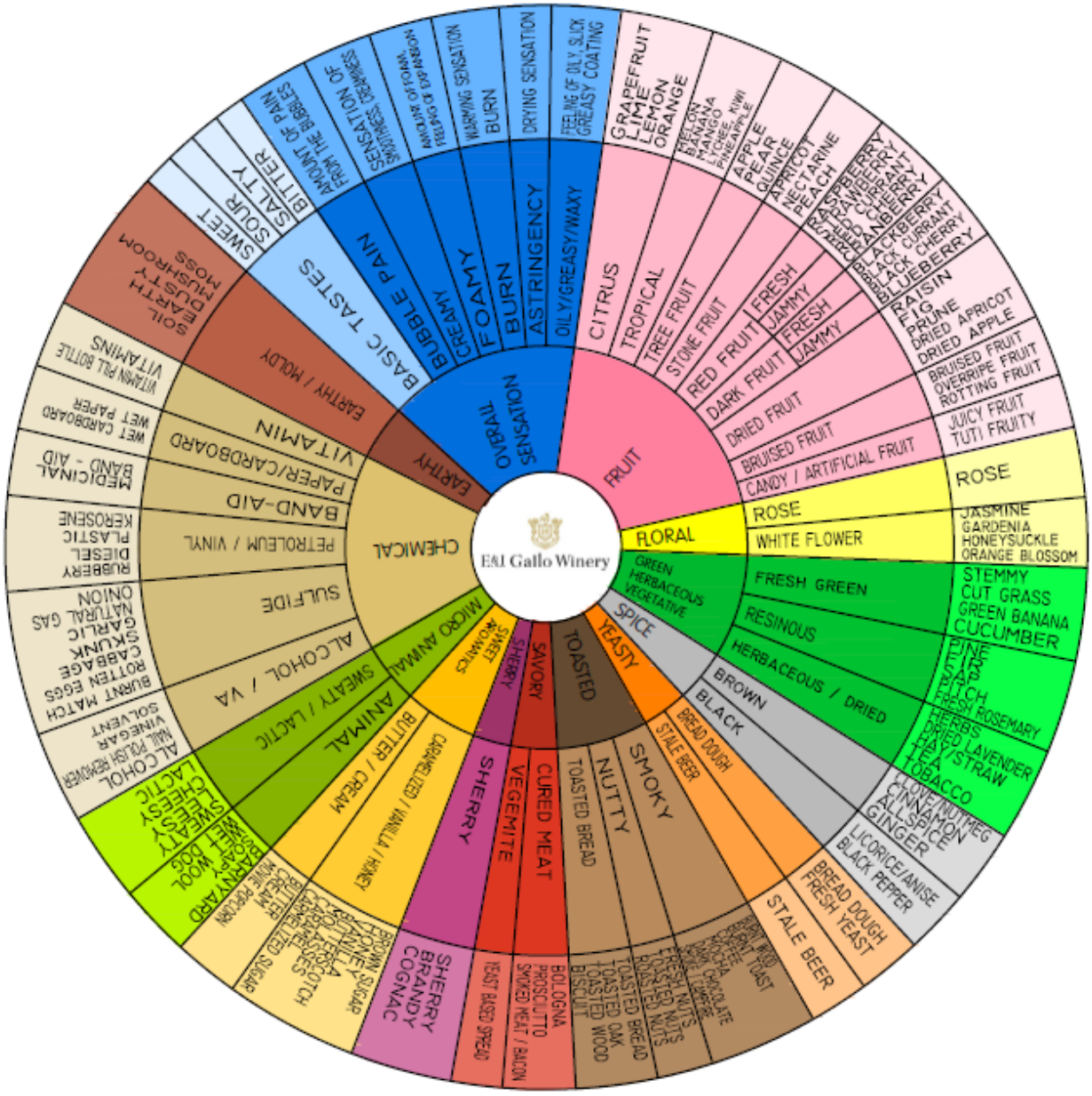
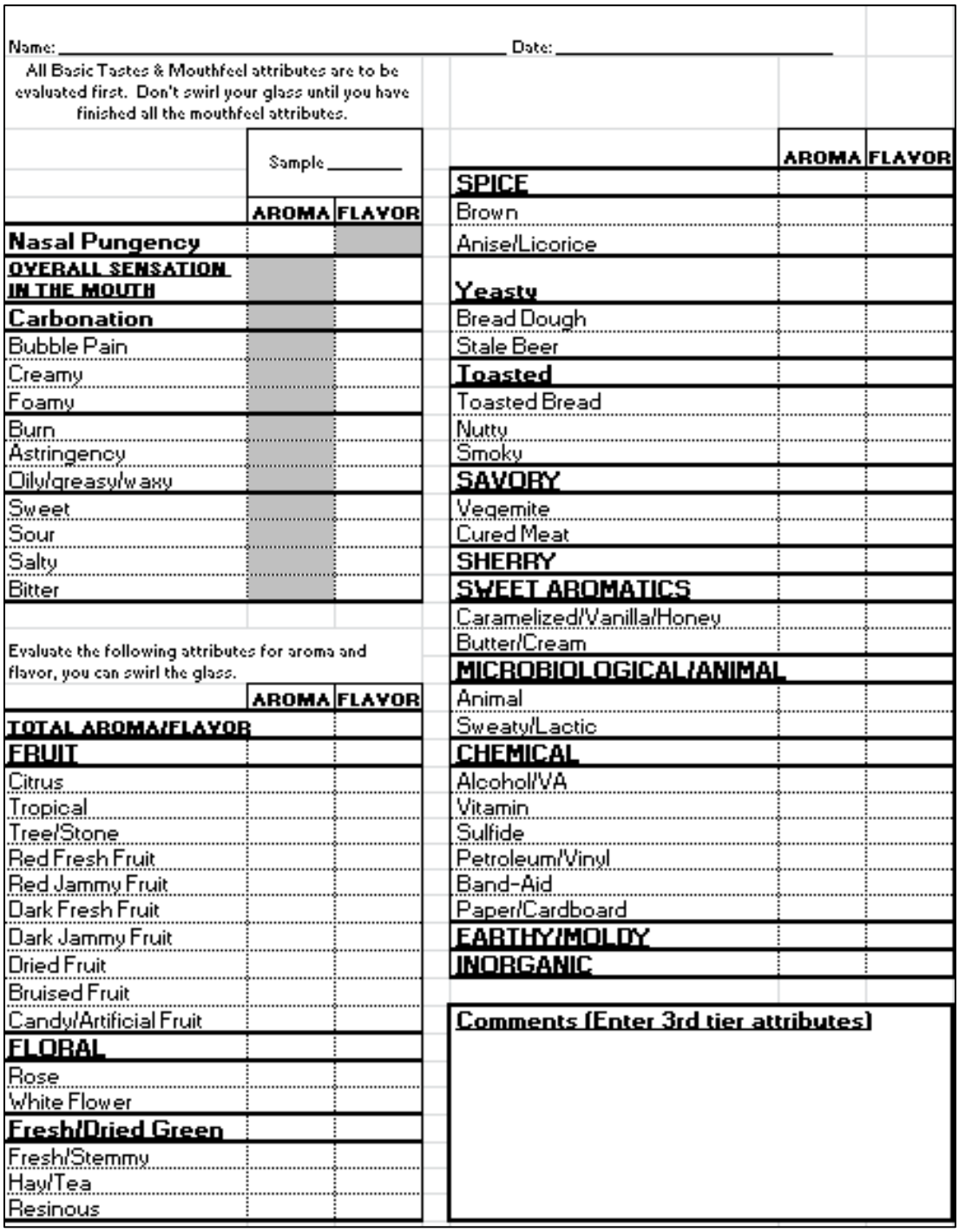


Figure 2: Sparkling Wine Ballot



Name: _____ Date: _____

All Basic Tastes & Mouthfeel attributes are to be evaluated first. Don't swirl your glass until you have finished all the mouthfeel attributes.

	Sample _____	
	AROMA	FLAVOR
Nasal Pungency		
OVERALL SENSATION IN THE MOUTH		
Carbonation		
Bubble Pain		
Creamy		
Foamy		
Burn		
Astringency		
Oily/greasy/waxy		
Sweet		
Sour		
Salty		
Bitter		

Evaluate the following attributes for aroma and flavor, you can swirl the glass.

	AROMA	FLAVOR
TOTAL AROMA/FLAVOR		
FRUIT		
Citrus		
Tropical		
Tree/Stone		
Red Fresh Fruit		
Red Jammy Fruit		
Dark Fresh Fruit		
Dark Jammy Fruit		
Dried Fruit		
Bruised Fruit		
Candy/Artificial Fruit		
FLORAL		
Rose		
White Flower		
Fresh/Dried Green		
Fresh/Stemmy		
Hay/Tea		
Resinous		

	AROMA	FLAVOR
SPICE		
Brown		
Anise/Licorice		
Yeasty		
Bread Dough		
Stale Beer		
Toasted		
Toasted Bread		
Nutty		
Smoky		
SAVORY		
Vegemite		
Cured Meat		
SHERRY		
SWEET AROMATICS		
Caramelized/Vanilla/Honey		
Butter/Cream		
MICROBIOLOGICAL/ANIMAL		
Animal		
Sweaty/Lactic		
CHEMICAL		
Alcohol/VA		
Vitamin		
Sulfide		
Petroleum/Vinyl		
Band-Aid		
Paper/Cardboard		
EARTHY/MOLDY		
INORGANIC		

Comments (Enter 3rd tier attributes)

Figure 3: Principal Component Biplot of Descriptive Analysis Data for Mouthfeel, Aroma, and Flavor Attributes of 20 Sparkling Wines In Study 1.

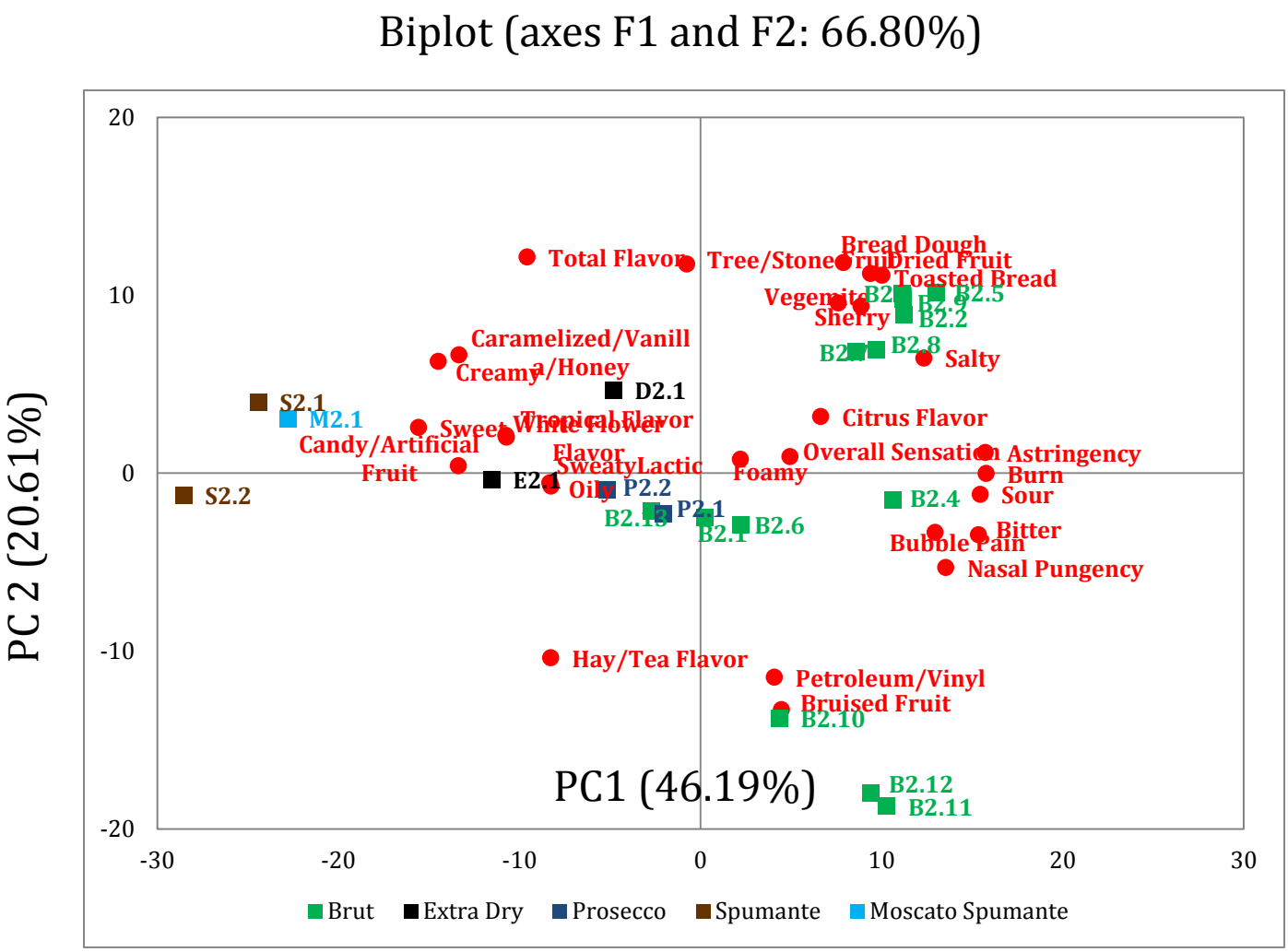


Figure 4: Principal Component Biplot of Descriptive Analysis Data for Mouthfeel, Aroma, and Flavor Attributes of 16 Sparkling Wines in Study 2.

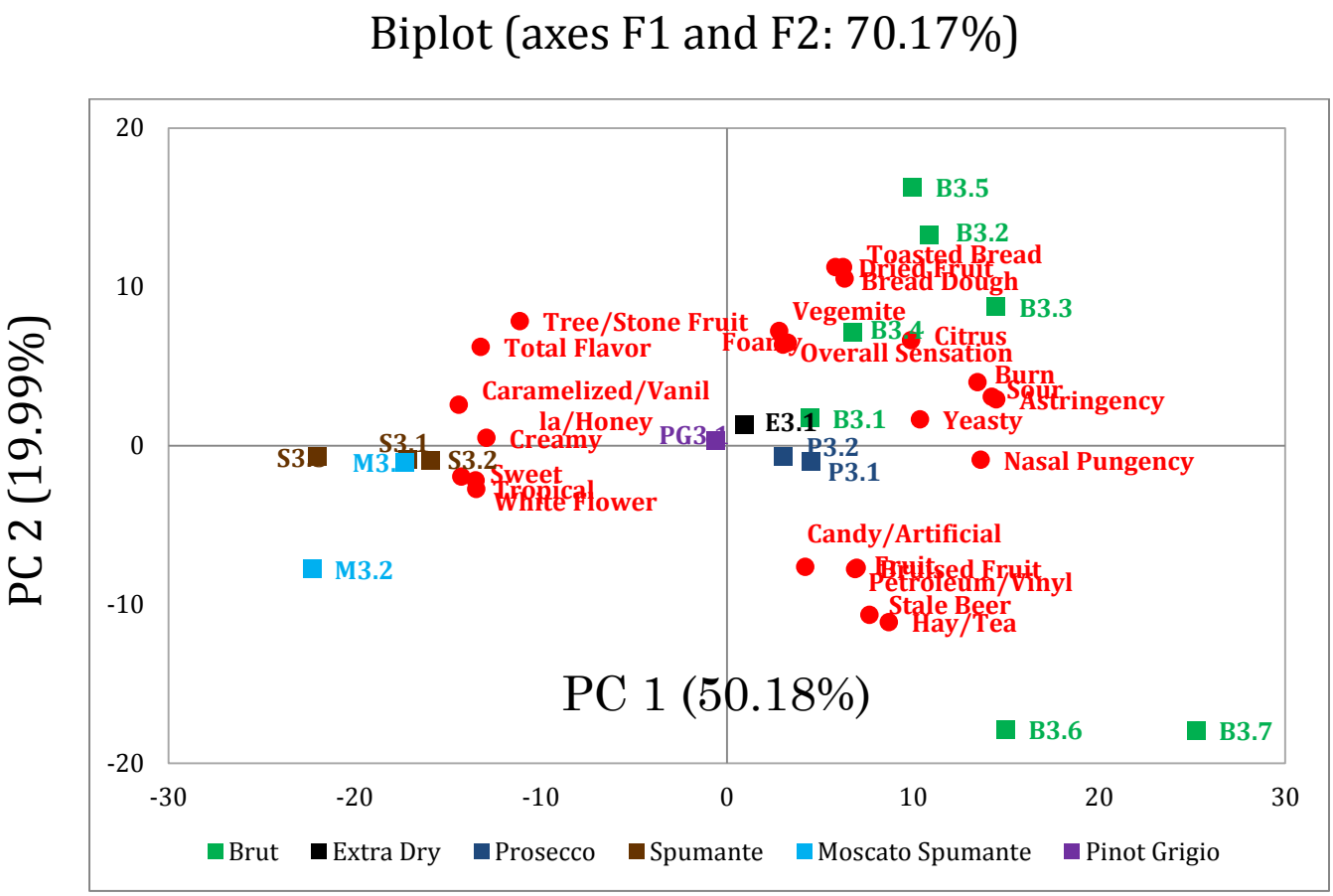


Table 1: Type, Origin, Residual Sugar, % Alcohol, and Price Range of 25 Sparkling Wines Used in Lexicon Development

Sparkling Wine	Type	Origin	Residual Sugar (g/100ml)	% Alcohol	Price Range (US dollars, Dec 2010)
B1.1	Brut	CA, USA	0.91	11.5	8.00-12.99
B1.2	Brut	CA, USA	1.28	12.5	>35.00
B1.3	Brut	CA, USA	1.31	13.5	13.00-17.99
B1.4	Brut	CA, USA	1.53	12.0	8.00-12.99
B1.5	Brut	CA, USA	2.48	12.2	13.00-17.99
B1.6	Brut	CA, USA	2.72	11.5	5.00-7.99
B1.7	Brut	CA, USA	3.39	12.5	13.00-17.99
B1.8	Brut	CA, USA	4.33	10.5	5.00-7.99
B1.9	Brut	France	0.94	12.0	≥35.00
B1.10	Brut	France	0.95	12.0	≥35.00
B1.11	Brut	France	0.99	12.0	≥35.00
B1.12	Brut	France	1.13	12.5	18.00-34.99
B1.13	Brut	France	1.24	12.0	18.00-34.99
B1.14	Brut	France	1.33	10.5	8.00-12.99
B1.15	Brut	France	-	12.0	18.00-34.99
B1.16	Brut	Spain	BDL*	11.5	13.00-17.99
B1.17	Brut	Spain	0.93	11.5	8.00-12.99
B1.18	Brut	Spain	1.03	12.0	8.00-12.99
B1.19	Brut	Spain	1.09	11.5	8.00-12.99
E1.1	Extra Dry	CA, USA	3.69	9.5	≤4.99
E1.2	Extra Dry	WA, USA	2.68	11.5	8.00-12.99
P1.1	Prosecco	Italy	1.76	11.0	8.00-12.99
M1.2	Moscato	Italy	14.71	6.0	8.00-12.99
M1.1	Moscato	CA, USA	5.84	8.5	8.00-12.99
S1.1	Spumante	Italy	9.10	7.5	8.00-12.99

* "-"not measured. BDL=Below detectible limit

Table 2: Type, Origin, Residual Sugar, % Alcohol, Carbonation and Price Range of 20 Sparkling Wines Used in Study 1

Sparkling Wine	Type	Origin	Residual Sugar (g/100ml)	% Alcohol	CO2 mg/100 ml	Price Range (US dollars, Feb 2011)
B2.1	Brut	CA, USA	0.91	11.5	1006	8.00-12.99
B2.2	Brut	CA, USA	1.17	13.1	1042	18.00-34.99
B2.3	Brut	CA, USA	1.28	12.0	977	≥35.00
B2.4	Brut	CA, USA	1.33	13.5	1058	13.00-17.99
B2.5	Brut	CA, USA	1.35	12.0	1066	18.00-34.99
B2.6	Brut	CA, USA	1.41	12.0	994	8.00-12.99
B2.7	Brut	France	1.01	12.0	1077	≥35.00
B2.8	Brut	France	1.02	12.0	1039	18.00-34.99
B2.9	Brut	France	1.18	12.5	1096	18.00-34.99
B2.10	Brut	France	1.32	10.5	762	8.00-12.99
B2.11	Brut	Spain	0.96	12.0	1031	8.00-12.99
B2.12	Brut	Spain	1.01	11.5	972	8.00-12.99
B2.13	Brut	Spain	2.81	11.5	10.8	5.00-7.99
E2.1	Extra Dry	CA, USA	3.72	9.5	887	≤4.99
D2.1	Demi-Sec	France	4.92	12.0	944	≥35.00
M2.1	Moscato	CA, USA	5.61	8.5	968	8.00-12.99
P2.1	Prosecco	Italy	1.74	11.0	901	8.00-12.99
P2.2	Prosecco	Italy	2.01	11.0	670	13.00-17.99
S2.1	Spumante	Italy	8.40	7.5	878	8.00-12.99
S2.2	Spumante	Italy	10.63	5.0	491	≤4.99

Table 3: Type, Origin, Residual Sugar, % Alcohol, Carbonation and Price Range of 16 Sparkling Wines Used in Study 2

Sparkling wine	Type	Origin	% Alcohol	Residual Sugar g/100ml	CO2 mg/100 ml	Price Range (US dollars, June 2012)
B3.1	Brut	CA, USA	11.5	0.91	942	8.00-12.99
B3.2	Brut	CA, USA	12.0	1.31	931	≥35.00
B3.3	Brut	CA, USA	13.5	1.34	1013	13.00-17.99
B3.4	Brut	CA, USA	12.0	1.40	924	8.00-12.99
B3.5	Brut	France	12.5	1.18	1050	18.00-34.99
B3.6	Brut	France	10.5	1.31	720	8.00-12.99
B3.7	Brut	Spain	12.0	0.92	1016	8.00-12.99
E3.1	Extra Dry	CA, USA	11.5	2.46	963	8.00-12.99
PG3.1	Pinot Grigio	CA, USA	11.5	2.12	915	8.00-12.99
P3.1	Prosecco	Italy	11.0	1.21	708	13.00-17.99
P3.2	Prosecco	Italy	11.5	1.86	891	8.00-12.99
M3.1	Moscato	CA, USA	8.5	5.95	900	8.00-12.99
M3.2	Moscato	Italy	7.0	6.94	344	8.00-12.99
S3.1	Spumante	CA, USA	9.0	8.21	863	5.00-7.99
S3.2	Spumante	CA, USA	9.0	8.49	863	≤4.99
S3.3	Spumante	Italy	7.5	8.36	853	8.00-12.99

Table 4: Sparkling Wines Sensory Attributes, Definitions, and References

Attribute	Definition	Reference[1], preparation intensity,
Nasal Pungency	Irritation, prickling, burn in nasal cavity.	Horseradish sauce, Beaver Brand regular Horseradish (not cream style)
Overall Sensation in the mouth	**Includes the mouth feel sensations of chemical feeling factors (carbonation, burn, astringency) and texture (creamy, foamy, mouth coating); may also include basic taste sensations but not the actual taste; what you feel when sparkling wine is in your mouth, what sensations you have on the surfaces of your mouth before and after expectoration; an overall perception of what is felt in the mouth.**	
Carbonation	**Overall perception of carbonation including bubble pain, creamy and foamy attributes.**	
Bubble Pain	Perception of the amount of pain from the bubbles bursting in the mouth.	Coors Banquet Beer: Low bubble pain=2.5 Pellegrino: Medium pain=5; 7Up Medium-high bubble pain =7; Canada Dry Club Soda High bubble pain=9
Creamy	Sensation perceived in the mouth. A creamy sensation is made up of small, dense bubbles with a feeling similar to mousse or whipped cream, it may have a smooth sensation.	Coors Banquet Beer: low sensation of smoothness on tongue, low creamy=1 Creaminess similar to Guinness=3
Foamy	Sensation perceived in the mouth. A foamy sensation is similar to egg white foam or the froth on the top of an ice cream float, a foamy sensation may feel like the foam is expanding in the mouth.	San Pellegrino Water =1 low expansion, Canada Dry Club Soda=3 slight increase of foam expansion. Coors Beer=5 Moderate expansion of foam Seven Up= 7 Quick expansion, foam lingers
Burn	Burning/warming sensation on surfaces of mouth, heat.	NSFG (Neutral Spirit From Grain) solution in Carlo Rossi Chablis 0%=2; 1.0%=4; 2%=6; 4%=8
Astringency	Drying sensation on tongue and pulling in and tightening of checks and mouth surfaces, sensed without moving tongue over surfaces caused by substances such as tannins or alum.	Grape juice (Welch's) =7
Oily/Greasy/Waxy	Feeling of an oily, slick, greasy coating left on the surfaces of the mouth after expectoration.	Wesson Oil.

(Table 4 Cont.)

Attribute	Definition	Reference, intensity, preparation
Sweet	The taste stimulated by sucrose and other sugars, such as fructose, glucose, etc.	Sucrose, solution in water 2.0%=2; 5.0%=5; 10%=10
Sour	The taste stimulated by acids, such as citric, malic, phosphoric, etc.	Citric acid, solution in water 0.05%=2; 0.08%=5
Salty	The taste stimulated by sodium salts, such as sodium chloride and sodium glutamate, and in part by other salts, such as potassium chloride.	NaCl, solution in water 0.2%=2.5; 0.35%=5
Bitter	The taste stimulated by substances such as quinine, caffeine, and hop bitters.	Caffeine, solution in water 0.05%=2; 0.08%=5

(**Table 4 Cont.)**

Attribute	Definition	Reference, intensity, preparation
Fruit	**Overall rating of fruit intensity**	
Citrus	The aromatics associated with citrus fruits	Fresh grapefruit, lemon, lime, orange, mandarin, tangerine and citrus peel.
Tropical	The aromatics associated with tropical fruits	Fresh pineapple, melon, banana, mango, kiwi, and canned lychee.
Tree/Stone	The aromatics associated with tree and stone fruits such as Fresh Apple-all varieties, Baked/Cooked Fruit/ Apple Sauce, pear, apricot, peach, nectarine, and quince.	5: Cooked apple, applesauce Mott, fresh apple, baked apple, fresh apricot, fresh nectarine, fresh peach, canned peach.
Red Fresh Fruit	The aromatics associated with a variety of red berries such as fresh strawberries, fresh raspberries, fresh red cherries, and fresh cranberries.	Fresh raspberries, fresh strawberries, fresh cranberries.
Red Jammy Fruit	The aromatics associated with a variety of red berry jams such as strawberry jam, raspberry jam, and red cherry jam	Trader Joe strawberry jam, Trader Joe raspberry jam.
Dark Fresh Fruit	The aromatics associated with a variety of dark berries such as fresh blackberries, fresh blueberries, and dark fresh plums.	Fresh blackberries, fresh blueberries, fresh dark plums.
Dark Jammy Fruit	The aromatics associated with a variety dark berry jam such as blackberry jam, blueberry jam, and plum jam.	Trader Joe blackberry jam, Trader Joe blueberry jam.
Dried Fruit	The aromatics associated with Prune, raisin, fig, dried apple, dried apricot.	Sunmaid Dried apples, Sunmaid dried apricots.
Bruised Fruit	The aromatics associated with bruised, overripe and/or rotting fruit flavor.	Bruised apples: old apples left for 3 months in cold storage
Candy/Artificial Fruit	Juicy Fruit, Tutti Fruity, Jolly Rancher type candy fruit flavors.	Artificial fruit: Wrigley Juicy fruit gums

(Table 4 Cont.)

Attribute	Definition	Reference, intensity, preparation
Floral	**Overall rating of floral intensity**	
Rose	Floral impression associated with the smell of rose.	Dabur red rose water.
White	Floral impression associated with white flowers such as Jasmine, gardenia, orange blossom, honeysuckle.	Jasmine: Givaudan Natural jasmine flavor. Honeysuckle: Givaudan natural honeysuckle flavor. Orange blossom: Givaudan natural orange blossom flavor.
Fresh/Dried Green	**Overall rating of green intensity**	
Fresh/Stemmy	Fresh green notes associated with fresh cut grass, cucumber, green banana	Wheat grass, cucumber
Herbaceous/Dried	Dried herbaceous notes associated with dried herbs, hay, straw, tea, tobacco, wet hay.	Herbs: McCormick dried Italian herbs. Straw: L&L Nursery & Supply multipurpose straw. Black tea: Tazo Awake Black Tea. Green tea: Celestial Seasonings Green Tea. Tobacco: Natural American Spirit Original Blend Tobacco.
Resinous	Resinous aromatic notes associated with pine, fir, sap, pitch, fresh rosemary.	IFF Resin flavor.
Spice	**Overall rating of spice intensity, including white pepper**	
Brown	Brown spice notes associated with cloves, cinnamon, nutmeg, allspice, ginger	12: Cinnamon Big Red Gum (Wrigley). McCormick all spice
Licorice/Anise	Spicy notes associated with Licorice, anise.	Licorice: Panda licorice. Anise: McCormick Anise seeds
Yeasty	**Overall rating of yeasty intensity**	
Bread Dough	Aromatics associated with notes of fresh bread dough such as unbaked, yeasted bread dough, fresh yeast	Red star yeast: Combine yeast in warm water with sugar.
Stale Beer	Aromatics associated with aged/stale beer.	Coors Banquet beer left opened in the light for 24 hours.

(Table 4 Cont.)

Attribute	Definition	Reference, intensity, preparation
Toasted	**Overall rating of toasted intensity**	
Toasted Bread	Aromatics associated with a range of toasted notes such as toasted white bread, toasted whole wheat bread, biscuit/digestive, graham cracker, toasted wood, toasted oak.	Toasted slices of Savemart white bread. Toasted slices of Savemart whole-wheat bread. Biscuit: Digestive biscuits. Graham crackers.
Nutty	Aromatics referring to nutty notes commonly associated with fresh nuts, toasted/roasted nut.	Walnut: Blue Diamond walnuts. Pecans: Blue Diamond walnuts.
Smoky	Aromatics of smoky notes associated with burnt wood, burnt toast, coffee, dark chocolate, mocha, smoke/campfire.	Coffee: Quest international coffee flavor QI500027.
Savory	**Overall rating of savory intensity**	
Vegemite	Aromatic notes associated with Vegemite yeast based spread.	Vegemite spread.
Cured Meat	Aromatics associated with cured meats such as Bologna, Prosciutto, smoked meat/bacon.	Meaty: Gallo Italian dry salami.
Sherry	Intensity rating for Sherry, Brandy or Cognac.	Fairbank sherry & E&J Gallo VSOP Brandy.
Sweet Aromatics	**Overall rating of sweet aromatics aroma intensity**	
Caramelized/Vanilla/Honey	Sweet aromatic notes that may include the character notes of honey, caramel, caramelized sugar, butterscotch, brown sugar, molasses.	Vanilla: Spice Island vanilla extract. Caramel: Smuckers caramel sauce. Honey: Sue Bee Clover honey.
Butter/Cream	Aromatic notes associated with dairy notes of butter, cream, movie popcorn.	Butter: melted Challenge unsalted butter.

(Table 4 Cont.)

Attribute	Definition	Reference, intensity, preparation
Micro/Animal	**Overall rating of microbiological/animal intensity**	
Animal	Aromatic notes associated with animal smells such as barnyard, soapy, wet wool, wet dog.	Barnyard: 100 ppb 4-ethylguiacol (aroma only).
Sweaty/Lactic	Aromatic notes associated with notes such as sweaty, cheesy, baby spit up, lactic, sour milk, rotten fruit.	Lactic: Kraft foot parmesan cheese.
Chemical	**Overall rating of chemical intensity**	
Alcohol/VA	Pungent aromatic notes associated with alcohol, vinegar, nail polish remover, solvent.	Vinegar: Heinz white vinegar. Solvent: Cutex nail polish remover.
Vitamin	Aromatic notes associated with the smell of vitamin pill bottle, vitamins.	VitaminB12: Walgreens vitamin B12.
Sulfide	Aromatic notes associated with burnt match, rotten eggs, cabbage, skunk, garlic, onion, natural gas, swamp, low tide.	Overcooked aged eggs. Burnt Matches: Match burnt and quickly left in a small plastic cup with a lid to capture smell.
Petroleum/Vinyl	Aromatic notes associated with petroleum, rubbery, diesel, kerosene, plastic, tar, waxy, crayon, vinyl.	Petroleum: Kingsford charcoal lighter fluid.
Band-Aid	Aromatic notes associated with Medicinal, Band-Aid.	Band-Aid: 1ppm 4-ethylphenol.
Paper Cardboard	Wet paper, wet cardboard.	Wet paper: Newsprint paper soaked in water.
Earthy/Moldy	Aromatic associated with a range of earthy/moldy notes such as soil, planting soil, dusty, mushroom, mulch-wet leaves, truffle, unwashed potato, Moldy, musty basement, moss.	Earthy: Miracle Grow planting soil.
Inorganic	Mineral, wet rocks, wet concrete, metallic, flint, chalk.	Mineral: Volvic Water.

[1]Most references are illustrative only and do not have a specific intensity associated with them.

Table 5: Summary of Significance of Attributes

	STUDY 2	**STUDY 3**
Total # of Attributes	109	109
Attributes Not Present (all "0")	43	48
Attributes with significant differences at $p \leq 0.10$	65	60
Distinguishing Attributes (present in ≤ 2 wines)	14	18

Table 6: Summary of Anovas for Study 1

Attributes	E2.1	B2.1	B2.2	B2.3	B2.4	B2.5	B2.6	M2.1	B2.7	B2.8	B2.9	B2.10	D2.1	P2.1	P2.2	S2.1	S2.2	B2.11	B2.12	B2.13	LSD
Nasal Pungency	2.5^{fg}	2.6^{f}	3.3^{bc}	3.1^{cd}	3.1^{cd}	3.1^{cd}	2.9^{e}	2.4^{h}	3.1^{cd}	3.1^{d}	3.2^{bc}	3.4^{b}	2.7^{f}	2.7^{f}	2.5^{fg}	2.3^{h}	2.4^{gh}	3.6^{a}	3.6^{a}	2.9^{e}	0.2
Overall Sensation in the Mouth	5.7^{cd}	5.9^{bcd}	5.9^{bcd}	6.0^{abc}	6.2^{ab}	6.0^{abc}	6.0^{abc}	6.2^{ab}	5.9^{bcd}	6.0^{abc}	5.9^{bcd}	5.6^{d}	5.6^{d}	5.8^{cd}	5.5^{d}	6.3^{a}	5.1^{e}	6.1^{abc}	6.1^{abc}	5.5^{de}	0.3
Carbonation	5.4^{bcde}	5.4^{bcde}	5.3^{cde}	5.4^{bcde}	5.8^{abc}	5.5^{abcde}	5.7^{abc}	5.8^{ab}	5.4^{bcde}	5.6^{abcde}	5.3^{cde}	5.1^{def}	5.1^{def}	5.5^{abcde}	5.1^{def}	6.0^{a}	4.6^{f}	5.6^{abcd}	5.6^{abcd}	5.0^{ef}	0.3
Bubble Pain	3.5^{fg}	4.2^{abc}	4.0^{abcd}	3.6^{fg}	4.3^{ab}	4.2^{abc}	4.4^{a}	3.4^{g}	4.0^{bcd}	4.1^{abcd}	3.8^{def}	3.8^{def}	3.5^{fg}	3.9^{cde}	3.5^{fg}	3.3^{g}	2.5^{h}	4.2^{abc}	4.3^{abc}	3.6^{efg}	0.3
Creamy	1.3^{cd}	0.6^{f}	1.1^{e}	1.1^{e}	0.4^{gh}	0.6^{f}	0.5^{fg}	1.7^{b}	1.0^{e}	0.9^{e}	1.1^{e}	0.7^{f}	1.4^{c}	1.0^{e}	1.4^{c}	1.9^{ab}	2.0^{a}	0.3^{h}	0.5^{fg}	1.1^{de}	0.2
Foamy	5.0^{bcde}	5.0^{bcde}	4.9^{bcde}	5.0^{bcde}	5.4^{ab}	5.2^{bcde}	5.3^{abc}	5.4^{ab}	5.0^{bcde}	5.3^{abc}	4.9^{bcde}	4.7^{def}	4.7^{ef}	5.2^{abcd}	4.6^{ef}	5.7^{a}	4.2^{f}	5.1^{bcde}	5.1^{bcde}	4.8^{cde}	0.3
Burn	4.4^{j}	4.8^{fg}	5.3^{ab}	5.3^{ab}	5.1^{bc}	5.3^{a}	4.9^{ef}	4.1^{k}	5.2^{ab}	5.1^{cd}	5.2^{ab}	5.0^{de}	4.7^{gh}	4.8^{fgh}	4.5^{i}	3.9^{l}	3.5^{m}	5.2^{ab}	5.2^{ab}	4.7^{h}	0.3
Astringency	1.3^{f}	1.6^{de}	2.0^{a}	2.0^{a}	1.8^{bc}	2.0^{a}	1.5^{de}	0.9^{g}	1.9^{ab}	1.8^{b}	1.9^{ab}	1.7^{cd}	1.4^{ef}	1.5^{de}	1.5^{e}	0.8^{g}	0.9^{g}	1.8^{b}	1.9^{b}	1.5^{de}	0.2
Oily/Greasy/ Waxy	0.0^{c}	0.1^{c}	0.0^{c}	0.0^{c}	0.5^{b}	0.0^{c}	0.0^{c}	0.6^{ab}	0.1^{c}	0.0^{c}	0.1^{c}	0.0^{c}	0.1^{c}	0.7^{a}	0.0^{c}	0.0^{c}	0.1^{c}	0.0^{c}	0.0^{c}	0.1^{c}	0.2
Sweet	5.1^{c}	4.2^{g}	4.0^{hi}	3.9^{i}	3.8^{j}	4.0^{hi}	4.1^{gh}	6.0^{b}	4.0^{hi}	4.0^{hi}	4.0^{hi}	4.0^{h}	5.1^{c}	4.4^{f}	4.7^{d}	6.2^{a}	6.1^{ab}	3.8^{j}	3.8^{j}	4.5^{e}	0.1
Sour	4.3^{j}	5.1^{fg}	5.2^{efg}	5.4^{b}	5.5^{a}	5.3^{c}	5.2^{fg}	3.9^{k}	5.1^{g}	5.3^{cde}	5.3^{cde}	5.1^{fg}	4.3^{j}	4.9^{h}	4.8^{i}	3.7^{l}	3.6^{m}	5.3^{cd}	5.2^{def}	4.8^{hi}	0.2
Salty	0.0^{e}	0.3^{de}	1.4^{a}	1.5^{a}	0.6^{c}	1.5^{a}	0.3^{d}	0.0^{e}	1.0^{b}	1.1^{b}	1.5^{a}	0.6^{c}	0.0^{de}	0.1^{de}	0.1^{de}	0.0^{de}	0.0^{e}	0.6^{c}	0.6^{c}	0.1^{de}	0.3
Bitter	1.8^{g}	2.6^{de}	3.2^{bc}	3.1^{bc}	3.1^{c}	3.0^{c}	2.7^{d}	0.8^{i}	3.0^{c}	3.0^{c}	3.2^{bc}	3.3^{ab}	2.3^{f}	2.6^{de}	2.4^{ef}	0.7^{i}	1.1^{h}	3.5^{a}	3.4^{a}	2.5^{ef}	0.3

* Averages not sharing a letter are significantly different at a 90% confidence level (LSD post hoc multiple comparisons test).

(Table 6 Cont.)

Attributes	E2.1	B2.1	B2.2	B2.3	B2.4	B2.5	B2.6	M2.1	B2.7	B2.8	B2.9	B2.10	D2.1	P2.1	P2.2	S2.1	S2.2	B2.11	B2.12	B2.13	LSD
Total Aroma	5.9^{cd}	5.7^{fgh}	5.9^{cde}	5.8^{cdef}	5.6^{i}	5.7^{fgh}	5.6^{i}	6.3^{a}	5.9^{c}	5.8^{efg}	5.8^{defg}	5.2^{j}	6.0^{c}	5.7^{ghi}	5.6^{hi}	6.3^{a}	6.1^{b}	5.1^{j}	5.1^{j}	5.6^{i}	0.1
Fruit	5.4^{cd}	5.2^{efg}	5.4^{cde}	5.3^{def}	5.1^{h}	5.2^{efg}	5.1^{h}	5.8^{a}	5.4^{cde}	5.3^{ef}	5.2^{efg}	4.7^{i}	5.5^{bc}	5.2^{fgh}	5.1^{gh}	5.8^{a}	5.6^{b}	4.5^{j}	4.5^{j}	5.1^{h}	0.1
Citrus	0.0^{e}	0.0^{d}	0.0^{e}	0.0^{e}	4.2^{a}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1^{b}	0.1^{c}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{d}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1
Tropical	1.0^{c}	0.1^{d}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	3.0^{a}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	3.0^{b}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.2
Tree/Stone Fruit	5.1^{abcd}	5.1^{abc}	4.8^{de}	4.7^{e}	2.5^{f}	4.8^{e}	4.9^{abcde}	5.2^{ab}	4.8^{bcde}	4.8^{cde}	4.7^{e}	0.1^{gh}	4.9^{abcde}	5.1^{abc}	5.0^{abcde}	5.2^{a}	0.0^{h}	0.3^{g}	0.1^{gh}	5.0^{abcde}	0.3
Dried Fruit	0.1^{c}	0.2^{c}	1.8^{ab}	1.9^{ab}	0.0^{c}	1.8^{ab}	0.1^{c}	0.0^{c}	1.8^{ab}	1.6^{b}	1.8^{ab}	0.0^{c}	2.0^{a}	0.2^{c}	0.3^{c}	0.1^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{c}	0.3
Bruised Fruit	0.0^{b}	0.0^{b}	0.1^{b}	0.2^{b}	0.0^{b}	0.1^{b}	0.1^{b}	0.0^{b}	0.1^{b}	0.1^{b}	0.0^{b}	4.6^{a}	0.1^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	4.2^{a}	4.4^{a}	0.0^{b}	0.3
Candy/Artificial Fruit	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	5.6^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.1
Floral	1.7^{b}	0.2^{c}	0.0^{f}	0.0^{f}	0.1^{e}	0.0^{f}	0.0^{f}	2.6^{a}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	0.1^{e}	0.1^{d}	0.0^{f}	2.6^{a}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	0.1
White Flower	1.7^{c}	0.2^{d}	0.0^{g}	0.0^{g}	0.1^{f}	0.0^{g}	0.0^{g}	2.6^{a}	0.0^{g}	0.0^{g}	0.0^{g}	0.0^{g}	0.1^{f}	0.1^{e}	0.0^{g}	2.6^{b}	0.0^{g}	0.0^{g}	0.0^{g}	0.0^{g}	0.2
Fresh/Dried Green	1.7^{c}	1.6^{ef}	1.6^{efg}	1.5^{g}	1.6^{efg}	1.5^{fg}	1.6^{ef}	1.9^{ab}	1.6^{efg}	1.6^{efg}	1.5^{g}	1.9^{a}	1.7^{cd}	1.7^{c}	1.6^{de}	1.9^{a}	1.9^{a}	1.8^{b}	1.9^{a}	1.6^{efg}	0.1
Hay/Tea	1.7^{c}	1.6^{e}	1.6^{efg}	1.5^{fg}	1.6^{efg}	1.5^{g}	1.6^{e}	1.9^{ab}	1.6^{ef}	1.6^{efg}	1.5^{fg}	1.9^{a}	1.7^{cd}	1.7^{c}	1.6^{de}	1.9^{a}	1.9^{a}	1.8^{b}	1.9^{a}	1.6^{efg}	0.1
Yeasty	0.1^{fg}	0.1^{fg}	1.8^{cd}	1.8^{cd}	0.8^{e}	1.9^{bc}	0.1^{fg}	0.0g	1.7^{cd}	1.6^{d}	2.0^{bc}	2.7^{a}	0.3^{f}	0.1^{fg}	0.3^{fg}	0.0^{g}	0.0^{fg}	1.9^{bc}	2.2^{b}	0.1^{fg}	0.3
Bread Dough	0.0^{f}	0.1^{f}	1.7^{bc}	1.8^{abc}	0.7^{d}	1.9^{ab}	0.1^{f}	0.0f	1.6^{bc}	1.6^{c}	2.0^{a}	0.1^{f}	0.4^{e}	0.1^{f}	0.2^{ef}	0.0^{f}	0.0^{f}	0.0^{f}	0.1^{f}	0.1^{f}	0.2
Stale Beer	0.1^{d}	0.1^{d}	0.1^{d}	0.0^{d}	0.0^{d}	0.1^{d}	0.0^{d}	0.0d	0.1^{d}	0.0^{d}	0.0^{d}	2.6^{a}	0.0^{d}	0.0^{d}	0.1^{d}	0.0^{d}	0.0^{d}	1.9^{c}	2.1^{b}	0.0^{d}	0.2
Toasted	0.0^{e}	0.0^{e}	3.2^{bc}	3.7^{a}	2.8^{d}	3.5^{ab}	0.1^{e}	0.0^{e}	3.2^{c}	3.2^{c}	3.6^{a}	0.1^{e}	3.0^{cd}	0.0^{e}	0.3^{e}	0.1^{e}	0.1^{e}	0.0^{e}	0.1^{e}	0.1^{e}	0.3
Toasted Bread	0.0^{e}	0.0^{e}	3.2^{bc}	3.7^{a}	2.8^{d}	3.5^{ab}	0.1^{e}	0.0^{e}	3.2^{c}	3.2^{c}	3.6^{a}	0.1^{e}	3.0^{cd}	0.0^{e}	0.3^{e}	0.1^{e}	0.1^{e}	0.0^{e}	0.1^{e}	0.1^{e}	0.3
Savory	0.0^{d}	0.0^{d}	1.2^{a}	0.3^{c}	0.1^{cd}	1.0^{ab}	0.0^{d}	0.0^{d}	1.0^{ab}	1.2^{a}	0.9^{b}	0.1^{cd}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{cd}	0.0^{d}	0.2
Vegemite	0.0^{d}	0.0^{d}	1.2^{a}	0.3^{c}	0.1^{cd}	1.0^{ab}	0.0^{d}	0.0^{d}	1.0^{ab}	1.2^{a}	0.9^{b}	0.1^{cd}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{cd}	0.0^{d}	0.2
Sherry	0.0^{i}	0.0^{i}	1.4^{d}	2.2^{a}	0.0^{i}	1.9^{b}	0.0^{i}	0.0^{i}	0.2^{f}	0.2^{e}	1.5^{c}	0.0^{h}	0.2^{g}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.3
Sweet Aromatics	3.8^{c}	3.1^{ef}	2.8^{h}	2.7^{h}	2.2^{i}	2.8^{gh}	3.0^{fg}	4.3^{b}	3.0^{fg}	2.7^{h}	2.7^{h}	2.1^{ij}	3.6^{d}	3.2^{e}	3.3^{e}	4.4^{b}	4.6^{a}	1.9j^{k}	1.9^{k}	3.3^{e}	0.2

Caramelized/ Vanilla/Honey	3.8^{c}	3.1^{ef}	2.8^{h}	2.7^{h}	2.2^{i}	2.8^{gh}	3.0^{fg}	4.3^{b}	3.0^{fg}	2.7^{h}	2.7^{h}	2.1^{ij}	3.5^{d}	3.2^{e}	3.3^{e}	4.4^{b}	4.6^{a}	1.9^{jk}	1.8^{k}	3.3^{e}	0.2
Microbial/ Animal	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	1.4^{a}	0.0^{c}	0.0^{b}	0.0^{c}	0.1
Sweaty/Lactic	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	1.4^{a}	0.0^{d}	0.0^{c}	0.0^{d}	0.1
Chemical	0.1^{c}	0.0^{d}	0.0^{d}	0.0^{d}	0.0d	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{c}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	2.7^{a}	2.2^{b}	0.0^{d}	0.1
Petroleum/Vinyl	0.1^{c}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	2.7^{a}	2.2^{b}	0.0^{d}	0.1

* Averages not sharing a letter are significantly different at a 90% confidence level (LSD post hoc multiple comparisons test).

(Table 6 Cont.)

Attributes	**E2.1**	**B2.1**	**B2.2**	**B2.3**	**B2.4**	**B2.5**	**B2.6**	**M2.1**	**B2.7**	**B2.8**	**B2.9**	**B2.10**	**D2.1**	**P2.1**	**P2.2**	**S2.1**	**S2.2**	**B2.11**	**B2.12**	**B2.13**	LSD
Total Flavor	6.5^{cde}	6.3^{h}	6.4^{def}	6.6^{c}	6.2^{ij}	6.4^{efg}	6.3^{gh}	6.9^{a}	6.5^{cdef}	6.3^{fgh}	6.4def	5.8^{k}	6.5^{cd}	6.3hi	6.2^{j}	7.0^{a}	6.7^{b}	5.7^{l}	5.6^{l}	6.1^{j}	0.2
Fruit	6.0^{cd}	5.8^{fg}	5.9^{def}	6.0^{c}	5.7^{h}	5.9^{cde}	5.8^{efg}	6.4^{a}	5.9^{def}	5.8^{efg}	5.9de	5.3^{i}	6.0^{c}	5.8^{g}	5.7^{h}	6.5^{a}	6.2^{b}	5.1^{j}	5.1^{j}	5.6^{h}	0.1
Citrus	0.1^{efg}	0.3^{def}	0.3^{def}	1.5^{b}	4.8^{a}	1.4^{b}	0.3^{de}	0.0^{g}	0.3^{d}	0.9^{c}	0.9c	0.1^{defg}	0.0^{fg}	0.1^{efg}	0.1^{efg}	0.0^{g}	0.0^{g}	0.1^{defg}	0.0^{g}	0.0^{g}	0.3
Tropical	1.3^{c}	0.1^{d}	0.0^{g}	0.0^{g}	0.0^{g}	0.0^{g}	0.0^{g}	3.5^{a}	0.0^{g}	0.0^{g}	0.0g	0.0^{f}	0.0^{g}	0.0^{g}	0.0^{g}	3.4^{b}	0.0^{g}	0.1^{e}	0.0^{g}	0.0^{g}	0.2
Tree/Stone Fruit	5.7^{ab}	5.7^{ab}	5.3^{bcd}	5.2^{d}	3.0^{e}	5.3^{cd}	5.6a^{bc}	5.7^{a}	5.3^{cd}	5.3^{bcd}	5.3^{cd}	0.3^{fg}	5.6^{abcd}	5.7^{ab}	5.6^{abcd}	5.8^{a}	0.0^{g}	0.4^{f}	0.1^{fg}	5.6^{abc}	0.4
Dried Fruit	0.1^{b}	0.2^{b}	2.3^{a}	2.2^{a}	0.0^{b}	2.4^{a}	0.1^{b}	0.1^{b}	2.2^{a}	2.0^{a}	2.2^{a}	0.0^{b}	2.3^{a}	0.2^{b}	0.3^{b}	0.1^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.2^{b}	0.3
Bruised Fruit	0.0^{b}	0.0^{b}	0.2^{b}	0.1^{b}	0.0^{b}	0.0^{b}	0.2^{b}	0.0^{b}	0.1^{b}	0.0^{b}	0.0^{b}	5.1^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	4.7^{a}	4.9^{a}	0.1^{b}	0.3
Candy/Artificial Fruit	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	6.2^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.1
Floral	0.8^{c}	0.0^{e}	0.0^{e}	0.0^{e}	0.1^{d}	0.0^{e}	0.0^{e}	2.0^{a}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1^{d}	0.0^{e}	1.9^{b}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1
White Flower	0.8^{c}	0.0^{e}	0.0^{e}	0.0^{e}	0.1^{d}	0.0^{e}	0.0^{e}	2.0^{a}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1^{d}	0.0^{e}	1.9^{b}	0.0^{e}	0.0^{e}	0.0^{e}	0.0^{e}	0.1
Fresh/Dried Green	2.2^{c}	2.1^{de}	2.1^{defg}	2.0^{fg}	2.1^{defg}	2.0^{efg}	2.1^{def}	2.4^{ab}	2.0^{efg}	2.0^{efg}	2.0^{g}	2.4^{a}	2.1^{def}	2.2^{c}	2.1^{d}	2.4^{a}	2.4^{ab}	2.3^{b}	2.4^{a}	2.0^{efg}	0.1
Hay/Tea	2.2^{d}	2.1^{ef}	2.1^{efgh}	2.0^{gh}	2.1^{efgh}	2.0f^{gh}	2.1^{efg}	2.4^{ab}	2.0^{fgh}	2.0^{fgh}	2.0^{h}	2.4^{a}	2.1^{efg}	2.2^{d}	2.1^{e}	2.4^{a}	2.3^{c}	2.3^{bc}	2.4^{a}	2.0^{fgh}	0.1
Yeasty	0.1^{g}	0.1^{fg}	2.2^{bcd}	2.3^{bcd}	1.0^{e}	2.4^{bc}	0.1^{fg}	0.0^{g}	2.2^{cd}	2.0^{d}	2.5^{bc}	3.2^{a}	0.4^{f}	0.2^{fg}	0.3^{fg}	0.0^{g}	0.1^{g}	2.0^{d}	2.6^{b}	0.1^{fg}	0.3
Bread Dough	0.0^{e}	0.1^{e}	2.1^{ab}	2.3^{ab}	0.9^{c}	2.4^{a}	0.1^{e}	0.0^{e}	2.1^{ab}	2.0^{b}	2.5^{a}	0.2^{de}	0.4^{d}	0.2^{de}	0.2^{de}	0.0^{e}	0.0^{e}	0.1^{e}	0.1^{e}	0.1e	0.3
Stale Beer	0.1^{d}	0.0^{d}	0.1^{d}	0.0^{d}	0.1^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	3.0^{a}	0.0^{d}	0.0d	0.1^{d}	0.0^{d}	0.1^{d}	2.1^{c}	2.5^{b}	0.1^{d}	0.3
Toasted	0.0^{e}	0.0^{e}	3.7^{bc}	4.2^{a}	3.2^{d}	4.1^{ab}	0.1^{e}	0.0^{e}	3.6^{cd}	3.6^{cd}	4.1^{a}	0.1^{e}	3.4^{cd}	0.0e	0.3^{e}	0.2^{e}	0.0^{e}	0.0^{e}	0.2^{e}	0.1^{e}	0.3

Toasted Bread	0.0^{e}	0.0^{e}	3.7^{bc}	4.2^{a}	3.2^{d}	4.1^{ab}	0.1^{e}	0.0^{e}	3.6^{cd}	3.6^{cd}	4.1^{a}	0.1^{e}	3.4^{cd}	0.0e	0.3^{e}	0.2^{e}	0.0^{e}	0.0^{e}	0.2^{e}	0.1^{e}	0.3
Savory	0.0^{d}	0.0^{d}	1.5^{a}	0.4^{c}	0.1^{cd}	1.4^{ab}	0.1^{d}	0.0^{d}	1.4^{ab}	1.6^{a}	1.2^{b}	0.1^{cd}	0.0^{d}	0.0d	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{d}	0.1^{cd}	0.0^{d}	0.2
Vegemite	0.0^{d}	0.0^{d}	1.5^{a}	0.4^{c}	0.1^{cd}	1.4^{ab}	0.1^{d}	0.0^{d}	1.4^{ab}	1.6^{a}	1.2^{b}	0.1^{cd}	0.0^{d}	0.0d	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{d}	0.1^{cd}	0.0^{d}	0.2
Sherry	0.0^{i}	0.0^{i}	1.7^{d}	2.8^{a}	0.0^{i}	2.3^{b}	0.0^{i}	0.0^{i}	0.2^{e}	0.2^{f}	1.8^{c}	0.0^{h}	0.1^{g}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.0^{i}	0.3
Sweet Aromatics	4.5^{c}	3.6^{efg}	3.2^{i}	3.2^{i}	2.7^{j}	3.3^{hi}	3.5^{fgh}	4.9^{b}	3.5^{gh}	3.2^{i}	3.2^{i}	2.5^{jk}	4.2^{d}	3.8^{e}	3.8^{e}	5.0^{b}	5.2^{a}	2.4^{kl}	2.3^{l}	3.7^{ef}	0.2
Caramelized/ Vanilla/Honey	4.5^{c}	3.6^{efg}	3.2^{i}	3.2^{i}	2.7^{j}	3.3^{hi}	3.5^{fgh}	4.9^{b}	3.5^{gh}	3.2^{i}	3.2^{i}	2.5^{jk}	4.2^{d}	3.8^{e}	3.8^{e}	5.0^{b}	5.2^{a}	2.4^{kl}	2.3^{l}	3.7^{ef}	0.2
Microbial/Animal	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	2.2^{a}	0.0^{c}	0.1^{b}	0.0^{c}	0.1
Sweaty/Lactic	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	2.2^{a}	0.0^{c}	0.1^{b}	0.0c	0.1
Chemical	0.1^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	2.5^{a}	1.6^{b}	0.0^{c}	0.2
Petroleum/Vinyl	0.1^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	2.5^{a}	1.6^{b}	0.0^{c}	0.2

*Averages not sharing a letter are significantly different at a90%confidence level (LSD posthoc multiple comparisons test).

Table 7: Summary of Anovas for Study 2

Attributes	**B3.1**	**M3.1**	**B3.2**	**B3.3**	**B3.4**	**PG3.1**	**E.3.1**	**S.3.1**	**S3.2**	**B3.5**	**B3.6**	**P3.1**	**P3.2**	**M3.2**	**S3.3**	**B3.7**	**LSD**
Nasal Pungency	2.7^{e}	2.7^{e}	3.0^{bc}	3.0^{bc}	3.0^{c}	2.6^{f}	2.7^{e}	2.4i	2.5^{fg}	3.0^{bc}	3.1^{b}	2.7^{e}	2.8^{d}	2.4^{hi}	2.5^{gh}	3.4^{a}	0.1
Overall Sensation in the Mouth	6.1^{bc}	6.3^{abc}	6.1^{cd}	6.2^{abc}	6.1^{bc}	5.9^{de}	6.3^{ab}	6.2^{abc}	6.3^{abc}	6.4^{a}	5.5^{g}	5.8^{ef}	5.7^{fg}	4.1^{h}	6.4^{a}	6.1^{bc}	0.2
Carbonation	6.0^{cde}	6.2^{abc}	6.0^{cde}	6.2^{abcd}	6.1^{bcd}	5.8^{ef}	6.3^{ab}	6.1^{abcd}	6.1^{abcd}	6.2^{abc}	5.4^{h}	5.7^{fg}	5.6^{gh}	3.7^{i}	6.3^{a}	6.0^{de}	0.2
Bubble Pain	4.6^{cde}	4.4^{ef}	5.2^{a}	4.8^{bcd}	4.6^{de}	4.4^{ef}	4.6^{de}	4.1^{g}	4.1^{gh}	5.1^{ab}	4.3^{fg}	4.3^{efg}	4.3^{fg}	2.6^{i}	3.8^{h}	4.9^{abc}	0.2
Creamy	0.3^{h}	1.6^{b}	1.2^{d}	0.3^{h}	0.4^{h}	0.9^{e}	0.6^{fg}	1.5^{bc}	1.4^{cd}	0.8^{ef}	0.4^{gh}	0.4^{h}	0.7^{ef}	1.6^{b}	2.0^{a}	0.3^{h}	0.2
Foamy	5.6^{bc}	5.8^{abc}	5.6^{bcd}	5.7^{abc}	5.6^{bc}	5.4^{de}	5.8^{ab}	5.6^{abc}	5.6^{abc}	5.8^{ab}	4.8^{g}	5.2^{ef}	5.1^{fg}	3.2^{h}	5.9^{a}	5.5^{cd}	0.3
Burn	5.0^{abc}	4.1^{e}	5.0^{ab}	4.9^{abcd}	4.9^{abcd}	4.7^{cd}	4.7^{d}	4.1^{e}	4.1^{e}	5.0^{ab}	4.7^{d}	4.8^{bcd}	4.8^{bcd}	3.2^{f}	3.4^{f}	5.2^{a}	0.2

Astringency	1.5^{d}	0.4^{f}	1.9^{ab}	1.8^{b}	1.4^{d}	1.2^{e}	1.2^{e}	0.2^{fg}	0.4^{f}	1.7^{bc}	1.4^{d}	1.4^{de}	1.5^{cd}	0.1^{g}	0.2^{g}	2.0^{a}	0.2
Oily/Greasy/Waxy	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.2^{a}	0.2^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.1^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.1^{a}	0.0^{a}	0.2
Sweet	3.7f^{g}	6.4^{b}	3.7^{fg}	3.7^{g}	3.9^{e}	4.3^{d}	4.2^{d}	6.1^{c}	6.3^{bc}	4.0^{e}	3.9^{ef}	3.9^{ef}	4.0^{e}	6.4^{b}	6.7^{a}	3.4^{h}	0.1
Sour	5.6^{b}	3.8^{f}	5.8^{a}	5.8^{a}	5.4^{c}	5.0^{e}	5.2^{d}	3.9^{f}	3.9^{f}	5.3^{cd}	5.3^{cd}	5.3^{cd}	5.2^{d}	3.6^{g}	3.5^{g}	5.7^{ab}	0.2
Salty	0.2^{ef}	0.0^{f}	1.3^{a}	0.8^{c}	0.9^{b}	0.0^{f}	0.1^{ef}	0.0^{f}	0.0^{f}	1.2^{a}	0.4^{d}	0.2^{e}	0.2^{e}	0.0^{f}	0.0^{ef}	0.6^{d}	0.1
Bitter	3.0^{df}	0.7^{f}	3.4^{b}	3.3^{c}	2.9^{e}	2.6^{f}	2.6^{df}	1.0^{f}	1.0^{f}	3.1^{b}	3.4^{a}	2.9^{d}	3.0^{d}	0.3^{f}	0.2^{df}	3.8^{a}	0.2

* Averages not sharing a letter are significantly different at a 90% confidence level (LSD post hoc multiple comparisons test).

(Table 7 Cont.)

Attributes	B3.1	M3.1	B3.2	B3.3	B3.4	PG3.1	E.3.1	S.3.1	S3.2	B3.5	B3.6	P3.1	P3.2	M3.2	S3.3	B3.7	LSD
Total Aromas	5.8^{ef}	6.5^{ab}	5.9^{e}	5.8^{fg}	5.8^{fg}	5.7^{gh}	5.8^{fgh}	6.4^{c}	6.2^{d}	5.9^{e}	5.2^{j}	5.6^{i}	5.7^{hi}	6.4^{bc}	6.5^{a}	5.1^{k}	0.1
Fruit	5.4^{de}	6.0^{ab}	5.4^{d}	5.3^{fg}	5.3^{ef}	5.3^{fg}	5.3^{fg}	5.9^{b}	5.7^{c}	5.3^{def}	4.6^{i}	5.1^{h}	5.2^{gh}	5.9^{ab}	6.0^{a}	4.3^{j}	0.1
Citrus	1.4^{b}	0.0^{i}	1.0^{d}	4.4^{a}	0.4^{g}	0.7^{e}	0.6^{f}	0.0^{i}	0.0^{i}	0.4^{g}	0.2^{h}	1.2^{c}	0.9^{d}	0.1^{hi}	0.0^{i}	0.6^{f}	0.3
Tropical	0.3^{d}	2.8^{a}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	2.3^{c}	2.3^{c}	0.1^{e}	0.0^{f}	0.0^{f}	0.0^{f}	2.6^{b}	2.7^{a}	0.0^{f}	0.2
Tree/Stone Fruit	4.6^{f}	5.4^{a}	4.6^{f}	1.9^{g}	4.7^{de}	4.8^{d}	5.0^{c}	5.4^{a}	5.2^{b}	4.6^{f}	0.2^{i}	4.7^{e}	4.8^{de}	5.2^{b}	5.4^{a}	0.6^{h}	0.3
Dried Fruit	0.0^{d}	0.0^{d}	1.9^{a}	0.9^{c}	1.3^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.1^{d}	1.9^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1
Bruised Fruit	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	3.5^{a}	0.1

Candy/Artificial Fruit	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	4.4^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.1
Floral	1.1^{d}	2.7^{a}	0.0^{h}	0.0^{h}	0.0^{h}	0.6^{e}	0.5^{f}	2.1^{c}	2.1^{c}	0.0^{h}	0.2^{g}	0.1^{h}	0.0^{h}	2.4^{b}	2.2^{c}	0.0^{h}	0.2
White Flower	1.1^{d}	2.7^{a}	0.0^{h}	0.0^{h}	0.0^{h}	0.6^{e}	0.5^{f}	2.1^{c}	2.1^{c}	0.0^{h}	0.2^{g}	0.1h	0.0^{h}	2.4^{b}	2.2^{c}	0.0^{h}	0.2
Fresh/Dried Green	1.5^{de}	1.5^{cde}	1.5^{de}	1.6^{bc}	1.5^{e}	1.5^{de}	1.5^{e}	1.5^{de}	1.5^{e}	1.7^{b}	2.3^{a}	1.7b	1.6^{bcd}	1.5^{e}	1.5^{de}	2.2^{a}	0.1
Hay/Tea	1.5^{e}	1.5^{cde}	1.5^{de}	1.6^{bc}	1.5^{e}	1.5^{de}	1.5^{e}	1.5^{de}	1.5^{e}	1.7^{b}	2.2^{a}	1.6bc	1.6^{bcd}	1.5^{e}	1.5^{de}	2.2^{a}	0.1
Yeasty	0.0^{f}	0.0^{f}	2.0^{a}	1.7^{c}	0.2^{d}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	1.9^{b}	0.1^{e}	0.1^{e}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	0.2
Bread Dough	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{c}	2.2^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	1.4^{b}	0.1
Stale Beer	0.0^{d}	0.0^{d}	3.8^{a}	2.6^{c}	3.0^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	3.9^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.2
Toasted	0.0^{d}	0.0^{d}	3.8^{a}	2.6^{c}	3.0^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	3.9^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1
Toasted Bread	0.0^{d}	0.0^{d}	0.0^{c}	0.1^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	1.2^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1
Savory	0.0^{d}	0.0^{d}	0.0^{c}	0.1^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	1.2^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.1
Vegemite	0.0^{p}	0.0^{c}	0.0^{f}	0.0^{l}	0.0^{k}	0.0^{d}	0.0^{e}	0.0^{a}	0.0^{b}	0.0^{h}	0.0^{g}	0.0^{n}	0.0^{o}	0.0^{m}	0.0^{j}	0.0^{i}	0.1
Sherry	0.0^{c}	0.0^{c}	1.9^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	1.6^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.1
Sweet Aromatics	2.1^{i}	4.6^{ab}	2.3^{hi}	1.8^{j}	2.5^{fg}	2.8^{de}	2.7^{ef}	4.3^{c}	4.3^{c}	3.0^{d}	1.8^{j}	2.2^{i}	2.5^{gh}	4.4^{bc}	4.7^{a}	0.3^{k}	0.2
Caramelized/Vanilla/Honey	2.1^{i}	4.6^{ab}	2.3^{hi}	1.8^{j}	2.5^{fg}	2.8^{de}	2.7^{ef}	4.3^{c}	4.3^{c}	3.0^{d}	1.8^{j}	2.2^{i}	2.5^{gh}	4.4^{bc}	4.7^{a}	0.3^{k}	0.2
Chemical	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	3.0^{a}	0.1
Petroleum/Vinyl	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	3.0^{a}	0.1

* Averages not sharing a letter are significantly different at a 90% confidence level (LSD post hoc multiple comparisons test).

(Table 7 Cont.)

Attributes	**B3.1**	**M3.1**	**B3.2**	**B3.3**	**B3.4**	**PG3.1**	**E.3.1**	**S.3.1**	**S3.2**	**B3.5**	**B3.6**	**P3.1**	**P3.2**	**M3.2**	**S3.3**	**B3.7**	**LSD**
Total Flavors	6.4^{efg}	7.0^{ab}	6.4^{efg}	6.5^{ef}	6.4^{gh}	6.4^{fgh}	6.4^{efg}	6.9^{c}	6.8^{d}	6.5^{e}	5.7j	6.2^{i}	6.3^{hi}	6.9^{bc}	7.1^{a}	5.6^{k}	0.1
Fruit	6.0^{c}	6.5^{a}	5.9^{c}	6.0^{c}	5.9^{cd}	5.9^{c}	5.9^{c}	6.4^{a}	6.2^{b}	5.9^{c}	5.1^{f}	5.7^{e}	5.8^{de}	6.4^{a}	6.5^{a}	4.9^{g}	0.1
Citrus	2.5^{b}	0.0^{h}	2.4^{b}	5.2^{a}	1.7^{e}	1.9^{de}	1.7^{e}	0.0^{h}	0.1^{h}	1.7^{ef}	0.5^{g}	2.3^{bc}	2.1^{cd}	0.1h	0.0^{h}	1.4^{f}	0.2

Tropical	0.2^{e}	3.3^{a}	0.0^{f}	0.2^{e}	0.0^{f}	0.0^{f}	0.2^{e}	2.8^{c}	2.8^{c}	0.3^{d}	0.0^{f}	0.0^{f}	0.0^{f}	3.1b	3.2^{a}	0.1^{f}	0.2
Tree/Stone Fruit	5.1^{e}	5.9^{a}	5.0^{f}	2.4^{i}	4.9^{gh}	5.4^{c}	5.3^{d}	5.9^{a}	5.7^{b}	4.8^{h}	0.2^{k}	5.0^{fg}	5.2^{d}	5.7b	5.9^{a}	0.6^{j}	0.3
Dried Fruit	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{b}	0.3^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.2
Bruised Fruit	0.0^{c}	0.0^{d}	0.0^{d}	0.1^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	0.0d	0.0^{d}	3.9^{a}	0.2
Candy/Artificial Fruit	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	4.8^{a}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.2
Floral	0.2^{d}	2.1^{a}	0.0^{f}	0.0^{f}	0.0^{f}	0.2^{de}	0.1^{ef}	1.5^{c}	1.4^{c}	0.0^{f}	0.1^{de}	0.0^{f}	0.0^{f}	1.5c	1.7^{b}	0.0^{f}	0.1
White Flower	0.2^{d}	2.1^{a}	0.0^{f}	0.0^{f}	0.0^{f}	0.2^{de}	0.1^{ef}	1.4^{c}	1.4^{c}	0.0^{f}	0.1^{de}	0.0^{f}	0.0^{f}	1.5c	1.7^{b}	0.0^{f}	0.1
Fresh/Dried Green	2.0^{de}	2.0^{cde}	2.0^{de}	2.1^{bc}	2.0^{cde}	2.0^{de}	2.0^{de}	2.0^{de}	2.0^{de}	2.2^{b}	2.8^{a}	2.1^{b}	2.1^{bcd}	2.0de	2.0^{e}	2.7^{a}	0.1
Hay/Tea	1.9^{c}	2.0^{bc}	2.0^{bc}	2.1^{bc}	2.0^{bc}	2.0^{bc}	2.0^{bc}	2.0^{bc}	2.0^{bc}	2.1^{bc}	2.7^{a}	2.1^{b}	2.1^{bc}	2.0bc	2.0^{bc}	2.7^{a}	0.1
Yeasty	0.0^{g}	0.0^{g}	2.5^{b}	2.2^{c}	0.3^{e}	0.0^{g}	0.0^{g}	0.0^{g}	0.0^{g}	2.5^{b}	2.8^{a}	0.1^{f}	0.0^{g}	0.0g	0.0^{g}	1.6^{d}	0.2
Bread Dough	0.0^{f}	0.0^{f}	2.5^{a}	2.1^{c}	0.3^{d}	0.0^{f}	0.0^{f}	0.0^{f}	0.0^{f}	2.3^{b}	0.1^{e}	0.1^{ef}	0.0^{f}	0.0f	0.0^{f}	0.0^{f}	0.2
Stale Beer	0.0^{c}	0.0^{c}	0.0^{c}	0.1^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.2^{c}	2.7^{a}	0.1^{c}	0.0^{c}	0.0c	0.0^{c}	1.6^{b}	0.2
Toasted	0.0^{d}	0.0^{d}	4.3^{a}	3.0^{c}	3.6^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	4.4^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0d	0.1^{d}	0.0^{d}	0.1
Toasted Bread	0.0^{d}	0.0^{d}	4.3^{a}	3.0^{c}	3.6^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	4.4^{a}	0.0^{d}	0.0^{d}	0.0^{d}	0.0d	0.1^{d}	0.0^{d}	0.1
Savory	0.0^{c}	0.0^{c}	0.1^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	1.6^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.1
Vegemite	0.0^{c}	0.0^{c}	0.1^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	1.6^{a}	0.0^{c}	0.0^{c}	0.0^{c}	0.0c	0.0^{c}	0.0^{c}	0.1
Sherry	0.0^{d}	0.0^{d}	2.1^{a}	0.0^{d}	0.1^{c}	0.0^{d}	0.0^{d}	0.0^{d}	0.0^{d}	2.0^{b}	0.0^{d}	0.0^{d}	0.0^{d}	0.0d	0.0^{d}	0.0^{d}	0.1
Sweet Aromatics	2.6^{f}	5.1^{b}	2.7^{f}	2.4^{g}	2.9^{e}	3.3^{cd}	3.2^{d}	5.0^{b}	5.1^{b}	3.4^{c}	2.3^{g}	2.7^{f}	3.0^{e}	5.1b	5.5^{a}	0.4^{h}	0.3
Caramelized/Vanilla/Honey	2.6^{g}	5.1^{b}	2.7^{g}	2.4^{h}	2.9^{f}	3.3^{de}	3.2^{e}	4.8^{c}	5.1^{b}	3.4^{d}	2.3^{h}	2.6^{g}	3.0^{f}	5.1b	5.5^{a}	0.4^{i}	0.3
Chemical	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0b	0.0^{b}	2.9^{a}	0.1
Petroleum/Vinyl	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0b	0.0^{b}	2.9^{a}	0.1

* Averages not sharing a letter are significantly different at a 90% confidence level (LSD post hoc multiple comparisons test)

Table 8: Panelists Intensity vs. Panel Intensity for Correlations Ranges for Validation Phase, Study 1, and Study 2.

Attributes	Study 1					Study 2					Study 3				
Mouthfeel	Mean	Min		Max		Mean	Min		Max		Mean	Min		Max	% Change
Nasal Pungency	0.63	0.11	-	0.90		0.80	0.51	-	0.97		0.80	0.48	-	0.95	28%
Overall Sensation in the Mouth	0.45	-0.16	-	0.74		0.51	0.15	-	0.83		0.82	0.66	-	0.92	82%
Carbonation	0.38	-0.20	-	0.64		0.47	0.19	-	0.79		0.83	0.57	-	0.94	119%
Bubble Pain	0.42	-0.10	-	0.71		0.67	0.25	-	0.93		0.82	0.60	-	0.92	93%
Creamy	0.58	0.28	-	0.81		0.78	0.51	-	0.94		0.80	0.42	-	0.95	39%
Foamy	0.37	-0.07	-	0.71		0.49	0.18	-	0.79		0.82	0.60	-	0.92	119%
Burn	0.69	0.05	-	0.92		0.81	0.34	-	0.98		0.87	0.41	-	0.96	25%
Astringency	0.72	0.12	-	0.91		0.74	0.17	-	0.91		0.91	0.69	-	0.97	27%
Mouthfeel Average Correlations	0.53					0.66					0.83				
Basic Tastes															
Sweet	0.94	0.82	-	0.98		0.96	0.90	-	0.99		0.98	0.93	-	0.99	4%
Sour	0.84	0.56	-	0.94		0.92	0.71	-	0.97		0.95	0.71	-	0.99	14%
Salty	0.73	0.44	-	0.93		0.79	0.00	-	0.93		0.87	0.46	-	0.99	19%
Bitter	0.89	0.61	-	0.97		0.91	0.76	-	0.97		0.97	0.91	-	0.99	8%
Basic Tastes Average Correlations	0.85					0.89					0.94				11%

(Table 8 Cont.)

Attributes	Study 1					Study 2					Study 3				
Aromas	Mean	Min		Max		Mean	Min		Max		Mean	Min		Max	% Change
Total Aroma	0.74	0.44	-	0.92		0.84	0.61	-	0.95		0.86	0.64	-	0.96	17%
Fruit Aroma	0.74	0.52	-	0.90		0.86	0.65	-	0.96		0.88	0.66	-	0.98	20%
Citrus Aroma	0.79	0.00	-	0.95		0.94	0.00	-	1.00		0.91	0.47	-	0.99	16%
Tropical Aroma	0.89	0.53	-	0.98		0.96	0.69	-	1.00		0.96	0.69	-	1.00	8%
Tree/Stone Fruit Aroma	0.80	0.54	-	0.95		0.97	0.85	-	1.00		0.94	0.46	-	0.99	18%
Dried Fruit Aroma	0.60	-0.13	-	0.84		0.89	0.45	-	0.99		0.95	0.83	-	0.99	59%
Bruised Fruit Aroma	0.75	0.00	-	0.93		0.97	0.79	-	1.00		1.00	0.95	-	1.00	33%
Candy/Artificial Fruit Aroma	0.90	0.00	-	1.00		0.95	0.00	-	1.00		0.94	0.00	-	1.00	4%
Floral Aroma	0.91	0.73	-	0.99		0.97	0.85	-	1.00		0.96	0.86	-	0.99	5%
White Flower Aroma	0.92	0.74	-	0.99		0.97	0.85	-	1.00		0.96	0.86	-	0.99	5%
Hay/Tea Aroma	0.60	-0.08	-	0.92		0.68	0.12	-	0.90		0.80	0.35	-	0.96	35%
Yeasty Aroma	0.74	0.50	-	0.90		0.90	0.40	-	0.99		0.93	0.36	-	0.99	26%
Bread Dough Aroma	0.70	0.47	-	0.89		0.92	0.69	-	1.00		0.94	0.56	-	0.99	34%
Stale Beer Aroma	0.65	0.00	-	0.92		0.91	0.45	-	1.00		0.89	0.00	-	1.00	38%
Toasted Aroma	0.77	0.61	-	0.90		0.96	0.80	-	1.00		0.99	0.91	-	1.00	28%
Toasted Bread Aroma	0.78	0.60	-	0.90		0.96	0.80	-	1.00		0.99	0.91	-	1.00	27%
Savory Aroma	0.70	0.31	-	0.90		0.82	0.01	-	0.96		0.97	0.64	-	1.00	39%
Vegemite Aroma	0.67	0.34	-	0.89		0.82	0.01	-	0.96		0.97	0.64	-	1.00	44%
Sherry Aroma	0.55	0.00	-	0.86		0.86	0.22	-	0.99		0.98	0.75	-	1.00	79%
Sweet Aromatics Aroma	0.88	0.76	-	0.94		0.92	0.64	-	0.98		0.96	0.83	-	0.99	9%
Caramelized/Vanilla/Honey Aroma	0.87	0.68	-	0.95		0.89	0.06	-	0.98		0.96	0.83	-	0.99	10%
Microbial/Animal Aroma	0.00	0.00	-	0.00		0.84	0.00	-	1.00		0.00	0.00	-	0.00	NA
Sweaty Lactic Aroma	0.00	0.00	-	0.00		0.81	0.00	-	1.00		0.00	0.00	-	0.00	NA

Chemical Aroma	0.81	0.44	-	0.95		0.96	0.61	-	1.00		1.00	1.00	-	1.00	23%
Petroleum/Vinyl Aroma	0.89	0.58	-	0.99		0.96	0.61	-	1.00		1.00	1.00	-	1.00	13%
Aroma Average Correlations	0.70					0.90					0.87				23%

(Table 8 Cont.)

Attributes	Study 1					Study 2					Study 3				
Flavors	Mean	Min		Max		Mean	Min		Max		Mean	Min		Max	% Change
Total Flavor	0.76	0.49	-	0.90		0.84	0.65	-	0.96		0.86	0.61	-	0.97	13%
Fruit Flavor	0.75	0.47	-	0.90		0.85	0.66	-	0.97		0.87	0.60	-	0.97	16%
Citrus Flavor	0.73	0.31	-	0.91		0.92	0.69	-	0.99		0.95	0.78	-	0.99	30%
Tropical Flavor	0.90	0.53	-	0.98		0.96	0.70	-	1.00		0.97	0.89	-	1.00	8%
Tree/Stone Fruit Flavor	0.80	0.54	-	0.95		0.97	0.79	-	1.00		0.94	0.61	-	0.99	18%
Dried Fruit Flavor	0.59	-0.14	-	0.85		0.89	0.41	-	0.99		0.95	0.82	-	1.00	60%
Bruised Fruit Flavor	0.75	0.00	-	0.93		0.97	0.81	-	1.00		0.99	0.90	-	1.00	33%
Candy/Artificial Fruit Flavor	0.86	0.00	-	0.99		0.95	0.00	-	1.00		0.94	0.00	-	1.00	9%
Floral Flavor	0.89	0.73	-	0.98		0.95	0.83	-	1.00		0.96	0.83	-	0.99	8%
White Flower Flavor	0.89	0.73	-	0.98		0.95	0.83	-	1.00		0.96	0.83	-	0.99	8%
Hay/Tea Flavor	0.61	-0.14	-	0.95		0.68	0.16	-	0.96		0.81	0.31	-	0.97	32%
Yeasty Flavor	0.74	0.50	-	0.89		0.90	0.43	-	0.99		0.93	0.38	-	0.99	26%
Bread Dough Flavor	0.69	0.46	-	0.90		0.92	0.64	-	0.99		0.94	0.58	-	0.99	37%
Stale Beer Flavor	0.66	0.00	-	0.93		0.90	0.50	-	1.00		0.90	0.00	-	1.00	36%
Toasted Flavor	0.77	0.62	-	0.90		0.96	0.80	-	1.00		0.99	0.90	-	1.00	28%
Toasted Bread Flavor	0.78	0.61	-	0.90		0.96	0.80	-	1.00		0.99	0.90	-	1.00	27%
Savory Flavor	0.69	0.24	-	0.90		0.83	0.00	-	0.96		0.99	0.90	-	1.00	43%
Vegemite Flavor	0.67	0.29	-	0.88		0.83	0.00	-	0.96		0.99	0.90	-	1.00	48%
Sherry Flavor	0.59	0.00	-	0.84		0.89	0.74	-	0.99		0.97	0.70	-	1.00	66%

Sweet Aromatics Flavor	0.85	0.74	-	0.92		0.91	0.69	-	0.97		0.96	0.79	-	0.99	13%
Caramelized/Vanilla/Honey Flavor	0.84	0.71	-	0.92		0.91	0.69	-	0.97		0.96	0.79	-	0.99	14%
Microbial/Animal Flavor	0.00	0.00	-	0.00		0.89	0.00	-	1.00		0.00	0.00	-	0.00	NA
Sweaty Lactic Flavor	0.00	0.00	-	0.00		0.89	0.00	-	1.00		0.00	0.00	-	0.00	NA
Chemical Flavor	0.82	0.53	-	0.95		0.93	0.53	-	1.00		1.00	1.00	-	1.00	22%
Petroleum/Vinyl Flavor	0.88	0.57	-	0.99		0.93	0.53	-	1.00		1.00	1.00	-	1.00	14%
Flavor Average Correlations	0.70					0.90					0.87				25%
Overall Average Correlations	0.69					0.87					0.87				

References

Adhikari, K., Chambers, E.IV, Miller, R., Vázquez-Araújo, L.Bhumiratana, N., and Philip, C. 2011. Development of a lexicon for beef flavor in intact muscle. J. Sensory Stud.26: 413-420.

Baldy, M. 2004. The university wine course: a wine appreciation text & self tutorial. The Wine Appreciation Guild. Third Edition, Fourth Printing.

Bett-Garber, K.L., Lea, J.M., Champagne, E.T. *and* McClung, A.M. 2012. Whole-grain rice flavor associated with assorted bran colors. J. Sens. Stud. 27: 78–86.

Bi, J. 2003. Agreement and reliability assessments for performance of sensory descriptive panel. J. Sens Stud.18, 61-76.

Byrne, D., Bak, L., Bredie, W., Bertelsen, G., Martens, M. 1999. Development of a sensory vocabulary for warmed-over flavor: Part I. In porcine meat. J. Sens Stud., 14, 47-65.

Byrne, D., Bredie, W., Martens, M. 1999. Development of a sensory vocabulary for warmed-over flavor: Part II. In chicken meat. J. Sens Stud., 14, 67-78.

Cadot, Y., Caillé, S., Samson, A., Barbeau, G., Cheynier, V. 2012. Sensory representation of typicality of Cabernet Franc wines related to phenolic composition: Impact of ripening stage and maceration time. Anal. Chim. Acta, 732, 91-99.

Carbonell, L., Izquierdo, L., Carbonell, I. 2007. Sensory analysis of Spanish mandarin Juices. Selection of attributes and panel performance. Food Qual. Prefer. 18, 329-341.

Castura, J., Findlay, C., and Lesschaeve I. 2005. Monitoring calibration of descriptive sensory using distance from target measurements. Food Qual. Prefer. , 16, 682-690.

Chambers, D., Allison, A., Chambers E. 2004.Training effects on performance of descriptive panelist. J. Sens. Stud., 19, 486-499.

Chambers, E., Jenkins, A., McGuire, B. 2005. Flavor properties of plain soymilk. J. Sens. Stud., 12, 165-179.

Chambers, E. IV, Lee, J., Chun, S. *and* Miller, A.E. 2012. Development of a lexicon for commercially available cabbage (*Baechu*) kimchi. J. Sens. Stud. 27, 511–518.

Chambers, E. IV and Smith, E.A. 1993. Effects of testing experience on performance of highly trained sensory panelists. J. Sens. Stud. 8: 155-166.

Cherdchu, P., Chambers, E. IV, and Suwonsichon, T. 2013. Sensory lexicon development using trained panelists in Thailand and the United States: soy sauce. J. Sens. Stud. 28:248-255.

Civille, G., Lapsley, K., Huang, G., Yada, S., Seltsam, J. 2010. Development of an almond lexicon to assess the sensory properties of almond varieties. J. Sens. Stud., 25, 146-162.

Clapperton, J., Dalgliesh, C, Meilgaard, M. (1976). Progress towards an international system of beer flavor terminology. J. I. Brewing, 82, 7-13.

De La Presa-Owens, C. and Noble, A. 1997. Effect of storage at elevated temperature on aroma of Chardonnay wines. Am J Enol. Viticult., 48 (3), 310-316.

De La Presa-Owens, C., Schlich P., Davies, H., Noble, A. 1998. Effect of *Méthode Champenoise* process on Aroma of four *V.vinefera* varieties. Am J Enol. Viticult, 49(3), 289-294.

Del Castillo, R. Valero, J, Casaňas, Costell, E. 2008. Training, validation and maintenance of a panel to evaluate the texture of dry beans. J. Sens. Stud.. 23, 303-319.

Dooley, L., Adhikari, K., Chambers, E. 2009. A general lexicon for sensory analysis of texture and appearance of lip products. J. Sens. Stud., 24, 581-600.

Drake, S., Yates, M., Drake, M. 2010. Development of a flavor lexicon for processed and imitation cheeses. J. Sens. Stud., 25, 720-739.

Findlay C., Castura, J., Schlich, P., Lesschaeve, I. 2006. Use of feedback calibration to reduce the training time for wine panels. Food Qual. Prefer., 17, 266-276.

García, J., Aleizndre, J., Álvarez, I., and Lizama, V. 2009. Foam aptitude of Bobal variety in white sparkling wine elaboration and study of volatile compounds. Eur. J. Food Res. Technol., 229, 133-139.

Gawel, R., Iland, P., Francis, I. 2001. Characterizing the astringency of red wine: a case study. Food Qual. Prefer, 12, 83-94.

Gawel R, Oberholster A and Francis I. 2000 A mouthfeel wheel: terminology for communicating the mouthfeel characteristics of red wine. Aust. J. Grape Wine R. 6: 203–207.

Gómez García-Carpintero, E., Gómez Gallego, M., Sánchez-Palomo, E., González Viñas, M. (2012). Impact of alternative technique to ageing using oak chips in alcoholic or in malolactic fermentation on volatile and sensory composition of red wines. Food Chem. 134, 851-863.

Hein, K., Ebeler, S., Heymann, H. 2009. Perception of fruity and vegetative aromas in red wine. J. Sens. Stud., 24, 441-455.

Hidalgo, P., Pueyo. E., Pozo-Bayón, M., Martínez-Rodríguez, A., Martín-Álvarez, P., and Polo, M. (2004). Sensory and analytical study of Rosé sparkling wines manufactured by second fermentation in the bottle. J. Agric. Food Chem., 52, 6640-6645.

Jackson, R. (2002). Wine Tasting: A professional handbook. Elsevier Academic Press.

King, E., Osidacz, P., Curtin, C., Bastian, S., and Francis, I. 2011. Assessing desirable levels of sensory property in Sauvignon Blanc wines – consumer preferences and contribution of key aroma compounds. Aust. J. Grape Wine Res., 17, 169-180.

King, M., Hall, J., Cliff, M. 2001. A comparison of methods for evaluating the performance of a trained sensory panel. J. Sens. Stud., 16, 567-581.

Koch, I.S., Muller, M., Joubert, E., Van Der Rijst, M. *and* Næs, T. 2012. Sensory characterization of rooibos tea and the development of a rooibos sensory wheel and lexicon. Food Res. Int. 46, 217–228.

Koppel, K., Chambers, E. 2010. Development and application of a lexicon to describe the flavor of pomegranate juice. J. Sens. Stud., 25, 819-837.

Labbe, D., Rytz, A., Hugi, A. 2004. Training is a critical step to obtain reliable product profiles in a real food industry context. Food Qual. Prefer., 15 (2004): 341-348.

Lawless, L.J.R. and Civille, G. V. 2013. Developing Lexicons: A review. J. Sens. Stud.. 28: 270–281.

Lawless, H., and Heymann H. 1999. Sensory Evaluation of Food Principles and Practices. Aspen Publications.

Lawless, L., Hottenstein, A., Ellingsworth, J. 2012. The McCormick spice wheel: a systematic and visual approach to sensory lexicon development. J. Sens. Stud., 27, 37-47.

Leksrisompong, P.P., Whitson, M.E., Truong, V.D. *and* Drake, M.A. 2012b. Sensory attributes and consumer acceptance of sweet potato cultivars with varying flesh colors. J. Sensory Stud.27, 59–69.

Lesschaeve, I., Findlay, C. 2004. Development of a wine style guided by consumer research. Presented at Twelfth Australian Wine Industry Technical Conference.

Liger-Belair, G., Marchal, R., Robillard, B., Vignes-Adler, M., Maujean, A., and Jeandet P. (1999). Study of effervescence in a glass of Champagne: Frequencies of bubble formation, growth rates, and velocities of rising bubbles. Am. J. of Enol Viticult., 50(3), 317-323.

Lohitnavy, N., Bastian, S., Collins, C. 2010. Berry sensory attributes correlate with compositional Changes under different viticultural management of Semillon (Vitis vinifera L.). Food Qual. Prefer., 21, 711-719.

Martin, N. 2002. Sweet/sour balance in champagne wine and dependence on taste/odours interactions. Food Qual. Prefer., 13, 295-305.

Maughan, C., Tansawat, R., Cornforth, D., Ward, R. *and* Martini, S. 2012. Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. Meat Sci. 90, 116–121.

Mc Donnell, E., Hulin-Bertaud, S., Sheehan, E., Delahunty, C. (2001). Development and learning process of a sensory vocabulary for the odor evaluation of selected distilled beverages using descriptive analysis. J. Sens. Stud., 16, 425-445.

Meilgaard, M., Civille, G., Carr, B. Sensory Evaluation Techniques Fourth Edition. CRC Press. 2006.

Miller, A.E., Chambers, E. IV, Jenkins, A., Lee., J., and Chambers, D.H. 2013. Defining and Characterizing the "Nutty" Attribute across Food Categories. Food Qual. Pref. 27: 1-7.

Noble, A., Arnold, R., Masuda, B., Pecore, S., Schmidt, J, Stern, P. 1984. Progress towards a standardized system of wine aroma terminology. Am. J. of Enol Viticult 35, 107-109.

Noble, A., Arnold, R., Buechsenstein, J., Leach, E., Schmidt, J., and Stern, P. 1987. Modification of a standardized system of wine aroma terminology. Am. J. of Enol Viticult, 38,143-146.

Noble, A. 2006. Describing the indescribable. Food Sci. Technol., 20 (3), 32-35.

Paola Parpinello, G., Plumejeau, F., Maury, C., Versari, A. 2011. Effect of micro-oxygenation on sensory characteristics and consumer preferences of Cabernet Sauvignon wine. J. Sci. Food Agr., 92, 1238-1244.

Pickering, G., and Demiglio P. 2008. The white wine mouthfeel wheel: A lexicon for describing the oral sensations elicited by white wine. Journal of Wine Research, 19(1), 51-67.

Pozo-Bayón, M., Martínez-Rodríguez,A., Encarnación, P., and Moreno-Arribas, V. 2009. Chemical and biochemical features involved in sparkling wine production: from a traditional to an improved winemaking technology. Trends in Food Sci. Technol., 20, 289-299.

Pritchard, T. 2005 Wine: It's a matter of taste. In Sensi DiVini. (J. Mai, B. Mallebrein) pp15-26. Via Grappoli: Edition Raetia GmbH.

Rossi, F. 2001. Assessing sensory panelist performance using repeatability and reproducibility measures. Food Qual. Pref. , 12, 467-479.

Suwonsichon, S., Chambers, E., Kongpensook, V., and Oupadissakoon, C. 2012. Sensory lexicon for mango as affected by cultivars and stages or ripeness. J Sens. Stud. 27: 148-160.

Tesfaye, W. Morales, M., Callejón, R., Cerezo, A., González A., García-Parrilla, M., Troncoso, A. 2010. Descriptive sensory analysis of wine vinegar: tasting procedure and reliability of new attributes. J. Sens. Stud.25, 216-230.

Tomic, O., Nilsen, A., Martens, M., and Næs, T. (2007). Visualization of sensory profiling data for performance monitoring. LWT Food Sci. Technol., 40, 262-269.

Torrens, J., Pilar, U., Riu-Aumatell, M., Vichi, S., López-Tamames, E., and Buxaderas, S. (2008). Different commercial yeast strains affecting the volatile and sensory profile of cava base wine. Int. J. Food Microbioloy, 124, 48-57.

Torrens, J., Riu-Aumatell, M., Vichi, S., López-Tamames, E., and Buxaderas, S. (2010). Assessment of volatile and sensory profiles between base and sparkling wines. Journal of Agr. Food Chem., 58, 2455-2461.

Varela, P. and Gámbaro A. 2006. Sensory Descriptive Analysis of Uruguayan Tannat Wine: Correlation To Quality Assessment. J. Sensory Stud., 21, 203-217.

Vannier, A., Brun, O., and Feinberg, M. 1999. Application of sensory analysis to Champagne wine characterization and discrimination. Food Qual. Pref. , 10, 101-107.

Vázquez-Araújo, L., Chambers, D. *and* Carbonell-Barrachina, Á.A. 2012. Development of a sensory lexicon and application by an industry trade panel for turrón, a European protected product. J. Sens. Stud., 27, 26–36.

Vázquez-Araújo, L., Chambers, E. IV, and Funk, D.B. 2011. References for "musty" odor notes in sensory analysis of grain sorghum. J. Cereal Sci. 54: 460-466

Yau, N., and McDaniel, M. 1991. The effect on temperature on carbonation perception. Chem. Senses, 16(4), 337-348.

Yau, N., and McDaniel, M. 1992. Carbonation interactions with sweetness and sourness. J. Food Sci., 57(6), 1412-1416.

Yildirim, H., Elmaci, Y., Ova, G., Altuğ, T. 2007. Descriptive analysis of red wines from different Grape cultivars in Turkey. Int. Journal Food Prop., 10, 93-102.

Zamora, M., and Guirao, M. 2004. Performance comparison between trained assessors and wine experts using specific sensory attributes. J. Sens. Stud., 19, 530-545.