The gastronomic experience of fine Australian wines of provenance and food pairings

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TABLE OF CONTENTS

THESIS SUMMARY

Wine has been consumed for centuries in Old World wine producing nations of Europe, where its characteristics and quality continue to be defined by geographical indications (GIs). As a result, consumers have learned to rely on GIs for quality assurance and are willing to pay a premium for wines coming from certain regions. In a similar fashion, Australia implemented a GI system to promote a link between its fine wines and provenance. However, for this approach to be successful, it is necessary to understand consumer perceptions of what constitutes a fine wine. Beyond provenance, the sensory experience of fine wine is often linked with their consumption with appropriate foods. The complex nature of food and wine pairing is not yet fully understood but experts agree that appropriate pairings can enhance desirable flavours of both food and wine, and could be an innovative and profitable strategy to meet consumers' demands. On the other hand, fine Australian wines of provenance (FAW) are rarely examined in food pairing context and no specific studies have addressed how wine sensory attributes and food-wine matching affect the overall dining experience. For this purpose, studies were undertaken to understand consumer perceptions of what constitutes a fine wine, what sensory and chemical factors define fine Chardonnay and Shiraz wines from various regions, what sensory attributes drive appropriate food and wine pairings, and how these relate to consumer behaviour and memorability of the dining experience. The studies presented within this thesis' chapters have been drafted as manuscripts that have been submitted for publication or have already been accepted in peer-reviewed journals. The manuscripts are presented in chapters as outlined below after an introductory chapter and prior a concluding thesis summary chapter.

The first study examined consumers' definitions and associations with FAW. After several focus groups to inform the development of questions, an online survey was conducted with Australian wine consumers (n= 349) to define FAW as a function of sensory attributes, grape variety, wine region, label information, and food pairing, and examine how the definition

differs by consumer wine involvement. Further, the study investigated Australia's single most important red and white varieties, Shiraz and Chardonnay, in a fine wine context. Consumers were segmented using the Fine Wine Instrument (FWI) to discuss the results in the context of their wine involvement. Overall, all consumers valued provenance, however, highly involved wine Enthusiasts appeared to utilise more information and had broader sensory vocabulary than Aspirant and No Frills consumers. The identified sensory attributes, regions and preferred food pairings for fine Australian Chardonnay and Shiraz wines can help the wine and hospitality sectors to tailor services, and the tourism industry to incorporate fine wines in their region-specific marketing. The manuscript detailing this work has been accepted by International Journal of Hospitality Management and is currently in press.

Further building on consumers' association with FAW, the second manuscript presents the sensory and chemical composition of Chardonnay and Shiraz wines from fine wine regions. Previous research on regional typicality mainly involved unoaked experimental wines, which were little reflective of the retail wine market. The regional typicality of commercially available FAW was therefore explored, based on the hypotheses that sensory and chemical compositions of varietal fine wines would discriminate by region, and further nuances within region could be explained by drivers of intraregional typicality. Chardonnay wines from Margaret River (MR, n=16) and Yarra Valley (YV, n=16), and Shiraz wines from Barossa Valley (BV, n=16) and McLaren Vale (MV=15), were selected for descriptive sensory analysis and underwent profiling of volatiles by gas chromatography-mass spectrometry (GC-MS). For both grape varieties, large variability was observed among wines from the same GI and wine styles mainly due to viticultural and winemaking techniques applied by wineries. As a consequence, human intervention seemed to be an important component of regional/intraregional typicality, which therefore cannot be determined solely on geographic origin. Perhaps, wines made with less oak influence or underwent extended maturation in bottle would convey regional typicality and serve as a tool for regional wine marketing. Undoubtedly, any variation emerging across wine regions, vintages, and viticultural and winemaking practices needs to be further explored but this work created a preliminary sensory and volatile map for future research. The manuscript detailing this work is currently under review at Food Research International journal.

Subsequently, the gastronomic potential of FAW was examined, to help identify the sensory attributes important to the most appropriate food and wine pairings and relate these to balance, liking, sensory complexity, and expected price of the wine according to consumers. Drawing from consumer responses to the survey presented in paper 1, seven food samples were selected and evaluated by a descriptive analysis panel (n=8). Four warm climate Shiraz wines (BV = 2, and MV = 2) from paper 2 and four from cooler Australian wine regions (Adelaide Hills, Canberra District, Eden Valley) were evaluated by the same panellists. Finally, the panel evaluated four distinct food samples and four wine samples as pairings, yielding 16 wine and food combinations. Based on the sensory profiles, distinct food and wine pairings (n=6) were selected for consumer preference tests, which comprised a pseudo-three course meal with two wines, representing a real life dining scenario. According to American consumers (n = 108), in the most appropriate pairings, the intensities of food and wine flavours increased and wine taste attributes changed in relation to the individual components. Appropriate pairings had a positive relationship with liking, sensory complexity of the pairing, and expected price to pay for the wine, and a negative correlation with balance due to a preference for wine to slightly dominate the pairing. Most importantly, the pairings had an increase in liking and sensory complexity over the individual wine but not the food component. To account for the large individual variability, consumers were segmented by their liking of the pairing. The key drivers of successful pairings across consumer clusters were similar to the average consumer results, however, the pairings they liked differed by cluster. The findings suggest that the quality of food and wine pairings might be more effectively measured with a combination of direct (dominance/balance, appropriateness of pairing) and indirect methods (sensory complexity, liking), instead of a single scale, and appropriate consumer segmentation may better account for the variability of results. The outcome of this study enhanced the understanding of the relationship between consumer behaviour and food and wine pairings. The manuscript detailing this work has been submitted to Food Quality and Preference is currently under review.

The fourth study extended the findings of paper 3 and explored food and wine pairing evoked emotions, and memorability of the dining experience. In addition to the six wine and food pairings examined in paper 3 an additional 2 pairings with the same two wines but spicy salami were subjected to consumer tests (n = 151) under blind and informed (provenance) conditions. The tastings explored Australian consumer perception of liking, appropriateness, sensory complexity, and emotional profiles of pairings, and expected price to pay at restaurants. One week after the tasting, consumers completed a follow-up survey to capture vividness of memory, remembered liking, memorability and loyalty (repurchase intention) of the wine they rated in food pairings. Significant pairing effect on all measures and an information effect on sensory complexity were found but no significant sample by information level interactions were evident. Food items within the pairings were more important overall than wine items, as they significantly influenced consumers' perceived liking, appropriateness of pairing, sensory complexity, emotional responses, and memorability. This finding suggests that restaurants operating with fixed wine lists (e.g., winery restaurants) may achieve more appropriate pairings by pairing the food to the wine and not the other way around. Appropriate pairings may be important for positive consumer behaviour and the memorability of dining experience, which can provide businesses with knowledge that could be translated into higher customer satisfaction and spending. The manuscript detailing this work has been prepared to submit to Food Quality and Preference.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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10/05/2019

Marcell Kustos Date

PUBLICATIONS

This thesis contains one manuscripts that was accepted in International Journal of Hospitality Management during candidature. International Journal of Hospitality Management had an impact factor of 3.445 according to Clarivate Analytics Journal Citation Reports (2018). Two additional manuscripts were submitted, and one additional manuscript is prepared for subsequent submission to scientific journals.

The publications included in this thesis are:

Chapter 2 Kustos, M., Goodman, S., Jeffery, D.W., Bastian, S.E.P., 2019. Using consumer opinion to define New World fine wine. To be published in International Journal of Hospitality Management

The following chapters contain the manuscripts submitted to scientific journals are:

Chapter 3 Kustos, M., Gambetta, J.M., Jeffery, D.W., Heymann, H., Goodman, S., Bastian, S.E.P., 2019. A matter of place: Sensory and chemical characterisation of fine Australian Chardonnay and Shiraz wines of provenance. Submitted to Food Research International

Chapter 4 Kustos, M., Heymann, H., Jeffery, D.W., Goodman, S., Bastian, S.E.P., 2019. Inter(t)wined: what makes food and wine pairings appropriate? Submitted to Food Quality and Preference

The following chapter contains the manuscript prepared for submission to scientific journal is:

Chapter 5 Kustos, M., Jeffery, D.W., Goodman, S., Bastian, S.E.P., 2019. Food and wine pairing: a tool for developing memorable dining experiences

CONFERENCES

Eurosense 2016 – A Sense of Time, the Seventh European Conference on Sensory and Consumer Research, 11 - 14 September 2016, Dijon, France

Presented a poster titled "The effect of wine mouthfeel on consumers' liking and emotions"

Australian Society of Viticulture and Oenology (ASVO) – Sensory Seminar, 15 November 2017, Adelaide South Australia

Presented a talk titled "Naïve consumers vs. trained assessors: Comparison of Rate-All-That-Apply (RATA) and Descriptive Analysis (DA)"

Crush 2017 – The Grape and Wine Science Symposium, 13 – 14 November 2017, Adelaide, Australia

Presented a talk titled "Using consumer perception to define New World fine wine"

Eurosense 2018 – A Sense of Taste, the Eight European Conference on Sensory and Consumer Research, 2 - 5 September 2018, Verona, Italy

Presented a talk and a poster titled "Food and wine pairings: A tool for memorable dining experiences"

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Chapter 1

Literature review

This literature review was prepared within the first six months of candidature and comprises the literature up to July 2016. Any relevant additional literature has been included in the introduction sections of the publications addressed under Chapters 2 to 5.

1.1 Introductory background

Food and wine are generally consumed and enjoyed together (Bode, 1992) and their unions have fundamental cultural, traditional, and physiological explanations (Madrigal-Galan & Heymann, 2006). Archaeologists have found evidence of wine residue in vessels associated with dining events in ancient Egypt (Guasch-Jané, Ibern-Gómez, Andrés-Lacueva, Jáuregui, & Lamuela-Raventós, 2004) and similarly, nowadays most wine is consumed during dining (Charters & Pettigrew, 2008). However, the conscious pairing of wine and food started in the nineteenth century, this is contrary to the belief that the pairing tradition has been enjoyed for centuries (Rossi-Wilcox, 2005). The ancient Romans and Greeks only consumed wine as a lubricant and as refreshment between bites. In wine producing countries, people drank wine, because it was considered to be safer than water.

Research showed that consuming food and wine together can increase enjoyment for both (S. E. Bastian, Collins, & Johnson, 2010; Harrington, 2006). Therefore, good pairing recommendations may be crucially important for the success of foods and beverages, both in the retail and hospitality sectors (Paulsen, Rognså, & Hersleth, 2015). There are many assumptions about the suitability of wine and food pairings, but little in the way of academic studies. Researchers tends to assume the link rather than analyse its nature and sometimes disagree with each other (Jackson, 2002; Werlin, 2003). A better understanding of food and wine pairing could provide guidelines for ideal pairings that may be used as a communication tool for increasing wine sales and consumer experience. However the effect of ideal match on consumers' emotions and willingness to pay, memorability of the dining experiences and how it differs between cultures has also not been examined. In addition, effects of a wine's extrinsic properties, such as provenance, on the perceived match have not been investigated to date.

1.1.1 Geographic origin in food and wine

As a longstanding version of food and wine pairing, cheese was consumed with the wine produced in the same region. It suggested that wines and cheeses fermented in the same region naturally pair as a result of their shared terroir (M. King & Cliff, 2005). Wines were the very first products to create a quality image linked to a specific location and specific grape varieties (Bruwer & House, 2003; Thode & Maskulka, 1998). The territory or "terroir" as the French call it represents a strong interrelation between product's quality and its origin of production (Vaudour, 2002). Many European countries align the unique sensory characters of regional products with a set of Geographic Indications (GIs) or appellation systems. The GIs permit linking a product to geographical parameters (sunshine, rainfall, irrigation, temperature, soil, and slope) as well as to other indigenous factors dependent on human ingenuity, culture, and traditions (Corade & Del'Homme, 2005). In 1855 the first wine appellation was created in France. There are French denominations, Appellation d'Origine Controlee (AOC) and now the strictest quality level is Appellation d'Origine Protégée (AOP), that are equivalent of Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) schemes created by the European Commission. This strategy is widely applied for local products, e.g., cheese and meat, but particularly for wines, of which reputation depends on both local climate and practices of production in association with other environmental and cultural aspects of the region (Mattiacci & Zampi, 2004). Generally speaking, regional appellations strictly govern the type and the style of wine (e.g., white, red, sparkling, etc.), the permitted grape varieties, soil type, viticultural practices, yields and winemaking processes. Grapes and techniques not permitted by the code may be used, although the produced wine is not to be sold under the name of the designation.

The principle behind appellations is to preserve the typicality and guarantee the authenticity of origin. Typicality denotes a special quality of a food product/wine, with specific sensory attributes, theoretically originating in a given production-space and not reproducible in any other (Letablier & Nicolas, 1994). Typicality also refers to the shared perception of how generations of people from a given place expect wine should taste when made locally from grapes grown in that place (Vaudour, 2002). In the literature it has been reported that a GI positively affects the consumer's quality perception (Santos, Blanco, & Fernández, 2006; Tustin & Lockshin, 2001; van Ittersum, Candel, & Thorelli, 2000).

The traditional (Old World) wine producing countries (e.g., Italy, France, Spain, etc.) base their strategy on the designation of origin, whereas the newer producing countries (New World, including Australia, Chile, California, etc.) tend to associate wine quality with grape varieties (Martinez-Carrasco, Brugarolas, & Martinez-poveda, 2005). On the other hand there are denominations of origin that blend the two strategies. For instance Mattiacci and Zampi (2004) defined the Italian Brunello di Montalcino wines as an extraordinary synthesis between tradition and the modern model of a great wine. It is due to Brunello di Montalcino being a monovarietal wine, and both the territory (Montalcino) and the related production methods and techniques (Brunello) representing an association with highly regarded, quality wines.

1.1.1.2 Australian wines

Australia introduced a GI system in 1993 in order to protect the names of their wine producing areas (Australia, 2016). GIs range in size from *Zones*, being the largest, to *Regions* and then smaller *Sub-regions*. Zones can be large areas without any particular qualifying feature. They can be part of a state, states themselves or can cover several states. Regions are smaller than zones and must have consistent and distinct qualities from neighbouring Regions. Sub-Regions refer to notable areas with unique qualities within Regions. There are currently 114 registered Australian GIs that are determined by the Geographical Indications Committee. There are no restrictions on viticultural or winery practices, however at least 85% of the fruit used to make the wine must be from the GI acknowledged on the label. Similarly, if varieties or vintages are stated, 85% of the wine in the bottle must come from those varieties and vintages. This relatively simple and clear varietal labelling contributed to Australia's extraordinary success in the 90s, along with their fruit-driven, easy drinking style and the value for money concept. On the other hand, the permissive GI system jeopardises the constant quality and the typicality associated with GIs.

Approximately 90 different grape varieties are planted over 135000 hectares of vineyards in Australia, with six red varieties and six white varieties having more than 1,000 hectares each (Wine Australia 2015). Shiraz and Chardonnay are the most highly planted in several Regions, accounting for a combined 46% of Australia's wine production. Shiraz, the classic Australian variety, became internationally recognised as a unique wine style at the forefront of wines from the Barossa Valley. McLaren Vale and Hunter Valley also are favoured regions for Shiraz wines with distinct quality attributes. Yarra Valley, Adelaide Hills and Margaret River are recognised as top Chardonnay Regions. Cabernet Sauvignon is the second most important red grape variety with the classic Regions being Coonawarra and Margaret River. The somewhat underappreciated Semillon found a home in the lower Hunter Valley (Bruwer & House, 2003). However, only a fraction of these examples are recognised as wine of provenance on the wine market, and marketing strategies have not focused on building international reputation for fine Australian wines (FAW) of provenance. Figure 1 shows the sales of Australian wines on the US market, Australia's number one export market by value and potential for growth (Wine Australia 2016). Both the volume and value are led by $0-5/bottle sales, indicating that Australian wines are not associated with the image of fine wines of provenance. Thus, having little regulation other than grape variety such as in the case of Brunello di Montalcino, might help promote FAW of provenance quality and notoriety, and opens the scope for developing new styles without stifling experimentation.

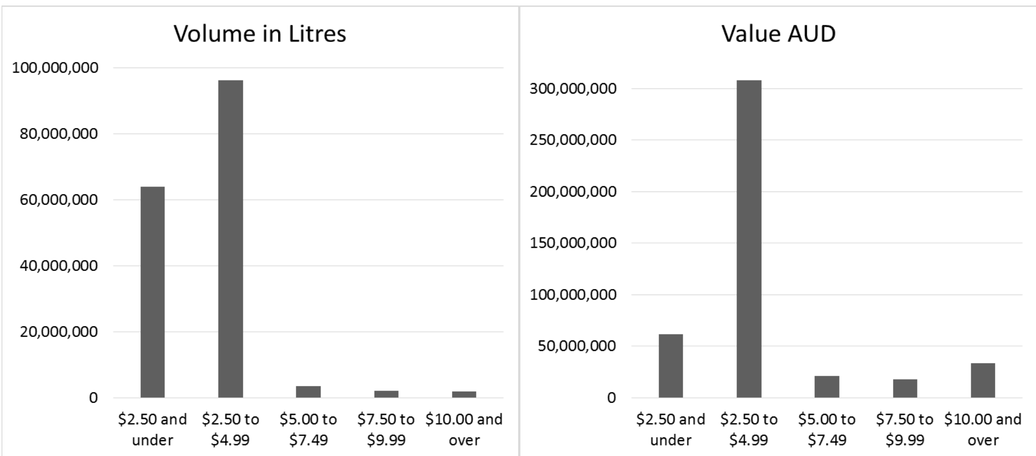

Figure 1: Australian wine sales in volume (L) and value (AUD) on the US market in 2015.

1.1.2 The evolution of food and wine pairing: Review on existing food and wine pairing theories

Historically food and wine produced in the same region were consumed together and, as they were evolving together, this meant they paired well. This territory-based theory has stood for a long time as a sole explanation for food and wine pairings and has followers to date. The "old rules" of colour coding: "red wine with red meat, and white meat and fish with white wine" were grounded in gastronomically-rich European countries. This historical jargon is also known as weight matching theory (Rosengarten & Wesson, 1989; Werlin, 2003). Usually, light wines tend to work well with light dishes and heavy, bold wines with heavy dishes. Nevertheless the weight of the dishes and wines do not depend on the colour and type of either, but rather on the production method (Harrington, 2006).

Another concept is known as "The Food Pairing Theory". The main hypothesis is quite straightforward: the more aroma compounds two foods have in common, the better they taste together (Blumenthal, 2008; Klepper, 2011). The foundation of the theory is that 80 percent of the food's flavour is perceived via volatile aroma compounds sensed with our nose. The remaining 20 percent is defined by mouthfeel and taste. The theory became popular among practitioners of European haute cuisine and was increasingly applied in seeking unconventional food aroma combinations such as salmon and liquorice, oyster and passionfruit, and banana and parsley (Klepper, 2011). However, when the theory was practiced by non-professional cooks, no consensus was reached on liking due to the difficulty of balancing the ratio of each ingredient. The Food Pairing Theory presupposes that there is an innate natural fit between foods, but it tends to neglect the body of scientific literature that shows that food preferences and successful flavour combinations are for the most part learned or culturally determined (Klepper, 2011). Moreover the flavour of a dish owes as much to the mode of preparation as to the choice of particular ingredients (Spence, Hobkinson, Gallace, & Fiszman, 2013; This, 2006).

The most explained theories to date investigate the key elements in food and wine. However, there is also a disagreement on the role and importance of individual elements. Harrington (2006) proposed "The hierarchy of taste" concept derived through a synthesis of the literature. He suggests the separation of food and wine elements into three categories: main taste components, texture elements, and flavour elements. Components can be defined as "very basic elements that correspond to basic sense perception on the tongue" (Beckett, 2002; Harrington, 2006; Rosengarten & Wesson, 1989); in other words sweet, salt, bitter, sour, and umami. Harrington (2006) describes texture as a tactile sensation in every corner of the mouth, and describes it as a basic spectrum from light to rich. In wine, texture mostly refers to body and astringency or tannins. Body can be described to increase from light, thin to medium-bodied, or viscous to full bodied, whereas astringency and tannins might range from low to high or fine to rough. In food, texture can be dry, grainy, loose, oily, or rough (Rosengarten & Wesson, 1989). Correspondingly to components and flavours, texture can be used with similarity and contrast in matching. Temperature can also serve as a texture contrast. Warm or hot food dishes served with cold wine can provide a refreshing match perception.

Flavours act as complementary building blocks in food and wine selections by adding interest and complexity to the overall relationship. Harrington places flavours at the top of the sensory hierarchy, due to the fact that they are considered once the "foundation" (components) and the "glue" (texture) are appropriate. The most common wine flavour qualities include fruity, nutty, smoky, herbal, spicy, cheesy, earthy, and meaty (Rosengarten & Wesson, 1989). The intensity and the persistence of the specific flavour can have importance in the pairing and can be used as either similar or contrasting attributes. However, Harrington uses flavours interchangeably with aromas. His definition contradicts the most recent studies (Auvray & Spence, 2008; Spence & Piqueras-Fiszman, 2014; Spence, Smith, & Auvray, 2015) as flavour being the multi-sensory perception of all sensory attributes of a food item during mastication (including, aroma, taste, texture, temperature, intensity). In a recent study Koone and others (2014) demonstrated that wine sweetness, acidity, and tannin levels all significantly impacted the level of match with certain food items, yet did not specifically explain the nature of the food and wine interactions.

Paulsen and others (2015) recently published a review of relevant books on the subject (Table 1). Balance of flavour intensity, and sweet-sour balance were most frequently cited principles regarding successful pairings. Levy and others (2006) found novelty, familiarity and perceived complexity influence the arousal potential for food items. His arousal theory suggests that everyone has an individual optimum level of complexity and if the perceived complexity is too low or too high, the liking is reduced. His finding also suggests that harmony and complexity can be related, because people prefer food items with high complexity while the food item maintains a high level of harmony (Demir, Desmet, & Hekkert, 2009).

There is an array of theories in the culinary literature for pairing food and wine, however, most of them are subjective and it is difficult to test them objectively. The key elements in food and wine have been investigated, however, none of the studies has succeeded in demonstrating the role of individual elements on consumers' match perception nor provided guidelines and scientific explanations on the findings. Questions still arise: Is it the body, the flavours or the main taste components that lead to the food and wine selections? In the following the potential taste interactions as well as food and wine interactions are examined (Table 2).

Table 1: Overview of the most common pairing principles cited in a review of culinary literature (Paulsen, Rognså, & Hersleth, 2015).

	Pairing principle	*Quotes*
1	Food sweetness level should be less than or equal to wine sweetness level	9
2	Wine overall body should be equal to overall body	8
3	Wine and food flavour intensity should be equal	8
4	Food and wine flavour types can be matched, using similarity or contrast	7
5	Fatty food requires a wine that cuts through the fat (either acidic, fruity or tannic)	7
6	Food acidity level should be less than or equal to wine acidity level	6

7	Wine tannin levels should be equal to animal-based food fattiness levels	5
8	Flavour persistency of wine and food should be equal	5

1.1.3 Complex taste interactions: food and wine

Literature encompassing taste interactions when consuming wine and food is scarce. It might be due to the complex taste interactions simultaneously involved to mimic food and wine consumption. Agrawal and Karban (1997) questioned what happens if a sodium salt is added to the bitter–sweet mixture, considering that sodium salts hinder bitterness and bitterness and sweetness are mutually suppressive? The addition of salt suppressed bitterness and the cognitive suppression of bitterness enhanced sweetness. Mojet and others (2004) studied the effect of concentrations of each tastant in complex food products. The results showed that for each of the tastants, except for acidity, increasing concentration evoked significant positive or negative interaction effects on the perception of one or more other taste qualities of the product.

Salt at low concentrations enhances sweetness, and sweetness can suppress salty taste at moderate intensities (Beebe-Center, Rogers, Atkinson, & O'Connell, 1959; De Graaf & Frijters, 1989; Rose Pangborn, 1960). Therefore slightly bitter wines can benefit from salty foods, while salty foods should be paired with sweet wines.

Sweetness in a dish can make a white wine seem to lose its fruitiness and be unpleasantly acidic. However, in solutions sweetness tends to supress other tastes (De Graaf & Frijters, 1989). Thus, with any dishes containing sugar, a wine with higher level of sugar should be paired (Keast & Breslin, 2003).

Sourness and saltiness in food can balance out a very high acid wine and enhance the fruitiness (P. A. Breslin, 1996; Curtis, Stevens, & Lawless, 1984; Rose Pangborn, 1960). However, low acid wines can seem flat and flabby. Therefore wine acidity levels should be equal to or greater than food acidity levels (Rosengarten & Wesson, 1989; J. Simon, 1997).

Generally, bitter tastes add to each other, so a food with pleasant bitterness can make a balanced wine unpleasantly bitter when they are combined. However, there are marked inter-individual differences in the perception of bitterness as the sensitivity to bitter tastes varies greatly from person to person (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006; Garcia-Bailo, Toguri, Eny, & El-Sohemy, 2009). Bitterness increases sourness, thus wines with high acidity might be as perceived harsh (P. Breslin & Beauchamp, 1995; Frijters & Schifferstein, 1994). As mentioned above, the addition of salt can suppress bitterness.

Foods containing high levels of umami, without salt to counteract the hardening effect on wine, thus low tannin red wines or white wines made with oak or skin contact can become surprisingly bitter and unbalanced When foods are high in salt in addition to umami the hardening effect of umami can be compensated. Bitterness tends to suppress umami, and bitterness as an additional component of the food or an aftertaste in wine may balance umami in foods (P. A. Breslin, 1996; Ninomiya, 2002).

1.1.4 Tactile sensations (trigeminal system)

The trigeminal system provides information about chemical irritation and nociception, temperature, texture, and consistency of food (Delwiche, 2004). All the listed tactile sensations influence the overall perception of flavour that we experience (Auvray & Spence, 2008).

Tannin-food interaction (astringency)

Astringency is a drying, roughing and puckering sensation due to red wine polyphenols (tannins) binding and inducing precipitation of salivary proteins in our mouth (Demiglio & Pickering, 2008). Condensed tannins in wine are extracted from grape seeds and skins during alcoholic fermentation, while hydrolysable tannins come from oak barrels (Cliff, Stanich, Edwards, & Saucier, 2012; Parker et al., 2007). The concentration and composition of tannins (e.g., chain length, hydroxylation, galloylation) can influence the quality of astringency sensation (Gonzalo-Diago, Dizy, & Fernández-Zurbano, 2013; McRae, Schulkin, Kassara, Holt, & Smith, 2013; Vidal et al., 2003). Here “the red wine with red meat” theory comes into play. Presumably, wine polyphenols bind to the protein in the meat, rather than to the salivary proteins. Thus, for example, when we consume rib-eye steak and a big, tannic red wine together, we perceive the tannins cutting the proteins and the fat. Besides tannins, low pH and high acid in wine can also promote precipitation of salivary proteins, and can therefore be alternative contributors of astringency sensation (Lawless, Horne, & Giasi, 1996; Peleg, Bodine, & Noble, 1998).

Temperature

The sensation of heat can be caused by the food or serving temperature. The temperature also can affect concentration threshold of the taste stimuli showing a U-shaped dependence, having the lowest threshold between 20 and 30 degrees (Komuro, 1921; McBurney, Collings, & Glanz, 1973; Talavera, Ninomiya, Winkel, Voets, & Nilius, 2007). Cruz and Green (2000) demonstrated that a proportion of the population perceived salty taste when they put a tasteless ice cube on the side of their tongue. On the other hand, sweetness increases with heating (Bartoshuk, Rennert, Rodin, & Stevens, 1982; Green & Frankmann, 1988). This suggests that the sensory modality of touch and temperature increased the sensory modality of taste. Flavour ratings of beef steaks has also been shown to increase with temperature (Caporaso, Cortavarria, & Mandigo, 1978; Olson, Caporaso, & Mandigo, 1980).

Alcohol in wine and food

Another factor that influences the taste and mouth-feel properties of wine is ethanol. Ethanol induces sensations of warmth and drying, and can taste sweet (Green, 1988; Scinska et al., 2000). Robichaud and Noble (1990) reported a large increase in bitterness and slight increase in astringency by raising the ethanol content of white wine from 8 to 14% (v/v). Enhanced bitterness with higher alcohol levels may lead to “hard” tannin perception (Peleg et al., 1998).

Spicy heat in food

This is a tactile (touch) sensation that develops the feeling of heat/burning rather than one of taste. Levels of sensitivity and the perception of pleasantness can vary greatly from person to person. Given the additive burning heat sensation of spicy food, the pungency increases with high levels of alcohol and astringency, thus robust, tannic wines are not recommended (Demiglio & Pickering, 2008; S. A. Simon & De Araujo, 2005; Vidal et al., 2003).

Body/texture

The texture of a food or beverage is perceived by the somatosensory system that can interact with the volatile odour and non-volatile taste compounds that predominantly determine flavour and taste (Baek, Linforth, Blake, & Taylor, 1999; Cook, Hollowood, Linforth, & Taylor, 2003; Hollowood, Linforth, & Taylor, 2002; Overbosch, Afterof, & Haring, 1991). Viscosity, the sensation of thickness in liquid, highly contributes to wine body (Runnebaum, Boulton, Powell, & Heymann, 2011). For sweet wine, body relies on the sugar content, whereas in dry wine body relies on alcohol content. However, there are other body/viscosity interactions as well. Christensen (1980b) showed that perceived viscosities of solutions were altered by increasing levels of sucrose, citric acid and sodium chloride. Additionally, increasing the viscosity of the solution resulted in suppression of taste and flavour intensities (Arabie & Moskowitz, 1971; Christensen, 1980a; Kokini, Bistany, Poole, & Stier, 1982; RM Pangborn, Gibbs, & Tassan, 1978; RM Pangborn, Trabue, & Szczesniak, 1973). Suppression of smell can even occur, despite changes in viscosity having no measurable effect on the concentration of the volatiles released in the nose (Hollowood et al., 2002).

Table 2: The effect of wine attributes on food

Element Categories	***Wine***	***Food***

Components	Level of Sweetness	>=	Synergises the perception of sweetness (Keast & Breslin, 2003)
		>=	Supresses the perception of acidity (De Graaf & Frijters, 1989)
		>=	Supresses the perception of bitterness (De Graaf & Frijters, 1989)
		>	Supresses the perception of hot spiciness (Harrington 2010)
	Level of Acidity	>=	Synergises the perception of acidity ((Rosengarten & Wesson, 1989; Simon, 1997)
		>=	Supresses the perception of Bitterness (P. A. Breslin, 1996)
		>=	Supresses the perception of sweetness (Curtis, Stevens, & Lawless, 1984; Rose Pangborn, 1960)
		>=	Supresses the perception of fat (Werlin 2003)

	Level of Bitterness	<=	Supresses the perception of sweetness (De Graaf & Frijters, 1989)
		<=	Enhances the perception of acidity (P. A. Breslin, 1996)
		<=	Supresses the perception of saltiness (Breslin 1996, Ninomiya 2002)
		<=	Supresses the perception of umami (Breslin 1996, Ninomiya 2002)
Texture	Level of Effervescence	=	Synergises the perception of saltiness (Cometto-MunizU, J. E., et al. 1987)
		>=	Supresses the perception of bitterness (Cometto-MunizU, J. E., et al. 1987; Cowart, B. J. 1998)
		>=	Enhances the perception of sourness (Cometto-MunizU, J. E., et al. 1987; Cowart, B. J. 1998)

	Astringency/Tannin	=	Supresses the perception of fat (de Wijk, R.A., Prinz, J.F. ,2004)
	Alcohol level		Enhances the perception of bitterness (Robichaud and Noble , 1990)
	Level of Oak		?
	Overall Body	=	Synergises overall body (Harrington and Hammond 2005; Harrinton 2006; Bastian 2010) Synergises flavour intensity (Auvrey&Spence, 2008) Synergises flavour persistence (Auvrey&Spence, 2008)
	Temperature		Temperature
Flavours	Flavour Quality(s)	=	Synergises flavour quality(s) (Chartier 2012)
	Flavour Intensity	=	Synergises flavour intensity (Chartier 2012; Geddes 2007, Harrington 2008)
	Flavour Persistence	=	Synergises flavour persistence (Geddes 2007, Harrington 2008)

1.1.6 The multisensory perception of flavour

Due to the multisensory interactions of flavour, many researchers defined flavour as a unified perception of tastes, smells, and tactile sensations as well as visual and auditory cues we perceive during the act of eating and especially simultaneous wine consumption (Abdi, 2002; Auvray & Spence, 2008; McBurney, 1986; Prescott, 1999; Small & Prescott, 2005). However, there seems to be something unique about the combination and cognitive interactions of taste and smell because there is no combination of sensory modalities that excludes taste and smell but still creates flavour (Delwiche, 2004). One robust finding that has emerged from recent psychophysical research on flavour perception is that odours can elicit changes in the perceived sweetness (i.e., taste) of foods (Stevenson, Prescott, & Boakes, 1999). In fact, flavour perception as a combination of smell and taste was foreseen many years ago (Brillat-Savarin, 1835). Gibson (1966) additionally included the sense of touch in his definition of "tasting system". As Gibson explained, the trigeminal system is one of the most important when drinking or eating because the tongue and the oral cavity are sensitive to shape, size, texture, and temperature. Based on the work of Auvray and Spence (2008), flavour perception is proposed to be used as a term to describe the combinations of taste, smell, the trigeminal system, and touch. Additionally, we consider visual and auditory cues that also influence our perception when tasting food.

1.1.7 Consumer behaviour

Food and beverage pairing is valued by consumers and appears to be an innovative and profitable strategy to meet consumers' demands (S. E. Bastian et al., 2010). Consumption patterns of both food and wine are reported to demonstrate distinct relationships with demographics including gender, age and social class (Levy, 1981). Pettigrew and Charters (2006) explored Australians' perceptions of the relationship between food and wine and found wine to be strongly associated with food along three dimensions: complementarity, social meaning, and lubrication. In fact, Tuorila et al. (1994) reported that wine consumption without food was deemed to be inappropriate.

It has been established that a wine which has been previously purchased and tasted is likely to be the consumers' choice if the opportunity presents; moreover, has endorsement of a trusted third party source; originates from a region or country from which the consumer has previously purchased; or is made from a grape variety with which the consumer also has previous knowledge or experience (Gluckman, 1990; Keown & Casey, 1995; Skuras & Vakrou, 2002). In particular, region of origin was confirmed by several studies to have a major impact on wine purchase (Gluckman, 1990; Jarvis, Rungie, & Lockshin, 2003; Perrouty, d'Hauteville, Lockshin, & Cliquet, 2004; Tustin & Lockshin, 2001) and was associated with higher sensory quality (Chancy, 2002). In recent years, several studies examined consumer liking of wines made from various grape varieties and of different styles (Frøst & Noble, 2002; E. King, Osidacz, Curtin, Bastian, & Francis, 2011; E. S. King et al., 2010; Lattey, Bramley, & Francis, 2010).

Fewer studies have also been conducted on wine and food parings (S. E. Bastian et al., 2010; Donadini, Fumi, & Lambri, 2012; Harrington & Seo, 2015). A recent study by Harrington and Seo (2015) reported wine liking as a driver of food-wine match liking. On the other hand, the impact of food-wine match on wine liking has not been investigated. Most of the above studies were based on sensory descriptive analysis with a trained panel quantifying selected sensory attributes of wines and food, and the liking of the match was assessed by consumers. Besides acceptability, consumers' willingness to pay for food or beverage is also linked with the liking of the product, which is evoked by emotions and mood (Cardello et al., 2012). An emotion can be defined as a short term, immediate feeling responding to a stimulus (S. Bastian, Ristic, Johnson, & Hoek, 2014).

Certain sensory attributes such as odours also are associated with memories and emotions (S. C. King, Meiselman, & Carr, 2010). The phenomenon is also known as "Proustian moment" that originates from Marcel Proust French novelist's nostalgic journey upon dipping madeleine cake into tea (Sutton, 2001). Studies have been carried out to link food and wine sensory attributes with emotions (S. Bastian et al., 2014; Pham et al., 2008; Porcherot et al., 2012), however food and wine pairings evocation of emotions has not been published. As consumers are becoming more adventurous, they are seeking more knowledge of food and beverage combinations in order to reap the full benefits of gastronomy (Van Westering & Edwards, 1996). Good pairing recommendations may be crucial for the market success of foods and beverages, both in the retail and hospitality sector (Paulsen et al., 2015).

1.1.7.1 Market segmentation of consumers (food and wine involvement)

Consumers' taste preferences are known to be heterogeneous. There is a diverse range of consumer behaviours, therefore the population generally cannot be treated as a single group (Kotler, Keller, Brady, Goodman, & Hansen, 2009). In research, consumers are segmented using multivariate analyses such as cluster analysis, so that consumers with similar behaviours are grouped together (Meilgaard, Carr, & Civille, 2006). The combination of liking scores, demographics, and wine and food consumption can be used for segmentation in order to better understand consumer responses (Cohen, Goodman, & Goodman, 2009; Frøst & Noble, 2002; Trent E Johnson & Bastian, 2007; E. King et al., 2011; E. S. King et al., 2010; Lattey et al., 2010; L. Lockshin & Halstead, 2005).

Purchase behaviour, especially that of wine, is a complicated issue as it is influenced by the level of knowledge, involvement and interest of consumers (Gluckman, 1990; L. S. Lockshin, Spawton, & Macintosh, 1997; Perrouty et al., 2004; Quester & Smart, 1998). The influence of both internal and external wine attributes on quality perceptions of wine consumers has been previously addressed (Charters & Pettigrew, 2007; Jover, Montes, & Fuentes, 2004; L. S. Lockshin & Timothy Rhodus, 1993). Intrinsic cues are defined by the drinking experience, including appearance, aroma, flavour and mouthfeel, as well as the most basic definition of wine quality, being the absence of faults and/or drinkability, typicality and potential. On the other hand, extrinsic cues including origin, brand, region, vintage, price, grape variety, bottle, label and winemaking are related to subjectively perceived quality and consumers with little wine knowledge tend to rate wine quality based on available extrinsic information. Additionally, wine can be intimidating due to the numerous different labels and the complexity of information (Batt & Dean, 2000; Olsen & Thach, 2001; Spawton & Bourqui, 1997).

Recently, Johnson et al. (2013) involved clusters of consumers who were more knowledgeable about wine and showed scores more similar to wine experts. Furthermore, Johnson and Bastian (2015) developed the Fine Wine Instrument (FWI) to measure the fine wine behaviour of consumers and then use that base to segment the Australian wine market. Cluster analysis identified three segments of consumers, denoted “Wine Enthusiasts”, “Aspirants”, and “No Frills” wine drinkers. Participants in the Wine Enthusiasts segment consumed more wine, spent more money on wine and were more knowledgeable about wine than the other two segments. Previously, Lattey et al. (2010) found Australian wine experts in general appeared to consider wines with “high flavour intensity” as a wine of higher quality. While only a relatively small set of sensory attributes was important to consumer liking, which were mainly markers of varietal differences. Lockshin and Halstead (2005) compared Australian and Canadian wine consumers with high and low wine involvement. Australian consumers’ choices were driven mainly by the region of origin and to some extent by a gold medal. Although studies have demonstrated an effect of wine involvement on consumer behaviour, limited research is available on food and wine pairing. Therefore FWI may be a field of interest for the Australian wine industry and hospitality sector, especially if the wine purchase is linked to food.

1.1.7.2 The impact of expectations and cognition on perceived quality and hedonic scores

Expectations can be described as "subjective notions of things to come" or a "type of hypothesis formulated by the consumer" as reported by Anderson and Hair (1972). Over the past few decades, several studies investigated how information about food products influences hedonic expectations (Iaccarino, Di Monaco, Mincione, Cavella, & Masi, 2006; Laureati, Jabes, Russo, & Pagliarini, 2013; Napolitano et al., 2010). Most commonly, consumers were asked to rate the degree of liking after given food samples under different informed conditions: blind (tasting the product without any given information), expected (judging the product based on the written or visual information without tasting), and informed (tasting and judging the product after receiving information). When consumers have previous experience or information of a product these lead to prior expectations, thus the quality of the information is crucial for hedonic scores (Deliza & MacFie, 1996). Prior information may include extrinsic cues such as price, packaging, labelling and brand name, which are related to subjectively perceived quality and also create expectations, which can be low or high. A high expectation is likely to cause product choice and a low one almost certainly results in product rejection. After choosing the product, its expected sensory attributes can be confirmed or refuted by tasting (Deliza & MacFie, 1996). Confirmed expectations lead to satisfaction and probably to a repeated product use. Nonetheless, refuted expectations may also induce satisfaction, when a positive disconfirmation occurs; however, negative disconfirmation will lead to product rejection. The result of both events (confirmation or disconfirmation) will affect the hedonic liking of the product and also the next experience with the product, contributing either to raising or lowering a consumer's expectations (Yeomans, Chambers, Blumenthal, & Blake, 2008). Sensory descriptions of food names can bias consumer quality expectations as well (Wansink, van Ittersum, & Painter, 2005). Thus we hypothesise that information provided on FAW will influence the consumer liking of wines and in turn impact consumer perception of food-wine pairings.

1.1.7.3 Memorable experiences (MEs)

The importance of delivering memorable experiences is well-documented (Kozak, 2001; Lehto, O'Leary, & Morrison, 2004; Wirtz, Kruger, Scollon, & Diener, 2003). For example, tourism research has put emphasis on tourist satisfaction and memorable experiences driving revisits, and found that tourists recall past experiences when deciding to travel and search for specific destinations. Kim, Ritchie and McCormick (2010) developed the Memorable Tourism Experiences (MTE) scale composed of seven dimensions: hedonism, refreshment, social interaction and local culture, meaningfulness, knowledge, involvement, and novelty. Gastronomic experiences were cited as part of local culture, thus demonstrating a strong relationship with MTE. Furthermore, a recent study by Saayman and van der Merwe (2015) identified factors that contributed to memorable wine-tasting experience at wineries, such as attributes of the winery, themes and activities, education, and novelty. They propose that by providing unique, novel and imaginative products/services, hospitality and tourism operators could gain a competitive advantage over those who continue to offer food and wine pairings based on outdated guidelines, for example.

1.2 Research questions

The relationship between food and fine Australian wines of provenance has been rarely examined and no specific studies addressing how wine sensory attributes and food and wine pairing affect the overall dining experience exist. Therefore, this research project set out to answer the following research questions:

1. What are consumer perceptions of FAW as a function of sensory attributes, grape variety, wine region, label information, and food pairing?
2. What are the sensory and chemical profiles of varietal FAW by region and sub-region?
3. What are the sensory attributes of FAW and food pairings that drive the appropriateness of pairing and positive consumer behaviour?
4. What is the impact of FAW and food pairing on consumer emotions and the memorability of the dining experiences as a function of wine provenance information (blind vs. informed)?

1.3 Summary of research aims

The main objectives of this project were to investigate consumers' perceptions of FAW; to characterise the chemical and sensory profile of a range of FAWs; and to explore the gastronomic potential of FAW of provenance in food and wine pairings. We hereby aimed for covering FAWs from a range of wine regions and two grape varieties of major industrial and consumer importance, which was executed as follows (listed in order of the respective manuscripts prepared):

1. A survey tool was developed based on consumer focus groups to explore consumer opinions of FAW as a function of sensory attributes, grape variety, wine region, label information, and food pairing. Australia's single most important red and white varieties, Shiraz and Chardonnay, were further investigated.
2. Further building on consumers' association with FAW, Chardonnay (n = 32) and Shiraz (n = 31) wines from the 2015 and 2014 vintages were analysed for their chemical composition, volatile and sensory profiles, allowing for a varietal characterisation by region and sub-region.
3. Subsequently, selected Chardonnay and Shiraz wines and food samples from the consumer survey were evaluated in pairings to identify the sensory attributes important to the most appropriate food and wine pairings and relate these to balance, liking, sensory complexity, and expected price of the wine according to consumers.
4. Following on the sensory attributes of appropriate food and wine pairings, the next study extended the gastronomic potential of FAW of provenance and explored food and wine pairing evoked emotions, and the memorability of the dining experience.

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Chapter 2

Using consumer opinion to define New World fine wine: Insights for hospitality

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Name of Principal Author (Candidate)	Marcell Kustos
Contribution to the Paper	Organised and conducted focus groups, designed consumer survey and conducted pilot-test prior data collection via Qualtrics, analysed and interpreted data, drafted and constructed the manuscript.
Overall percentage (%)	75%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 7/5/19

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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper	Supervised the work, contributed to the research idea, experimental design, survey design, and interpretation of the data. Assisted in the preparation and editing of the manuscript and acted as the corresponding author.		
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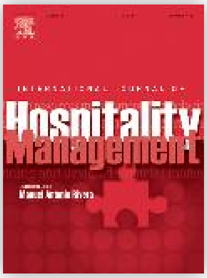

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Using consumer opinion to define New World fine wine: Insights for hospitality

Abstract

Australia, the world's 4th largest wine exporter by value, has implemented marketing to promote a link between fine wines and its provenance, however to be successful, it is necessary to first understand consumer perceptions of what constitutes a fine wine. An online survey was conducted with Australian wine consumers (n = 349) to define Australian fine wine, based on sensory attributes, grape variety, wine region, label information, and food pairing, and how that definition differs as a function of consumer wine involvement. Overall, all consumers valued provenance, however highly involved wine Enthusiasts appeared to utilise more information and had broader sensory vocabulary than Aspirant and No Frills consumers. The identified sensory attributes, regions and preferred food pairings for fine Australian Chardonnay and Shiraz wines will help the wine and hospitality sectors to tailor its services and communication to incorporate fine wines in wine lists and their region specific marketing.

Keywords

Wine provenance, food pairing, wine quality wine marketing, segmentation

1. Introduction

Wine, as an Old World product, has been particularly important for hospitality and regional tourism sectors (Chen et al., 2016) as it accounts for the majority of the alcoholic beverage sales in restaurants and bars (Hall et al., 2004). Usually, wines are marketed within hospitality to consumers in a manner in which quality is defined by geographical designations (Bernabéu et al., 2008; Chancy, 2002). Following this approach, more recently in New World wine countries like Australia there is currently a drive towards using fine Australian wines of provenance - the region they come from - as a 'positive point of differentiation' strategy to increase the price premium paid for the leading Chardonnay and Shiraz varieties in domestic and export markets. This approach mimics the Old World's geographical designation system, although Australian wine quality is still largely defined by brand and price point (Johnson and Bruwer, 2007). For the hospitality business, trying to compete and position for consumer experience, well known brands are not necessarily a suitable vehicle, and so follows that New World wines are not typically used in the hospitality sector to promote exclusivity and prestige (Corsi et al., 2012). Although product origin might be a successful marketing strategy (Bruwer and Johnson, 2010; Johnson and Bruwer, 2007), many consumers are not familiar with fine wines of new wine regions. Thus, a greater understanding of consumer impressions of quality and/or fine wines is still required for hospitality businesses to perfect their wine offering. This paper sets out to develop and provide a consumer perspective of fine wine, in a New World context. This generates insight for hospitality practitioners to educate their consumers about New World fine wines and better market their offerings in such a manner that consumers comprehend and appreciate and enhances their experience.

2. Literature review

2.1. What makes wine 'fine'?

Academically, quality wines are often described as fine wines (Charters & Pettigrew, 2007; Voronov et al., 2013a, 2013b). The Merriam-Webster Online Dictionary (2018) defines quality as "degree of excellence", "superiority in kind", or "a distinguishing attribute" whereas the word fine as an adjective is defined as "superior in kind, quality, or appearance". The definition even uses *fine wines* as an example for use of this term in context and the assumption that quality wines are fine wines follows from this. A problem with the concept of 'quality wines' is that there are no objective ways of measuring wine quality nor communicating what it is and how sensory factors driving quality are weighted (Gambetta et al., 2017). Regarding predictors of wine quality in Australia, Horowitz and Lockshin (2002) reported that the importance of price, region, expert rating, vintage and size of winery varied depending on grape varieties but region did not correlate as significantly with quality as expected. However, the authors cited AUD$20 as the expected cost for high quality wines based on corresponding expert ratings. In a more recent study (Johnson & Bastian, 2015), fine Australian wines (FAW) were defined as wines that retailed for more than AUD$20 or were contained within the Langton's Classification. Langton's is a wine auction house in Australia where the majority of scarce and collectible wine sales take place (Fogarty, 2006). However, price points are just one of the myriad of factors in the multi-dimensional construct of wine quality, which consists of extrinsic factors such as provenance, vintage, marketing and awards plus intrinsic factors including sensory attributes, grape variety, and liking (Charters & Pettigrew, 2007). In Europe, the unique sensory characters of products are ensured by strict appellation systems that dictate grape growing and winemaking practices (Sutton, 2010; Vaudour, 2002; White et al., 2009). In turn, consumers learnt to rely on provenance to predict wine quality and became willing to pay a premium accordingly, a facet which is lacking in consumer understanding of New World fine wine (Casini, Corsi, & Goodman, 2009; Goodman, 2009; Johnson & Bruwer, 2007).

The Australian-EU trade agreement for wine led Australian wine branding to a clear, varietal labelling, which matches consumer drivers of choice for wine (Goodman, 2009; Johnson & Bruwer, 2007). To counter the loss of using EU appellations on wine labels, Australia adopted the geographic indication (GI) system to define wine producing areas (Battaglene, 2005). As a consequence, in the New World, notably Australia and the USA, efforts are focussed on building strong wine identities (based on location and/or brand) with corresponding price points to establish a sense of fine wine in consumers' minds (Martinez-Carrasco et al., 2005). The trouble with this approach for the practitioner is two-fold, (i) well-known brands have well known prices so generating margin is difficult and (ii) New World GIs do not have the same wine making approaches, neither culturally nor legislatively, so quality is not consistent. As such, wine-lists in many premium hospitality establishments are dominated by Old World wines and a limited representation of New World offerings (Corsi et al., 2012).

Indeed, information exists on the benefits of region-based marketing (Bruwer and Johnson, 2010; Mattiacci and Zampi, 2004) but there appear to be no studies examining consumer perceptions of Australian GIs in relation to fine wines and the associated intrinsic and extrinsic attributes. This paper presents a consumer driven definition of FAW and in so doing, equips the hospitality practitioner with the knowledge of how to best promote FAW to bolster their offering. The FAW definition also provides a base for other researchers keen to modify it for use by other New World wine producers.

2.2. Sensory experience of fine wine and food

Beyond provenance, the sensory experience of fine wine is often linked with the consumption of appropriate foods (Pettigrew and Charters, 2006). The complex nature of food and wine pairing is not yet fully understood, but experts agree that appropriate pairings can enhance desirable flavours of both food and wine, and could be an innovative and profitable strategy to meet consumers' demands (Bastian et al., 2010; Pettigrew and Charters, 2006). The scarce literature on food and wine pairing tends to base the success of a pairing on consumer liking (Bastian et al., 2010; Donadini et al., 2012; Harrington and Seo, 2015). Moreover, the liking of a pairing appears to be driven by wine liking (Bastian et al., 2010; Harrington and Seo, 2015). As consumers become more adventurous, they seek more knowledge and experiences of food and beverage combinations to reap the full benefits of gastronomy (Van Westering and Edwards, 1996). Therefore, food and wine pairing is not only a valuable tool to increase consumers' satisfaction, but good pairing recommendations may lead to an estimated 44.5% increase in wine sales at restaurants (Paulsen et al., 2015; Wansink et al., 2006). Thus, understanding how consumers perceive FAW on a sensory level, and which food pairings are desired, would give an indication of the way restaurateurs should design and communicate their wine offerings.

2.3. Consumer segmentation effect on perceptions of fine wine

Consumers' taste preferences and behaviours are heterogeneous, therefore the population generally cannot be treated as a single group (Kotler et al., 2009). To gain deeper insight, consumers are segmented using multivariate analyses upon various bases, e.g., hedonic scores, demographics, and wine and food consumption, so that consumers with similar behaviours are grouped together (Frøst and Noble, 2002; King et al., 2011; Ristic et al., 2016). Levels of consumer knowledge, involvement and interest further contribute to the complicated nature of consumer purchase behaviour (Gluckman, 1990; Johnson and Bastian, 2015; Lockshin et al., 1997; Perrouty et al., 2004). The influence of internal and external wine attributes on consumers' wine quality perceptions has been previously addressed (Charters and Pettigrew, 2007; Danner et al., 2017; Jover et al., 2004). Extrinsic cues are related to subjectively perceived quality, and consumers with little wine knowledge tend to rate wine quality based on available extrinsic information (Mueller and Szolnoki, 2010). There are however, intrinsic characteristics of the consumers themselves such as emotion and cultural impacts, that influence perceptions (Bruwer et al., 2002; Charters and Pettigrew, 2008; Danner et al., 2017; Kacen and Lee, 2002).

The Fine Wine Instrument (FWI) (Johnson and Bastian 2015) measures the fine wine behaviour of consumers across three dimensions, connoisseur, provenance, and knowledge. The FWI was used to identify three consumer segments, No Frills (NF), Aspirants (ASP), and Enthusiasts (ENT). The ENT segment consumed more wine, spent more money on wine and were more knowledgeable about wine than the other two segments. ASP had similar characteristics to ENT, however scored lower on wine knowledge and wine involvement. NF scored lowest on all three dimensions, demonstrating low wine involvement and knowledge, which corresponded with low levels of wine consumption, household income, and education. Contrary to conventional belief (Bruwer and Li, 2007; Johnson and Bruwer, 2003), many ENT were under the age of 35, highlighting their long term importance to the wine industry (Johnson & Bastian, 2015). The FWI is used in this research in order to assist the food and beverage practitioners and researchers in understanding how different segments might have different expectations and understanding of FAW, enabling users of the findings to work with their own target and existing customer base in menu design and hospitality offering.

2.4. Aims

This study seeks to (i) present a comprehensive consumer definition of fine wines of Australia in terms of sensory attributes, region, grape variety, and label information, (ii) explore consumer expectations in terms of sensory descriptors and regions for Australia's most important white and red varietals in a fine wine context, and (iii) examine consumer perceptions of food pairing fine Chardonnay and Shiraz wines across FWI segments.

In doing so, this paper contributes to knowledge for hospitality researchers and practitioners in several ways, (i) understanding consumer perceptions of fine wine from a non-GI view would assist developing strategies to extend or recreate the consumer dining experience beyond traditional Old World GIs, thus providing pathways for increased margin and reputation, (ii) offering insight that may instil confidence for menu redesign with New World wine suggestions in line with what consumers perceive as fine wine, (iii) incorporate menu and wine list descriptors that resonate with consumers' notion of FAW.

3. Method

3.1. Focus groups

Forty-nine Australian wine consumers (25 male, 24 female, 25 to 72 years old) who regularly (at least once a month) consume Chardonnay and Shiraz wines and eat out at restaurants (at least once a month) participated. Platters of cheese, cured meat, antipasto, and one standard drink each of Chardonnay and Shiraz wine were presented to stimulate discussion. Focus groups were audiotaped and participant's attention was guided to themes, including quality perceptions of FAW, Australian wine regions in relation to grape varieties, and preferred foods to consume with Chardonnay and Shiraz wines.

3.2. Online survey

The survey was piloted with 16 target respondents and the final version consisted of 35 forced response questions. The initial page described the research project and research team. The first section had five questions exploring consumer wine consumption and purchase preference information. In section two, fine wine behaviour was measured by the Fine Wine

Instrument with segmentation according to Johnson and Bastian (Johnson and Bastian, 2015) Section three included check-all-that-apply (CATA) questions to capture consumer perceptions of FAW, related wine regions, grape varieties, and food pairings, and intensity scales to measure the importance of label information. The focus groups, literature review, local restaurant menus, and consulting experts were used for generating the food pairings relevant to common menu items in Australia. The final section included demographic questions. Consumers (n = 349) who were of legal drinking age, Australian citizens, consumed wine at least once a week, had consumed Chardonnay and Shiraz wines in the last six months, and on average ate out at restaurants once a month, were recruited for the survey via Qualtrics (Qualtrics, LLC, Seattle, USA). The survey data was also collected using Qualtrics.

3.3. Data analysis

Data were analysed with a combination of techniques using SPSS 25.0 (IBM Corp) and XLSTAT Version 2017 (Addinsoft SARL, France). SPSS was used to calculate frequencies for CATA questions and chi-square tests were performed on the number of responses to investigate how FWI segments differed (Meyners et al., 2013). Frequencies were converted into response rates by dividing the number of counts by the population of the segments and multiplying by 100. Questions with intensity scales were subjected to univariate ANOVA to test differences between FWI segments. Frequencies were calculated for the food pairings, which were then analysed with correspondence analysis (CA) in XLSTAT (Greenacre, 2017).

4. Results and Discussion

4.1. Focus groups discussions

The focus groups were conducted to inform the development of questions that were included in the online survey. As a result, participants generated 27 words they associate with

FAW and also identified 12 items on wine labels that influence their decision when buying FAW. The focus group created lists of sensory attributes for Chardonnay (31) and Shiraz (31) FAW along with naming the most renowned wine regions for both varieties. Twenty-five food items, subsets of which would be enjoyed with either Chardonnay or Shiraz, both or neither were identified during the discussions.

4.2. Consumer segments

Demographic data (Table 1) showed similarities to previous studies, therefore the sample of wine consumers was considered reflective of the Australian wine consumer population. The K-means cluster analysis of the FWI data identified three clusters, NF, ASP, and ENT wine consumers (Table 1). Overall, the FWI segments showed similar traits to those in the study of Johnson and Bastian (2015). ENT (n = 99, 26.4% of the sample) were more likely to be male, under the age of 35, well-educated, and approximately 40% earned more than AU$100,000 per annum (Table 1). About 75% (Table 1) consumed wine more than once a week, all kept records of their wines, had special wine storage space, and checked wine for faults prior to consumption. They purchased wines from different countries/regions that are often scarce. They are confident in their ability to choose bottles for purchase, but not afraid to seek recommendations. ASP (n = 163, 46.7% of the sample) had similar characteristics to ENT, although scored lower on wine knowledge and wine involvement (Table 1). The gender composition of this segment was balanced (49.7% male and 50.3% female) and tended to have a lower level of education, household income and wine consumption in comparison to ENT; again, the properties of this segment align with Johnson and Bastian (2015). The NF (n = 86, 24.6% of the sample) segment was female dominated with the highest representation of consumers over the age of 55. It had the lowest scores on each of the three dimension of the FWI scale, indicating low connoisseur-like behaviour, wine knowledge and interest in provenance. Other than gender balance, the NF segment had similar qualities to Johnson and Bastian (2015).

Table 1. Demographic composition of the Australian consumers answering the survey.

Demographics	No Frills n=86 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Gender			
Male	39.1	49.7	65.7
Female	60.9	50.3	34.3
Age			
Under 35	32.2	39.9	49.5
35–55	37.9	39.3	41.4
Over 55	29.9	20.9	9.1
Education			
Did not finish High School	10.3	11.0	5.1
Finished High School	14.9	23.3	11.1
Diploma/Trade	27.6	17.8	16.2
Bachelor's Degree	31.0	27.6	32.3
Postgraduate Diploma	3.4	8.0	16.2
Higher degree (e.g. master's, PhD)	12.6	12.2	19.2
Household income (AUD$)			
< $25000	8	4.3	1
$25,000 - $50,000	25.3	27	12.1
$50,001 - $75,000	20.7	20.9	19.2
$75,001 - $100,000	20.7	21.5	27.3
$100,001 - $150,000	18.4	16	28.3
$150,001 - $200,000	4.6	6.1	6.1
> $200,000	2.3	4.3	6.1
Wine consumption frequency			
More than 3 times a week	11.5	16	27.3
2-3 times a week	29.9	46.6	47.5
Once a week	20.7	25.2	20.2
Once every 2 weeks	19.5	8	5.1
Once a month	18.4	4.3	0

4.3. Consumer perceptions of Australian fine wine

Using CATA, consumers selected words that they associated with FAW (Table 2); which mostly included the terms high quality, satisfying, clean, balanced, easy-drinking, expected to be of good value, affordable, fruit-driven, and available in lots of varieties. This is in line with Charters and Pettigrew (2007) who defined the dimension of wine quality by pleasure and enjoyment, gustatory dimensions, taste, drinkability, structural balance and interest. Similar to consumer results, Volnorov (2013a) reported that wine critics' perceptions of fine wine had a similar pleasure-driven logic; fine wines are good value for money, and possess a high quality image inherited from the terroir. Whilst wine experts have linked oak with high quality Chardonnay (Gambetta et al., 2017), the consumers in this study rarely associated terroir or oak, nor the words young, high alcohol, or heavy to define FAW. Consumers considered regional to be important for FAW, suggesting Australian wine regions are linked to high quality in consumers' minds, thus the reputation of a region over terroir might be used as a marketing strategy (Johnson and Bruwer, 2007; Skuras and Vakrou, 2002). The list of the most frequently associated words with FAW allows a tentative overall definition to be formulated for further testing:

"Australian fine wines are of high quality, good value for money, are easy to drink and consistently show balance, plus diversity, fruity and regional characteristics."

Across the FWI consumer segments, only easy-drinking ($p < 0.05$) and romantic ($p < 0.01$) were significantly different; so the fine wine definition may be adjusted for both NF and ENT consumers with an emphasis on 'easy-drinking', and further for ENT by linking FAW consumption with 'romantic occasions'. ENT tended to utilise more words to describe FAW than the other segments, future studies need to confirm this.

Table 2. The most cited words associated with Australian fine wines of provenance by Australian consumers and FWI segments.

Definition	All n=349 (%)	No Frills n=86 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
High quality	59.6	65.5	58.9	55.6
Satisfying	46.1	47.1	45.4	46.5
Good value	45.3	46	43.6	47.5
*Easy-drinking**	42.4	55.2a	36.2b	41.4ab

Lots of variety	40.1	43.7	39.9	37.4
Affordable	36.7	41.4	36.8	32.3
Balanced	35.2	25.3a	38.7b	38.4ab
Regional	34.4	40.2	32.5	32.3
Clean	33	34.5	28.8	38.4
Fruit-driven	32.4	28.7	33.7	33.3
Interesting	30.9	29.9ab	26.4b	39.4a
Reliable	30.7	29.9	30.7	31.3
Grape varietal	26.6	20.7	28.2	29.3
Accessible	24.6	26.4	23.3	25.3
Diverse	24.1	24.1	23.3	25.3
Big and bold	22.9	19.5	22.1	27.3
Robust	21.8	20.7	19.6	26.3
Dynamic	19.8	18.4	17.2	25.3
Expensive	18.6	20.7	16.6	20.2
Complex	18.3	19.5	16.6	20.2
*Romantic***	17.8	8a	16.6a	28.3b
Sustainable	16	11.5	16	20.2
Young	15.5	10.3a	14.7ab	21.2b
Oak	11.5	6.9a	10.4ab	17.2b
High alcohol	11.2	8	11.7	13.1
Terroir	6.9	3.4a	6.1ab	11.1b
Heavy	6.3	6.9	6.1	6.1

*p < .05 Mean differences by Pearson Chi Square test

**p < .01 Mean differences by Pearson Chi Square test
Values followed by different letters within a row are significantly different between segments.

4.4. What grape varieties are fine wines made from?

Shiraz, Chardonnay, Cabernet Sauvignon, Sauvignon Blanc, Merlot, Pinot Noir, Riesling and Semillon (Table 3) are the grape varieties survey respondents associate with FAW; these varieties are also the most planted varieties in Australia (Wine Australia, 2018a) and tend to receive the highest quality ratings from James Halliday, a highly influential Australian wine critic (Schamel and Anderson, 2003). The opinions of critics are a quality moderating extrinsic factor for consumers (Charters and Pettigrew, 2007; Goodman et al., 2008), therefore, consumer perceptions of FAW are likely to be influenced by the market share of varieties and expert opinions. These findings offer the Australian wine industry promise of being able to continue existing varietal production for the fine wine space, as well as suggesting to hospitality and beverage operators that the most produced Australian grapes are also those regarded as grapes which produce FAW. Varieties with response rates below 10% tended to be of Mediterranean origin, often referred to as alternative varieties in the Australian market (Wine Australia, 2018b). Moreover, it seems to be an industry interest to explore the potential of alternative varieties as a point of differentiation (Kennison and Fennessy, 2011) if they can be positioned as fine wines, not alternatives for the curious.

Varieties associated with FAW, were not significantly different across the three FWI segments, except Cabernet Sauvignon, Semillon, and Grenache. Cabernet Sauvignon was most associated with FAW by NF (62.1%), ENT and ASP scored it significantly lower (36.4%, ranked sixth 44.8%, ranked third). This aligns with Charters and Pettigrew (2007) findings that lower involved consumers consider wines such as Cabernet Sauvignon as heavier and higher quality than others, however the result must be carefully interpreted as they scored Chardonnay in the second position (58.6%). NF and ENT consumers rated Semillon higher than ASP and the long history of fine Grenache in the Australian wine industry was recognised by ENT as they rated it more frequently than the other two clusters. Chardonnay (58.6%) and then Shiraz (52.9%) were the next most selected varieties among NF. ENT rated Shiraz (55.6%) highest, followed by Chardonnay (45.5%) and Merlot (42.4%) as the varieties most associated with FAW. ASP however ranked Shiraz and Sauvignon Blanc equal highest (48.5%) followed by Cabernet Sauvignon and Merlot as equal second (44.8%). Generally, there was a tendency that ENT responded with a higher frequency for certain varieties than NF and ASP consumers, which might be explained by their higher wine knowledge and involvement scores on the FWI (Johnson and Bastian, 2015). The importance of Shiraz is unquestionable in the Australian market – it accounts for 46% of the red grape crush with an estimated total value of AU$353million (Wine Australia, 2018a) - and was the variety most recognised as FAW by participants. Contrarily, consumer fine wine associations with non-Shiraz varieties largely varied by wine involvement, thus hospitality operators may work with a diverse wine list to satisfy customers from all segments. Varieties without a strong FAW image might still be financially viable, especially in regional restaurants with local food pairing recommendations (Wansink et al., 2006).

Table 3. Grape varietals associated with fine wines of provenance by Australian consumers and across FWI segments.

Grape variety	Mean n=349 (%)	No Frills n=86 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Shiraz/Syrah	51.6	52.9	48.5	55.6
Chardonnay	48.1	58.6a	44.2b	45.5ab
*Cabernet Sauvignon***	46.7	62.1a	44.8b	36.4b
Sauvignon Blanc	46.4	50.6	48.5	39.4
Merlot	45.6	50.6	44.8	42.4
Pinot Noir	40.4	35.6	42.3	41.4
Riesling	37.8	42.5	38.0	33.3
White Blends	28.9	32.2	27.6	28.3
*Semillon**	27.8	33.3a	21.5b	33.3a
Muscat	26.9	28.7	23.3	31.3
Red Blends	26.4	26.4	23.3	31.3
Pinot Gris/Grigio	21.5	19.5	21.5	23.2
*Grenache**	14.3	12.6ab	9.8b	23.2a
Petit Verdot	13.5	8.0	16.6	13.1
Verdelho	12.6	14.9	12.3	11.1
Viognier	12.3	9.2	12.3	15.2
Malbec	11.7	9.2	11.0	15.2
Sangiovese	10	8.0	10.4	11.1
Fiano	8.9	3.4	9.8	12.1
Tempranillo	8.6	4.6	9.8	10.1
Barbera	8	4.6	7.4	12.1
Vermentino	8	4.6	8.6	10.1
Aglianico	7.7	4.6	6.1	13.1
Gewürztraminer	7.7	5.7	9.2	7.1
Mataro/Mourvedre	6.6	3.4	6.1	10.1
Nebbiolo	5.4	3.4	6.7	5.1
Montepulciano	4.9	2.3	5.5	6.1

*$p < .05$ Mean differences by chi-square test

**$p < .01$ Mean differences by chi-square test
Values followed by different letters within a row are significantly different between segments.

4.5. Consumer perceptions of wine label information importance

Label information including grape variety, brand, wine region, alcohol level, wine subregion, medals, vintage, story, recommended food pairing, taste description, vineyard practices, winemaker's name, organic/biodynamic, were rated between 38% and 76% from the left end of the scale, suggesting they were considered of some importance amongst all consumers (Figure 1). The importance of grape variety, brand, region and vintage supports previous studies (Batt and Dean, 2000; Gluckman, 1990; Jarvis et al., 2003).

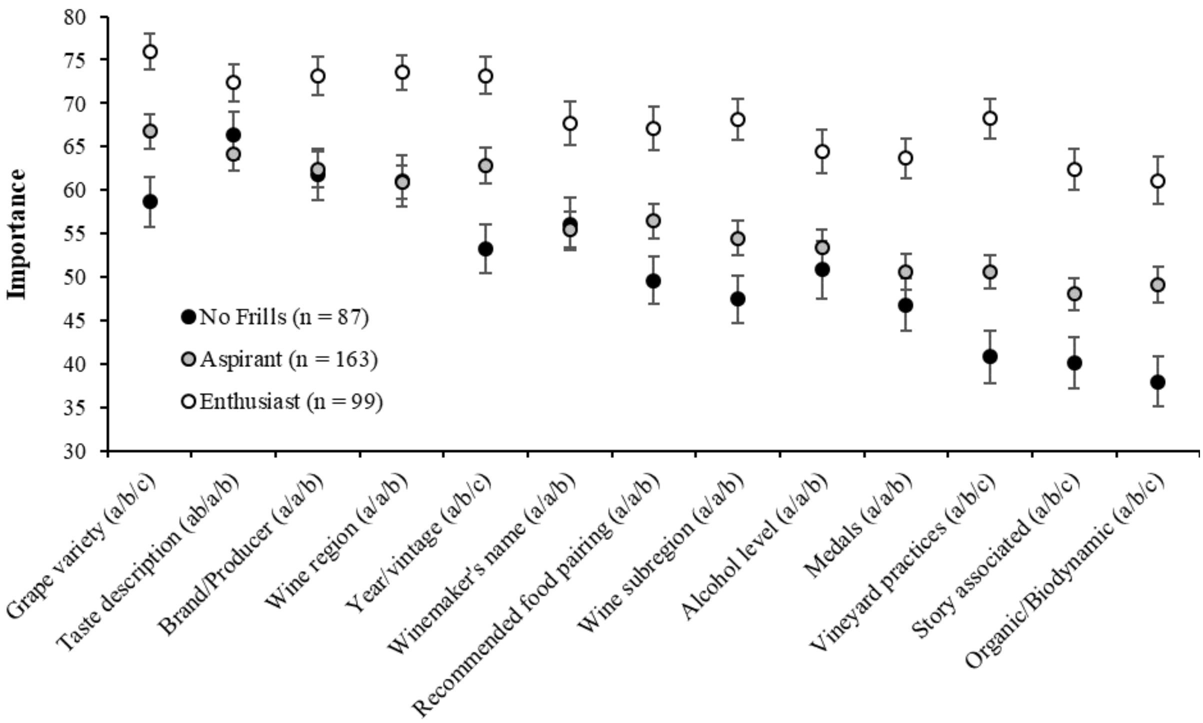

Figure 1. Importance of label information of FAW across FWI segments (ordered by overall mean). Data points are mean segment importance (0-100 scale) with standard error bars. The result of the one-way ANOVA with Tukey HSD post hoc test is given in brackets next to the wine label information in the order of No Frills, Aspirants, and Enthusiasts segments. Different letters indicate significantly different means for importance of label information for purchase of FAW.

There were significant FWI segment effects for all 13 attributes. ENT placed more importance on the need for information as they scored significantly higher than the other FWI segments for all elements except taste description. They were especially interested (>70%) in grape variety, brand, wine region, and year of vintage, but considered subregion (68.1%) and vineyard practices (68.3%) important too. This could be explained by their higher score on the wine knowledge and provenance dimensions of the FWI (Johnson and Bastian, 2015) and tendency to process extrinsic and intrinsic wine information (Berry MW, 1990; Bruwer and Johnson, 2010). NF and ASP were less interested in regions but more so in taste descriptions. NF tended to place less importance on all categories of label information than the other two segments. ASP responses ranged between NF and ENT and were significantly different on five factors, grape variety, year/vintage, vineyard practices, story, and organic/biodynamic. Interestingly, the story of the wine was perceived as being of less importance by all segments, however this result contradicts a recent study (Danner et al., 2017), which found information to positively moderate consumer preferences and emotions for wine. This means that the wine industry may focus on food recommendation and tasting notes on labels and the hospitality sector can extend the wine experience by telling stories to diners.

4.6. Provenance of fine Chardonnay

As Chardonnay accounts for 42% of Australia’s white wine production, one aim of this study was to determine regions associated with fine Chardonnay wines (Table 4). Consumers frequently selected Barossa Valley, Adelaide Hills, Hunter Valley, Margaret River, Yarra Valley, and Tasmania, irrespective of FWI segment, which suggests that all segments are interested in region when Chardonnay is concerned (Goodman et al., 2008; Johnson and Bruwer, 2007). The association of Barossa Valley and fine wine is highest. Although the region established its reputation with Shiraz (Halliday, 1993; Schamel and Anderson, 2003), regional branding increases consumer confidence in the quality of wine from that region (Bruwer and Johnson, 2010). Barossa Valley Chardonnay has the lowest price per tonne (Wine Australia, 2018a) compared with the five most associated regions (Table 4), so consumer perceptions of a region’s quality may not match those of critics.

Table 4. Wine regions considered by consumers according to FWI segments to be associated with fine Australian Chardonnay.

Region	All n=349 (%)	No Frills n=87 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Barossa Valley	46.4	44.8	51.5	39.4
Adelaide Hills	37	35.6	40.5	32.3
Hunter Valley	33.8	28.7	35	36.4
Margaret River	33.2	39.1	33.1	28.3
Yarra Valley	30.7	31	29.4	32.3
Tasmania	26.4	20.7	27	30.3
Clare Valley	26.1	21.8	27	28.3
McLaren Vale	22.6	23	22.1	23.2
Rutherglen	15.8	18.4	12.3	19.2
Murray Darling	14.6	9.2	17.2	15.2
Coonawarra	14.3	14.9	11	19.2
Riverland	13.8	9.2	16	14.1
*Mornington Peninsula**	13.8	8a	12.3ab	21.2b
Grampians	12	6.9a	11.7ab	17.2b
*Eden Valley***	11.7	9.2a	7.4a	21.2b
Riverina	11.7	13.8	12.3	9.1
Queensland	11.5	4.6a	14.1b	13.1b
*South Eastern Australia**	11.2	5.7a	10.4ab	17.2b
Mudgee	10.9	8	11.7	12.1
*Orange***	10.3	3.4a	6.7a	22.2b
Geelong	8.3	5.7	8.6	10.1
Bendigo	7.7	2.3a	8.6ab	11.1b
Langhorne Creek	7.4	5.7	6.7	10.1
*Canberra District**	7.4	2.3a	6.7ab	13.1b
Beechworth	7.4	2.3a	9.8b	8.1ab
*Pemberton**	6.9	2.3a	11b	4a
Heathcote	6	2.3	6.1	9.1
Pyrenees	6	3.4	8	5.1
*Hilltops**	5.7	1.1a	4.9ab	11.1b
Great Southern	5.4	2.3	6.1	7.1
Macedon Ranges	5.4	4.6	5.5	6.1
Tumbarumba	4.3	3.4	3.1	7.1
Padthaway	4.3	2.3	3.7	7.1
Wrattonbully	4	1.1	6.1	3
Geographe	2.6	1.1	3.7	2
Other	1.7	3.4	1.8	0

*$p < .05$ Mean differences by Chi Square test

**$p < .01$ Mean differences by Chi Square test
Values followed by different letters within a row are significantly different between segments.

ENT tended to have higher response levels than other segments and acknowledged lesser-known, up-and-coming Chardonnay regions, such as Eden Valley, Mornington Peninsula, Orange, Bendigo, Hilltops, and Canberra District more frequently. Most of the aforementioned regions are known as cooler climate regions (Halliday, 1993) and produce a distinct Chardonnay style (Gambetta et al., 2017). ENT might be displaying their greater understanding of the interaction of region, variety and wine quality (Berry MW, 1990; Bruwer and Johnson, 2010) as they place more importance on provenance for FAW than ASP and NF (Johnson & Bastian, 2015).

4.7. Consumer sensory description of fine Chardonnay

Respondents associate fine Australian Chardonnay with fresh, fruity, flavourful, full bodied, elegant, fragrant and balanced qualities with medium alcohol level (11.5-13.5% ABV) (Table 5). Although oak itself was among the top ten cited terms, flavours associated with age and complexity, or derived from oak or malolactic fermentation, such as nougat, popcorn, cheesy and toasty, were rated lowest by the consumers; this is in contrast to what experts might perceive (Gambetta et al., 2017; Niimi et al., 2018). One explanation for this may be that a consumer's wine vocabulary is less refined and their memory-based conceptualisation is less consistent than experts (Gawel, 1997; Parr et al., 2004); this might result in the discrepancy between the concept of using oak in winemaking and what could be considered as oak-derived attributes. Furthermore, without oak influence, even experts had difficulty to discriminate between Chardonnay research wines from various regions (Niimi et al., 2018). So, although the presence of oak is an important measure for Chardonnay quality, the diverse styles of Australian Chardonnay tend to be more balanced between oak and fruit flavours than international styles (Saliba et al., 2013), and consumers do not expect oak-related flavours to stand out. This highlights the need to derive definitions of fine wine from the consumer's perspective, not just on wine labels, but also in tasting notes complementing wine lists. Using descriptors consumers associate with the wine style/variety is more likely to lead to purchase and satisfaction as long as the wine meets their expectations (Deliza and MacFie, 1996). In the current study, full bodied was a term highly rated for fine Chardonnay, and possibly specifically for fine Chardonnay, as earlier Australian consumers described generic Chardonnay to be medium bodied (Niimi et al., 2017).

Table 5. Sensory attributes associated with fine Australian Chardonnay by Australian consumers and FWI segments.

Sensory attributes	All n=349 (%)	No Frills n=87 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Fresh	33.5	29.9	31.3	40.4
*Flavourful**	33.2	40.2a	25.2b	40.4a
Fruity	30.7	29.9	29.4	33.3
Full bodied	26.9	24.1	29.4	25.3
Elegant	26.9	20.7	25.2	35.4
Balanced	26.6	24.1	27.6	27.3
*Fragrant***	23.5	11.5a	27b	28.3b
Delicate	21.5	21.8	23.9	17.2
Ripe/juicy	19.5	13.8	20.2	23.2
Oak	18.9	18.4	19	19.2
Soft/mellow	18.1	18.4	16	21.2
Lingering flavours/long finish	17.5	12.6	17.8	21.2
Complex flavours	16	11.5	17.8	17.2
Medium alcohol (11.5-13.5%)	14.3	12.6	12.3	19.2
Robust	14	12.6	14.7	14.1
Tropical fruits	14	8	15.3	17.2
Apple/Pear	13.5	10.3	12.3	18.2
*Fine tannins**	11.7	5.7a	11ab	18.2b
Buttery	11.7	5.7	12.3	16.2
Creamy	10.6	9.2	8.6	15.2
Stonefruit	9.2	11.5	9.2	7.1
Nutty	8.9	4.6	10.4	10.1
*Mineral**	8.6	3.4a	8ab	14.1b
Spicy	8	4.6	8	11.1
Drying	8	9.2	7.4	8.1
High alcohol (over 14%)	6.6	5.7	6.7	7.1
Toasty	6.6	2.3	8	8.1
Cheesy	6.3	4.6	6.1	8.1
Low alcohol (less than 11.5%)	5.4	3.4	5.5	7.1
*Popcorn**	4.9	0a	6.1b	7.1b
Nougat/Toffee/Caramel	4.6	4.6	4.9	4

*$p < .05$ Mean differences by Pearson Chi Square test
**$p < .01$ Mean differences by Pearson Chi Square test

Values followed by different letters within a row are significantly different between segments.

ENT indicated more technical and ageing related sensory terms more frequently than NF and ASP, which resulted in significant differences across segments for terms such as fine tannins, mineral, and popcorn alongside with fragrant and flavourful (Table 5). Of these terms in particular, minerality has a positive connotation with quality and is better understood by expert wine drinkers (Charters & Pettigrew, 2007; Rodrigues et al., 2015). Additionally, some of these attributes (e.g., popcorn, fine tannins) may relate to style, and derive from a higher percentage of malolactic fermentation and new oak or more attentive practices during wine making (Gambetta et al., 2014), so choosing such attributes might be due to the knowledge of ENT, (Johnson & Bastian, 2015) and to the difference in language used to describe wine and wine quality between segments (Gawel, 1997; Parr et al., 2004). Indeed, NF tended to associate less sensory attributes to fine Chardonnay wine than other segments, which could be reflective of their lower wine knowledge as described in the FWI and hence hospitality practitioners may effectively target them with simple communication.

4.8. Provenance of fine Shiraz

As Shiraz accounts for 47% of Australia’s red wine production, this study sought to ascertain the regions associated with fine quality Shiraz wine (Table 6). Similar to the results obtained for Chardonnay, consumers frequently cited Barossa Valley, Hunter Valley, Adelaide Hills, McLaren Vale, Clare Valley, Margaret River and Yarra Valley, regions renowned for producing high quality Shiraz (Halliday, 2006). Barossa Valley, Australia’s premium region for Shiraz (Schamel and Anderson, 2003) was ranked well ahead of the Hunter Valley; this supports findings that consumers pay higher prices for Barossa Valley Shiraz over those from Hunter Valley and McLaren Vale (Ling and Lockshin, 2003). Riverland, Murray Darling and Riverina have a reputation as bulk wine producers (Wine

Australia, 2017) and respondents did not associate them with fine Shiraz. Adelaide Hills was associated with FAW for Shiraz, supporting previous studies that recognise the quality cool-climate wines (including Shiraz) arising from this region (Schamel and Anderson, 2003). These results provide alternative regions for the hospitality operator seeking to offer fine Australian Shiraz beyond Barossa Valley, rather than expecting all consumers to be adventurous and take a leap of faith in trusting the menu or wait-staff suggestion.

Table 6. Wine regions associated with fine Australian Shiraz by Australian consumers and FWI segments.

Region	All n=349 (%)	No Frills n=87 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Barossa Valley	41	41.4	39.9	42.4
Hunter Valley	26.4	23	28.2	26.3
Adelaide Hills	25.2	17.2	30.7	23.2
McLaren Vale	20.9	23	17.2	25.3
*Clare Valley**	20.9	11.5a	23.9b	24.2b
Margaret River	20.9	24.1	21.5	17.2
Yarra Valley	20.6	21.8	20.2	20.2
Coonawarra	16.6	11.5	18.4	18.2
*Grampians***	12	3.4a	12.9b	18.2b
*Mudgee**	12	4.6a	12.9b	17.2b
Rutherglen	11.5	9.2	12.9	11.1
*Riverland**	11.2	3.4a	13.5b	14.1b
Tasmania	11.2	13.8	8	14.1
Murray Darling	10	4.6	9.8	15.2
Eden Valley	9.7	8	9.2	12.1
Heathcote	9.5	4.6	9.2	11.1
Langhorne Creek	8.9	5.7	8.6	12.1
*Geelong***	8.3	2.3a	6.1a	17.2b
Mornington Peninsula	8	4.6	8.6	10.1
South Eastern Australia	8	4.6	9.2	9.1
Queensland	8	5.7	9.8	7.1
Beechworth	8	4.6	7.4	12.1
*Pemberton**	7.4	8ab	10.4b	2a
*Orange**	7.2	1.1a	8b	11.1b
Riverina	6.9	2.3	8	9.1
Hilltops	5.7	3.4	4.3	10.1
Canberra District	5.4	6.9	3.1	8.1
*Great Southern***	5.2	9.2a	1.2b	8.1a
Bendigo	5.2	2.3	5.5	7.1
Macedon Ranges	5.2	5.7	5.5	4
Pyrenees	4	2.3ab	2.5b	8.1a

Wrattonbully	3.7	2.3	5.5	2
Padthaway	3.2	2.3	3.7	3
Geographe	2.9	3.4	1.8	4
Tumbarumba	2.6	0	3.7	3
Other	1.7	1.1	3.1	0

*$p < .05$ Mean differences by Pearson Chi Square test

**$p < .01$ Mean differences by Pearson Chi Square test
Values followed by different letters within a row are significantly different between segments.

ENT tended to indicate regions more frequently than other segments, reflecting their extended wine knowledge and interest in provenance (Johnson & Bastian, 2015). NF cited the better-known wine regions for producing fine Shiraz, whereas ASP and ENT appeared to demonstrate their higher involvement by acknowledging lesser known regions such as Grampians, Mudgee, Geelong, Orange and Pyrenees (Halliday, 2006). The findings are consistent with previous research, namely that region has a moderating effect on wine attributes such as grape variety and is more important for consumers with higher wine involvement (Bruwer and Johnson, 2010; Perrouty et al., 2006), and suggests the FWI scale is an effective segmentation tool.

4.9. Sensory description of fine Shiraz

Respondents expect fine Shiraz to be full bodied, rich, balanced, fruity, elegant, and fragrant with complex flavours, dark fruits and red fruits (Table 7). This supports previous studies reporting a positive relationship between Shiraz wine quality and fruity, fragrant aromas (Lattey et al., 2010), heavier mouthfeel (Charters and Pettigrew, 2007) and consumer preference for wine with medium to full body (Bruwer et al., 2011). Full bodied and rich had similar high frequencies, which may relate to consumer associations between wine body and strength (Niimi et al., 2017), and suggests the importance of style descriptions over flavours when communicating fine Shiraz wine to consumers. However, non-tasted preferences are to be treated carefully; when consumers actually taste wines, viscosity as a measure of body had no effect on liking and emotions (Niimi et al., 2017). Oak and oak-influenced flavours like chocolate, toasty, tobacco and liquorice (Crump et al., 2015) were less frequently cited and fine Shiraz was seen as fresh, fruity and spicy/peppery rather than herbal and drying (Table 7). Earlier research found peppery aroma as a marker of Australian Shiraz wines (Herderich et al., 2007), which perhaps is associated with higher quality in consumers' minds. When beverage operators are designing wine lists and compiling notes for staff training, these are the kind of descriptors that should be matched to the expectations of the target customers.

Table 7. Sensory attributes associated with fine Australian Shiraz by Australian consumers and FWI segments.

Sensory attributes	All n=349 (%)	No Frills n=87 (%)	Aspirants n=163 (%)	Enthusiasts n=99 (%)
Full bodied	31.8	33.3	32.5	29.3
Rich	30.7	25.3	32.5	32.3
Balanced	27.8	24.1	27	32.3
Dark fruits/berries	22.3	23	19	27.3
Complex flavours	21.5	19.5	18.4	28.3
*Fruity***	21.2	13.8a	17.2a	34.3b
Elegant	20.3	18.4	19.6	23.2
*Fragrant**	20.1	10.3a	25.2b	20.2ab
Red fruits/berries	19.8	25.3	16	21.2
Robust	19.8	21.8	16	24.2
Lingering flavours/long finish	18.9	16.1	19	21.2
*Fresh**	18.1	10.3a	17.2ab	26.3b
*Spicy/peppery**	18.1	9.2a	18.4ab	25.3b
Ripe/juicy	17.5	12.6	16.6	23.2
Medium bodied	14.6	9.2	16.6	16.2
Savoury/earthy	11.7	9.2	12.9	12.1
*Fine tannins***	11.7	6.9a	8.6a	21.2b
*Oak**	11.2	5.7a	9.8ab	18.2b
Delicate	10.9	5.7	12.9	12.1
*High alcohol (over 14%)***	10	5.7a	7.4a	18.2b
Chocolate	9.7	6.9	11.7	9.1
Drying	9.2	5.7	9.2	12.1
Soft/mellow	8.6	6.9	8	11.1
Medium alcohol (11.5-13.5%)	8.3	5.7	6.7	13.1
Toasty	7.7	6.9	8	8.1
*Mineral***	6.3	2.3a	4.3a	13.1b
Tobacco/Leather	6	5.7	6.1	6.1
Licorice	6	3.4	6.1	8.1
Herbal	5.2	3.4	5.5	6.1
Mint/Eucalyptus	3.7	1.1	4.9	4
Low alcohol (less than 11.5%)	2.9	0	4.9	2

*$p < .05$ Mean differences by Pearson Chi Square test
**$p < .01$ Mean differences by Pearson Chi Square test
Values followed by different letters within a row are significantly different between segments.

The sensory terms fruity, fragrant, fresh, spicy/peppery, fine tannins, oak, high alcohol, and mineral were used differently between segments to define fine Shiraz wine. ENT described fine Shiraz wine as fresh, fruity, spicy/peppery, and mineral with fine tannins, high alcohol, oak and complex flavours, and balanced wine. ENT tended to select more sensory attributes to describe fine wines than NF and ASP. Besides utilising more descriptors, consumers with higher wine knowledge are more likely to use specific textural terms such as fine tannins (Gawel et al., 2016), suggesting they have greater objective knowledge than novices (Johnson and Bastian, 2007). NF and ASP did not regard high alcohol, and fruity as part of fine Shiraz and oak was higher amongst ENT.

4.10. Food pairings for fine Australian wines of provenance

Food and wine pairing may prove to be a valuable strategy to promote premium FAW (Bastian et al., 2010). Consumers were asked which of Chardonnay, Shiraz or Both they would consume with the foods listed in the survey. Correspondence analysis (CA) was used to analyse the data; the first two factors of the CA in combination explained over 94% of the preferred wine choices for the different food items (Figure 2). The food choices appeared to group together according to the chosen wine options. Wine consumers would drink Chardonnay with fish or chicken meals such as fish & chips, pan-fried snapper with parsnip puree, creamy chicken pasta, chicken parmigiana, and would choose Shiraz with red meat dishes like beef burger, beef tartare, braised lamb shoulder, lasagne and spicy sausage pizza. This finding reflects the conventional “white wine with fish and red wine with meat” approach (Harrington, 2006) and weight matching theory (Werlin, 2003), as consumers described fine Chardonnay as fresh, fruity, elegant, and delicate, and fine Shiraz as full bodied, rich, dark fruited and complex. The intensity and the persistence of specific flavours can have importance in the pairing and can be used in either a similar or contrasting pairing approach (Rosengarten and Wesson, 1989). For example, can similarity be seen between braised lamb shoulder and full bodied, rich Shiraz? Would a fresh Chardonnay contrast the greasiness of fish & chips? The coherent food and wine choices observed in Figure 2 suggest a generally conscious behaviour of consumers to look for appropriate food pairings with FAW and to enjoy the gastronomic potential of both (Van Westering and Edwards, 1996).

Brie, camembert, cheddar, and blue cheese, as well as paté, prosciutto and mushroom risotto would be equally enjoyed with Chardonnay and Shiraz. This mirrors the general practice of consuming cheese and wine together, where the social context might be more important than the pairing (Bastian et al., 2010; Mouret et al., 2013). Previously, brie, camembert and similar soft cheeses were reported to be the least versatile with wines alongside with blue cheese, whereas cheddar was viewed as an all-rounder (Bastian et al., 2009) and particularly desirable with Shiraz wines. In this study, consumers' pairings did not differentiate within the cheese product category, except for fresh goat cheese, which might have been associated with the 'freshness' of Chardonnay. Neither Shiraz nor Chardonnay would be expected to pair with chocolate mousse, apple pie, pavlova, or popcorn (Figure 2), which is likely reflective of sweet foods being better paired with sweet wines than dry table wines (Koone et al., 2014). Overall, the outcome of the expected pairing aspect of the study suggests the importance of appropriate food pairings with fine Chardonnay and Shiraz wines for Australian wine consumers, which may prove a valuable marketing strategy for the wine, hospitality and tourism sectors through meeting consumer expectations and creating higher satisfaction and resultant value. However, a cautious approach is required because sensory attributes of FAW first need to meet consumer expectations in order to successfully apply food and wine pairings. Consumers seemed to take a conservative approach to pairings, however, the style of foods paired with the expected fine wine sensory attributes offers guidance to hospitality operators to develop novel combinations.

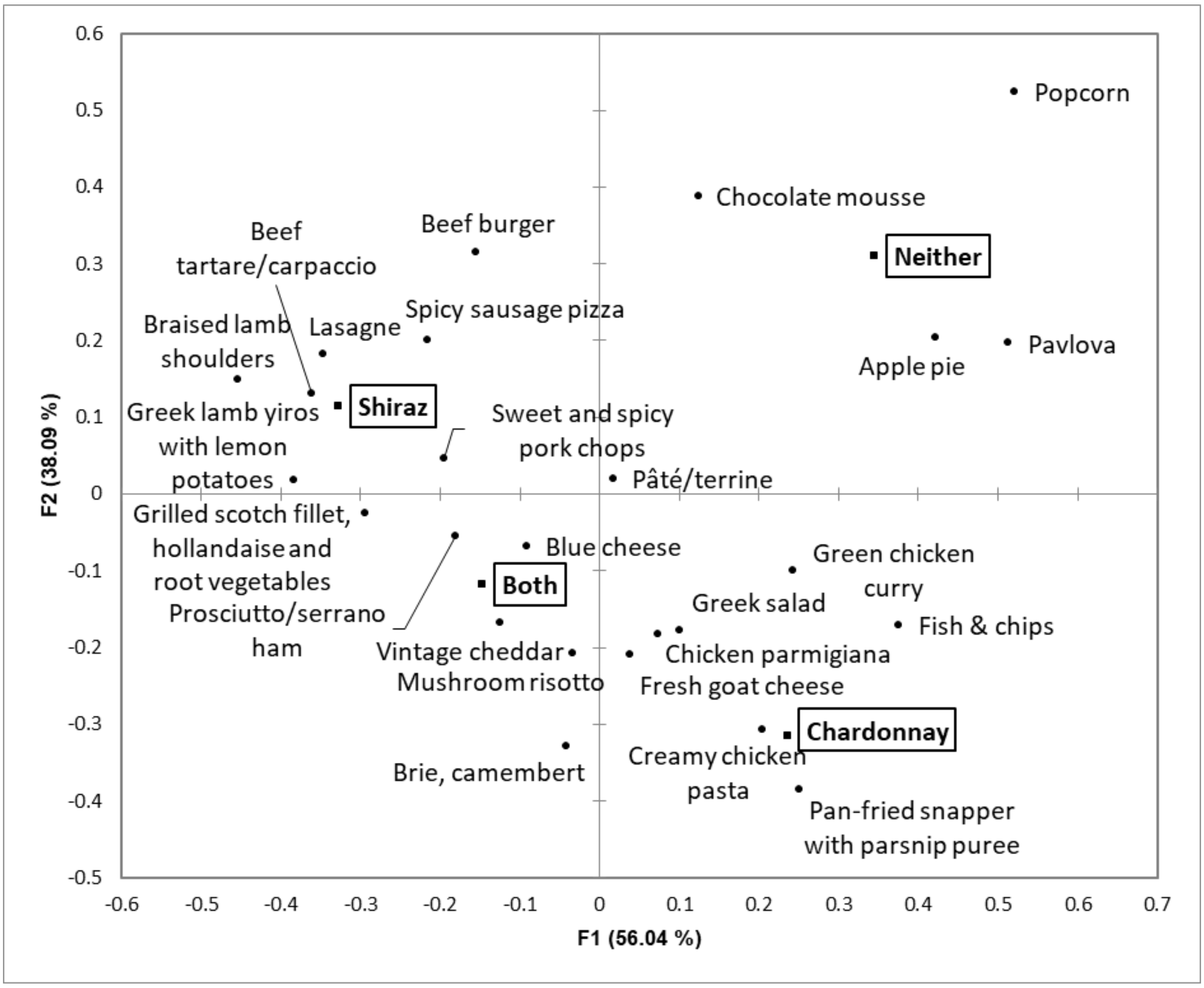

Figure 2. Correspondence analysis of expected food and wine pairings.

5. Conclusions

This study explored the consumers' perception of what constitutes fine Australian wine. In particular, it focused on Australia's most important varieties, Chardonnay and Shiraz, and how perceptions of these as fine wines differs across consumer segments. Most importantly, we propose a consumer definition of Australian fine wine:

> *"Australian fine wines are of high quality, good value for money, are easy to drink and consistently show balance, plus diversity, fruity and regional characteristics"*

This intended to provide a tool for the wine and hospitality industries to tailor their offer to consumers' expectations and thus assist in positioning fine Australian wine. The frequency of words used to define fine wine was related to FWI segments, with ENT appearing to utilise the most information, implying that the fine wine definition can be tailored to the preferences of each FWI segment as required, allowing marketers to develop relevant communication strategies. In terms of label information, grape variety, brand, region, and vintage, broadly arose as the most important elements, however ENT also value technical information highly.

The survey explored regions most related to fine Australian Chardonnay and Shiraz wines, resulting in the dominance of Barossa Valley in both cases, suggesting consumers actually associate provenance to FAW, much as they do for Old World wines. ENT appeared to utilise the most information, reflecting their extended wine knowledge and interest in provenance. In a similar way, Enthusiasts tended to use a greater vocabulary of sensory descriptors of Chardonnay and Shiraz, where these participants favoured complex, oak derived attributes over ASP and NF. Overall, fine Australian Chardonnay are seen as fresh, fruity, elegant, and delicate, whereas Shiraz as full bodied, rich, dark fruited and complex. These are important signals for the hospitality sector to utilise with different consumer segments.

As for food and wine pairings, consumers indicated they expect to drink Chardonnay with fish and chicken meals, and Shiraz with red meat dominated meals. The general association that cheese and wine go hand in hand was reaffirmed, as consumers equally expect Chardonnay or Shiraz to pair with various cheese styles. On the other hand, desserts were not considered appropriate matches with either of the wines consumers were asked to consider. In addition to exploring consumer perceptions of fine wine, this research reinforced the use of the FWI as an effective tool for segmenting wine consumers.

There is now a need for future research to investigate the hedonic relationships between FAW and FWI segments with consumer preference taste tests. As food pairings gain interest globally, research is required to investigate FAW and food pairing in real meal situations and varied dining contexts to offer more insights for the hospitality sector. Consumer perceptions of FAW should be explored in Australia's export markets in order to develop tailored marketing strategies appropriate to different market places, cuisines and cultures. Future research could be extended to all wine producing nations that seek to position their fine wines, particularly in on-premise settings.

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Chapter 3

A matter of place: Sensory and chemical characterisation of fine Australian Chardonnay and Shiraz wines of provenance

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Contribution to the Paper	Designed experiments, trained sensory panels and undertook sensory descriptive analysis of 63 wines, performed wine non-volatile, assisted volatile analysis (by GC-MS), analysed and interpreted data, drafted and constructed the manuscript.		
Overall percentage (%)	65%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Abstract

Establishing a fine wine image through regional typicality has been of interest to New World wine producing countries like Australia, but previous research mainly involved unoaked experimental wines, which were not reflective of the retail wine market. The regional typicality of commercially available fine Australian wines (FAW) was therefore explored, based on the hypotheses that sensory and chemical composition of varietal fine wines would discriminate by region, and further nuances within region would be explained by drivers of intraregional typicality. Chardonnay wines (2015 vintage) from Margaret River (MR, n=16) and Yarra Valley (YV, n=16); and Shiraz wines (2014 vintage) from Barossa Valley (BV, n=16) and McLaren Vale (MV=15), were selected for descriptive sensory analysis and underwent profiling of volatiles by gas chromatography-mass spectrometry (GC-MS). For both grape varieties, there was large variability in wine styles among wines from the same GI, ascribed mainly to viticultural and winemaking techniques applied by wineries. Consequently, human intervention seemed to be an important component of regional/sub-regional typicality, which therefore cannot be determined solely on geographic origin of the fruit. Perhaps commercial wines made with less oak influence or that underwent extended bottle maturation would convey geographical differences more, although changing oak regime might be risky for wineries as consumers perceived the presence of oak as part of FAW. Undoubtedly, variation of wine styles emerging across wine regions, vintages, and viticultural and winemaking practices needs to be further explored, but this work created a preliminary sensory and volatile map for future research.

Keywords

Descriptive sensory analysis, GC-MS, Regional typicality, Terroir, Geographical Indication

1. Introduction

Regional typicality is an important concept for the wine industry as it not only delineates geographic areas but also comprises wines with recognisable sensory characters and composition (Lecat & Chapuis, 2017; Luykx & Van Ruth, 2008; Maitre, Symoneaux, Jourjon, & Mehinagic, 2010). This concept is also intertwined with "terroir", a sense of place, where place has a rather holistic meaning including the interaction amongst place (topography, climate, soil), people (tradition, winemaking and viticultural practices) and the resulting product (grape varieties, wines) (Vaudour, 2002). The notion of terroir has demarcated many historical regions in Europe over the centuries, such as the famed vineyard sites of Burgundy, Mosel, and Barolo or the classified wine estates of Bordeaux. In turn, consumers learned to rely on provenance to predict wine quality and are willing to pay premium for it (Benfratello, Piacenza, & Sacchetto, 2009; Casini, Corsi, & Goodman, 2009; Charters & Pettigrew, 2007; Johnson & Bruwer, 2007).

The sensory and chemical profiles differentiating wine regions received research interest across a wide range of disciplines (Cadot et al., 2012; Di Paola-Naranjo et al., 2011; López-Rituerto et al., 2012). Besides soil and climatic determinants, regional typicality also has a non-sensorial, anthropological/cultural aspect adding to the complexity of the matter (Demossier, 2018). In Europe, regional appellations aim to preserve wine typicality by regulating allowable grape varieties, minimum levels of alcohol, production methods, maximum yield levels and methods of harvesting, in other words, the extent of human intervention (van Caenegem, 2003). However, traditions and human practices may vary markedly by region and appellation. In vineyard driven classifications (e.g., Burgundy, Mosel, Barolo, Tokaj) human intervention is strictly regulated, while in other appellations, distinct wine styles are impacted by local winemaking traditions to a higher degree (e.g., Amarone della Valpolicella, Port, Madeira). Further, Bordeaux sees economic importance in classifying individual wine estates (Smith & Deroy, 2014). Where the concept of terroir has yet to be firmly established, as in New World wine producing countries such as Australia, brands and price points are commonly used to create a sense of fine or quality wine in consumers' minds (R. Johnson & Bruwer, 2007).

In 1993, the Australian GI system was introduced mimicking the Appellation Controlee of France. Although less restrictive of permitted grape varieties and production methods than its Old World counterparts, the Australian GI system ensures at least 85% of the grapes come from the acknowledged region (Johnson et al., 2013), and if varieties or vintages are stated, 85% of the wine in the bottle must come from those varieties and vintages. Moreover, Wine Australia (Wine Australia, 2016) defines a GI for wine as one that ‘‘identifies the wine as originating in a region or locality where a given quality, reputation or other characteristics of the wine is essentially attributable to the geographical origin’’. Embedded in this definition, wines from a designated GI should possess unique sensory characteristics and varietal expression deriving from the region, rather than overt viticultural and winemaking practices (Johnson, Hasted, Ristic, & Bastian, 2013).

This relatively simple approach and clear varietal labelling contributed to the extraordinary success of Australia's wine in the 1990s, along with their fruit-driven, easy drinking style and good value for money (Easingwood, Lockshin, & Spawton, 2011). Australian Shiraz, became internationally recognised as a unique wine style with examples coming from the Barossa Valley, McLaren Vale and Hunter Valley. Shiraz is planted in almost every wine-producing region in Australia, accounting for 46% of all red varieties (Wine Australia, 2018). Aromas and flavours can range from plum, berries and chocolate to liquorice and spice (Herderich et al., 2007) resulting in medium to full-bodied wines with varying structure depending on region, climate and winemaking techniques.

Chardonnay, the most important white variety encompasses 44% of all white wine production. Yarra Valley, Adelaide Hills and Margaret River are cited as top Chardonnay producing regions with wine sensory descriptors covering the fruit spectrum, from citrus and green apple, to peach, apricot, and tropical fruit (Bruwer & House, 2003; Gambetta, Bastian, Cozzolino, & Jeffery, 2014). Chardonnay is an extremely flexible grape with regard to various winemaking techniques (Gambetta et al., 2014) resulting in diverse wine styles within and across regions (Saliba, Heymann, Blackman, & MacDonald, 2013).

In a recent study, consumers defined Australian fine wines as high quality, good value for money, easy to drink, showing consistent balance, and having diversity, fruity and regional characteristics (Kustos et al., unpublished). The importance of regional typicality has been recognised for some varieties such as Barossa Valley Shiraz, Coonawarra Cabernet Sauvignon, Margaret River Chardonnay, Hunter Valley Semillon, however research is yet to firmly establish sensory and chemical composition associated to GIs similarly to the Old World appellation system (Conduit, Plewa, & Brodie, 2016; van Caenegem, Drahos, & Cleary, 2015). Johnson et al (2013) studied the regional characteristics of Australian Shiraz (n=29) from different GIs (n=10) and although some wines from the same region shared similar sensory attributes, they were not able to define a unique regional character due to the diverse geography and meso-climate within regions and applied winemaking interventions. The authors suggested, future research should use wines made under controlled conditions and/or encompass sub-regions within regions that are smaller and/or more homogenous in geography as well as a larger sample size. The Barossa Grounds project is one such endeavour, which resulted in the identification of three main grounds (Northern, Central, Southern) with two further supplementary grounds (Eastern Edge and Western Ridge) in the Barossa Valley (Robinson & Sandercock, 2014). The Scarce Earth program highlighted 19 wine districts in McLaren Vale (Bekkers, 2012) and the Rocks project defined five sub-regions in Clare Valley (Werner & Roche, 2016).

Other than these well-known GIs in South Australia, there are Australian fine wine producing regions that are yet to be investigated. Margaret River in Western Australia has no official sub-regions, although six sub-regions have been suggested based on climate and soil differences for the production of Cabernet Sauvignon wines (Gladstone, 1966). In the Yarra Valley, Victoria, official sub-regions are again absent but there is a longstanding tradition of division between the Valley Floor and the highly regarded Upper Yarra. Boundaries between the two are unclear to date, thus a township-based distinction is emerging among producers that mimics the French Village classification system. Understandably, the aforementioned industry studies used research wines, which are typically young, mostly unoaked, and produced with standardised winemaking protocols that do not necessarily reflect the commercial wines and styles available in the market. In contrast, consumers face myriad wines from within a region made by various winemakers who aim to personalise their products using different winemaking techniques. As such, whether from consumer or scientific perspectives, the questions remain whether regional typicality is expressed more with less intervention and whether consumers can benefit from the research outcomes. Thus, the connection between Australian GIs, grape varieties, and regional typicality needs to be further explored.

1.1. Aims

This study explores the hypothesis that the sensory properties and chemical composition of fine Chardonnay and Shiraz wines will vary by sub-region within Australian GI. The primary aim of this study was to use descriptive sensory analysis and gas chromatography-mass spectrometry (GC-MS) as a means to investigate regional or sub-regional patterns in the sensory attributes and chemical composition of Australia's most important fine white and red wine varieties, Chardonnay and Shiraz. Furthermore, the study aimed to investigate whether commercially available wines fit the provenance models proposed by previous research and industry experts.

2. Materials and methods

2.1. Wine samples

Smaller wine regions and sub-regions[2] with homogenous geographical characteristics were targeted, as suggested by Johnson et al. (2013). The precise sub-regions were chosen on the basis of industry research projects (Bekkers, 2012; Gladstone, 1966; S. Robinson & Sandercock, 2014), and by consulting winemakers and industry experts via email and telephone. Chardonnay wines from the 2015 vintage were selected from Margaret River (MR, n=16) and Yarra Valley (YV, n=16). The Margaret River wines were sourced from Wilyabrup (MRW, n=6), Wallcliffe (MRA, n=5), and blends from across the region (MRR, n=5) as a control group. Yarra Valley was represented by Dixons Creek (YVD, n=5), Gladysdale (YVG, n=5) and regional blends (YVR, n=6). Shiraz wines were sourced from Barossa Valley (BV, n=16) and McLaren Vale (MV, n=15) from the 2014 vintage. The sampling criteria was further refined to two sub-regions from each region, namely Northern Grounds (BVN, n=9) and Southern Grounds (BVS, n=7) from Barossa Valley, and Blewitt Springs (MVB, n=8) and Willunga (MVW, n=7) districts from McLaren Vale. All wines were commercially produced, and thus authors did not have control over the winemaking process. Nonetheless, all samples were aged in oak barrels, underwent malolactic fermentation, and were chosen to represent the currently available fine Chardonnay and Shiraz wines in the Australian market, and thus they were assumed to be good representations of the GIs. Selection criteria included cost (AU$20 and above), origin (GIs recognised to

[2] The sub-regions in this study are not equivalent to the ones defined by the Australian GI system (e.g., High Eden GI within Eden Valley GI). However, due its internationally transparent meaning, sub-region was used to express intraregional variation within region.

produce fine wines from the selected grape variety), and score (>90 points) assigned by wine critic James Halliday (Halliday, 2018).

2.2. Sensory assessments

2.2.1. Chardonnay

Ten sensory assessors (three males and seven females, aged between 22 and 34 years) with previous descriptive analysis experience were recruited from among staff and students in the School of Agriculture, Food and Wine and from a trained external sensory panel. Ten training sessions of 90 min each were held, in which four to six wines were presented and panellists generated wine sensory descriptors and defined aroma reference standards. Panellists reached consensus about the attributes and the order in which to rate them. Four booth practice sessions were included during the training, where judges rated the samples under the same conditions as the formal sessions, except for a constant presentation order. Some wines underwent duplicate evaluations to examine the reproducibility of the panel. The final two training sessions were carried out under identical conditions to the formal sessions, and the formal evaluation commenced once there were no significant judge-by-sample interactions. A total of 39 sensory attributes were agreed upon, comprising 16 aroma attributes, 7 taste and mouthfeel attributes, and 16 flavour attributes (Table A.1). These were rated for each wine on a 15-cm scale with low and high word anchors placed at 10% and 90% of the line, respectively. At the beginning of each tasting session, panellists evaluated the low (4 g/L) and high (8 g/L) acidity standard and low (11.5% ABV) and high (14% ABV) heat standard that represented the range of the wine samples, and also served as a “warm-up” sample. Reference standards for the aroma attributes were provided in covered dark glasses prior to evaluation. The wines were assessed in duplicate with 16 wines presented individually in a randomised order during each session, with a 60 s pause between samples and a 5 min break after every four samples. The sensory evaluation was conducted using

RedJade Sensory Software (RedJade Software Solutions, LLC). Additional details about sensory attributes and reference standards appear in Table A.1.

2.2.2. Shiraz

Eleven sensory assessors (five females and six males, aged between 22 and 38 years) with previous sensory evaluation experience were recruited from among staff and students of the School and from a trained external DA panel. The training and evaluation procedures were identical to those described above for the Chardonnay wines, except panellists did not require warm-up samples for acidity. The final41 sensory attributes included 20 aroma attributes, 7 taste and mouthfeel attributes and 14 flavour attributes. Additional details about sensory attributes and reference standards appear in Table A.2.

All sensory evaluation was performed in accordance with the ethical guidelines for scientific research at The University of Adelaide and approved by the Human Research Ethics Committee (approval number: H-2016-150).

2.3. Basic chemical composition

Wine pH and titratable acidity (TA, reported as g/L tartaric acid equivalents at pH 8.2) were measured using a combined pH meter and auto-titrator (Crison, CompacTitrator, Crison Instruments, Spain), and percent alcohol by volume (% abv) was determined using an Alcolyzer Wine ME+DMA 4500M (Anton Paar GmbH, Austria). Residual sugar (glucose + fructose) was determined using an enzymatic test kit (Megazyme, Wicklow, Ireland), and phenolic parameters were measured for the Shiraz wines using the MCP tannin assay (Mercurio, Dambergs, Herderich, & Smith, 2007) and modified Somers assay (Mercurio et al., 2007) . All measurements were performed in duplicate within three months of the sensory evaluations. Summary tables are attached as supplementary data (Table A.3 and Table A.4).

2.4. Volatile composition by GC-MS

Headspace-solid phase micro-extraction-gas chromatography-mass spectrometry (HS-SPME-GC-MS) analysis of wines was carried out on duplicate bottles of wine following the protocol used by Gambetta et al (2016).

2.5. Data analyses

Basic chemical data were processed with Microsoft Excel 2010. Other data analysis was conducted using XLSTAT (version 19.6, Addinsoft, Paris, France). Three-way analysis of variance (ANOVA) with sample and replicate as fixed factors and panellist as a random factor, including interactions, was performed on DA attributes to identify significant differences between samples. When sample by panellist or sample by replicate interaction effects and the sample main effect was significant, a pseudomixed model (Næs & Langsrud, 1998) was used to determine the importance of the interaction effect. If the new F-value was still significant, the interaction was considered as not important and the sample effect was considered as still significant. However, if the new F-value was not significant, the interaction effect was significant and the sample effect was not anymore. In a similar fashion, one-way ANOVA (sample) was performed on the means of the chemical data. The Pearson correlation matrix was calculated and inspected and only variables with significant correlation ($r \geq 0.5$) at $\alpha = 0.05$ were further analysed (Gambetta et al., 2016). Significant sample attribute means from sensory analysis were subjected to Pearson (n) correlation type principal component analysis (PCA) with the significant chemical and volatile data as supplementary variables. PCA was used to reduce the number of variables and to explain the relationships among the variables and the wines. The number of principal components used for PCA was determined from scree plots. To explore which attributes defined the typicality of sub-regions, two-way ANOVA was performed on the sensory data with sub-region as fixed factor nested within region, and panellists as random factor. One-way ANOVA with sub-region as fixed factor was carried out on the GC-MS and chemical composition data matrices. The means of significant sub-region attributes were analysed using discriminant analysis with forward step-wise model to allocate the wines to the sub-region group for which the probability of belonging is the highest. Cross-validation (leave-one-out) was performed for classifying the wine samples after the discriminant functions were estimated from the remainder. Graphic representation was executed using the canonical variables. All statistical analyses were performed at 5% level of significance.

3. Results and discussion

3.1. Chardonnay

3.1.1. Flavour profile of fine Australian Chardonnay wines

Sensory DA panellists defined 39 sensory attributes for the 32 fine Australian Chardonnay wines selected from YV and MR, with 22 attributes significantly differing among the wines (Table A.1). As observed in previous studies of Chardonnay wines, panellists used a wide range of attributes such as citrus, confectionery, tropical fruit, pineapple, stone fruits, green apple, floral, beer, vegetal, oak, vanilla, and toffee (Gambetta et al., 2016; Saliba et al., 2013). A total of 33 aroma volatiles were quantified by HS-SPME-GC-MS, and ANOVA revealed 25 significantly different analytes across the wine samples (Table A.5), which were above sensory threshold levels. They included a range of esters, acids, alcohols and other volatiles typically found in Chardonnay wines arising during berry ripening, alcoholic fermentation, and ageing (Gambetta et al., 2014) and their variation revealed intra-varietal differences among Chardonnay wines resulting from wine region, and viticultural and winemaking practices.

PCA was performed on the significantly different sensory attributes, with significant GC-MS and basic chemical compositional data as supplementary variables. The first three principal components (F1-F3) accounted for 70% of the total variance. F1 (42%) contrasted tropical fruit, pineapple, confectionery, floral, beer, and vegetal aromas and flavours (and volatiles including β-damascenone, isoamyl acetate, ethyl hexanoate, hexyl acetate, and 2-phenylethyl acetate) with oak, vanilla, toffee, citrus, green apple, flavour length, and acidity (along with furfural, *cis*-oak lactone, and TA, Figure 1). F2 (19%) was defined by stock, beer aromas and flavour and stonefruit, confectionery, floral aromas (and volatiles including isoamyl acetate, hexyl acetate, 2-phenylethyl acetate). F3 (9%) further explained the sensory space by contrasting vegetal aroma and flavour from fruit attributes (Figure A.1). The majority of volatile compounds were positioned close to their expected sensory aroma and flavour terms (Figure 1) (Gambetta et al., 2014).

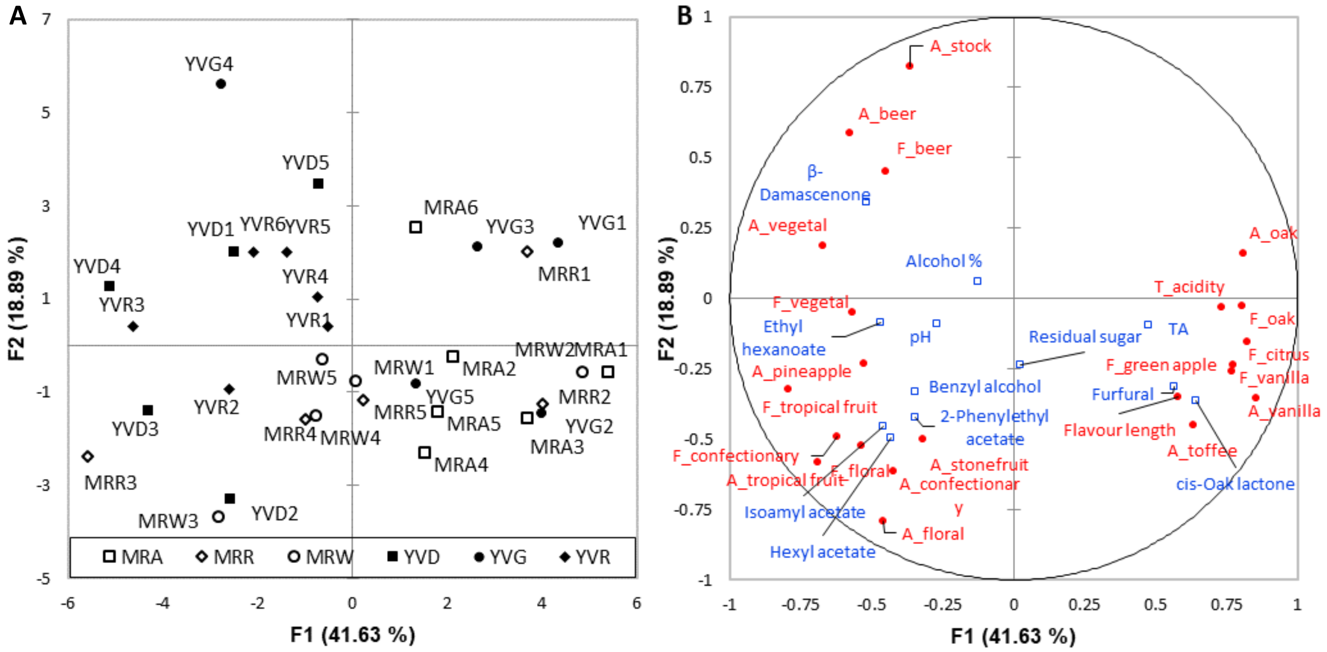

Figure 1. PCA plot showing scores (A) and loadings (B) for mean ratings of significant sensory attributes with significant volatile and chemical compositional data as supplementary variables for fine Australian Chardonnay wines.

As a broad observation, PC2 tends to separate YV from MR samples. Wines in the top left quadrant of the PCA represented the majority of YV samples (YVD1, YVD4, YVD5, YVR1, YVR3, YVR4, YVR5, YVR6, and YVG4), and were perceived to be higher in beer, stock, vegetal, and lower in tropical fruit, toffee, vanilla aroma and flavour length. The same wines had lower contents of esters and acetates, but higher contents of β-damascenone, which can result from lower sunlight exposure and temperature (Gambetta et al., 2014), and could be reflective of the YV region's cooler climate compared to MR (1352 vs 1690 heat degree days (Wine Australia, n.d.)). The vegetal, stock aromas perceived by the sensory panel did not sensibly relate to any volatile compounds measured but such attributes and may derive from extended time spent on yeast lees during maturation. Lees absorb fruity esters and decrease the levels of oak-derived volatiles while creating a highly reductive environment (Towey & Waterhouse, 1996). Wines in the top right quadrant (YVG1, YVG3, MRR1 and MRA6) were also described by beer and stock characters but additionally displayed oak aroma, and higher acidity and TA. In contrast, MRR3 MRR4, MRW3, MRW4, MRW5, YVD2, YVD3 and YVR2 (lower left quadrant) were characterised by floral, confectionery, tropical fruit, pineapple, stone fruit, vegetal, and higher levels of esters and acetates, which corresponds with a fresher, fruitier, less oaked Chardonnay style (Gambetta et al., 2017) or fruity/crisp style (Saliba et al., 2013). Such sensory and volatile profiles are expected to result from a higher proportion of stainless steel vessels and/or partial malolactic fermentation (Gambetta et al., 2014). The latter quadrant comprised different regions and sub-regions indicating those sensory attributes are not unique to GI but rather to similar winemaking practices.

Besides similar stonefruit and floral characters, wines in the lower right quadrant (MRA1, MRA2, MRA3, MRA4, MRA5, MRW1, MRW2, MRR2, MRR5, YVG2 and YVG5) also exhibited citrus, green apple, acidity and flavour length along with oak, vanilla and toffee, with the related volatile compounds such as furfural and *cis*-oak lactone deriving from fermentation and ageing in oak barrels (Gambetta et al., 2014). These wines also had higher TA values, and citrus flavour that highly correlated with acidity (taste) (r = 0.763) and TA (r = 0.511). Therefore, it is possible that the emerging citrus flavour resulted from a cross-modal interaction with sour taste (Noble, 1996). Green apple showed a moderate positive correlation with furfural (r = 0.436) in comparison to Spillman et al. (2004) who reported a negative correlation that depended on the level of barrel toasting. Wines situated closest to the origin of the plot (YVR1, YVR4, MRW1, and MRW5) were moderate in most attributes. The plot of F1 and F3 (Figure A1) demarcated wines higher in confectionery that also displayed vegetal, toffee and oak, such as MRR1, MRR3, MRA6, MRW1 and YVD4.

PCA revealed strong variation within region and sub-region for the chosen wines, which potentially demonstrated a strong impact of wine style and thus winemaking influence. This is in agreement with Fischer et al. (1999) who similarly observed a strong impact of winery (winemaking style), along with vintage and vineyard, on sensory attributes for German Riesling wines, for which quality is solely based on the degree of ripeness of the grapes. Although our sample selection criteria (e.g., fine wines, matured in oak, underwent malolactic fermentation, same vintage) intended to minimise winery and vintage impact, Australian Chardonnay is known to be made in diverse wine styles that can perhaps dominate the sensory and volatile profiles of wines compared to more subtle contributions of climate and region (Saliba et al., 2013).

3.1.2. Regional typicality of fine Australian Chardonnay wines

To specifically examine the typicality associated with each sub-region of fine Chardonnay, discriminant analysis was conducted with the sensory and volatile attributes that significantly differed according to sub-region (Figure 2). Based on the results of the ANOVA, 17 sensory attributes (Table A.1) and 20 volatiles (Table A.5) (Table 1) were included in the discriminant analysis, which explained 74% of the variation in sub-regions along the first two factors. All significant volatiles were over threshold levels (Table 1). Regions separated to an extent with YV along F1 and MR along F2. F1 appeared to separate sub-regions by winemaking techniques and wine styles (Gambetta et al., 2014; Saliba et al., 2013), such as oak barrel fermentation and ageing related attributes (dough, oak, vanilla, oak lactone, TA), high acidity and citrus flavour on the left, and wines with tropical fruit, sweet taste, and perceivable heat and corresponding fruity volatiles, such as α-terpineol, β-damascenone, ethyl butanoate, ethyl 2-methylbutanoate, ethyl 3-methylbutanoate and linalool on the right (Figure 2). F2 contrasted the sub-regions by citrus, TA and furfural vs vegetal flavour and ethyl hexanoate. F3 did not change the sample configuration, however, F4 further explained sub-regions based on confectionery, vanilla, honey, 2-phenylethyl acetate, and *cis* oak lactone (data not shown).

In a broad sense, YV regions tended to be higher in ethyl esters, isoprenoids and acids than MR regions (Table 1), and carbonyls described MR wines, especially MRW. YVG, YVD and MRR wines clearly separated from other regions (Figure 2). YVG was described by oak, vanilla, dough, furfural, oak-lactone, citrus acidity, lack of floral and tropical aromas and flavours and corresponding ethyl and acetate esters. A high concentration of diethyl succinate (described as caramel odour, Table A.5) with lower oak lactone concentration (Table 1) suggests that YVG wines were aged in oak barrels with the presence of yeast lees decreasing the absorption of wood volatiles (Towey & Waterhouse, 1996). YVD wines were significantly different from YVG as the former grouped together based on high perceived heat, the presence of β-damascenone (described as stewed fruit aroma, Table A.5) α-terpineol, ethyl butanoate, ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, corresponding tropical fruit and lack of oak-derived sensory attributes. Such fruity style is likely to derive from ethyl esters and acetate esters produced during alcoholic fermentation at lower temperatures (Maarse, 2017). MRR wines positioned on the bottom left side of the DA plot were similar to YVG and also contained higher concentrations of vegetal flavour and ethyl hexanoate (green apple, pineapple odours, Table A.5). Wines from MRA and MRW sub-regions, which were positioned near the middle of the scores plot and possessed similar sensory and volatile attributes albeit with a tendency towards higher oak-derived attributes, might be the most complex from the studied wines. There was a strong negative correlation between diethyl succinate and isoamyl acetate (Table 1). In particular, MRW, YVR and YVG wines had high concentrations of diethyl succinate often associated with evolved and/or oak matured wines and lower acetate ester concentrations (Wang, Capone, Wilkinson, & Jeffery, 2016).

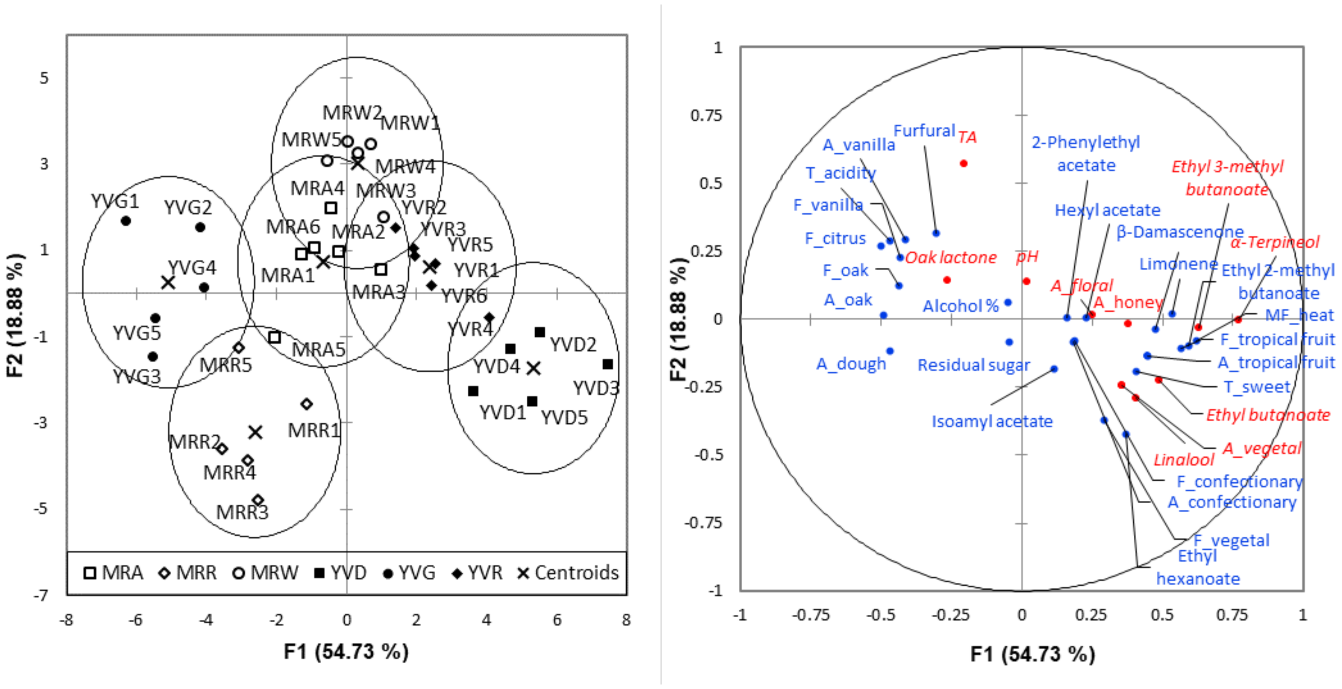

Figure 2. Projection of the first two discriminant functions from stepwise discriminant analysis of Chardonnay wine samples employing sub-region as grouping criterion. The italicised attributes were used in the model.

YVR and MRR wines were made from grapes sourced from multiple vineyards across YV and MR, and could have been expected to encompass the breadth of regional typicality. However, the significant differences between regions seemed to result from wine styles with the prominence of oak-derived characteristics (carbonyls (Table 1)) and honey in MRR (Figure 2), and the ethyl ester-driven fruity style in YVR (Table 1). As Niimi et al. (2018) observed, wide sensory variation in Chardonnay wines may not be as dependent on the starting grape material (and the influence of region) as other varieties like Cabernet Sauvignon, and numerous winemaking factors can influence the sensory properties of Chardonnay, an otherwise neutral grape variety (Gambetta et al., 2014).

In the Old World example to follow, winemaking tradition is an important factor of regional typicality as well as location. The cool climate Chablis AOC produces light-bodied Chardonnay with citrus, grassy, mineral characters and high acidity and is seldom influenced by oak flavours (Saliba et al., 2013). On the contrary, the fine Chardonnay wines of the warmer Cote d'Or, such as Mersault AOC, are fuller bodied and more suited for oak, lees and malolactic fermentation derived characters (Robinson & Harding, 2015). Both appellations specialise in the same grape variety, yet the different winemaking traditions emphasise but do not tend to override climatic differences, thus producing wines with unique characteristics (Easingwood et al., 2011). Perhaps in spite of the different climates in MR and YV, winemakers tend to follow similar practices that result in subtle differences between Chardonnay wines from those GIs. As an extension of the work of Saliba et al. (2013), our results suggest that not only Chardonnay wines in general, but also fine Australian Chardonnay, may be better described by flavour styles rather than regional and/or sub-regional styles.

Table 1. Mean concentrations (μg/L) of the significant volatile compounds detected in fine Australian Chardonnay wines from Margaret River (MR) and Yarra Valley (YV) sub-regions.

	MRR	MRA	MRW	YVR	YVD	YVG
Ethyl esters						
Diethyl succinate	4920±766 cd	4000±609 d	7367±1826 a	7355±1815 a	5744±2037 bc	7009±683 ab
Ethyl 2-methylbutanoate	12.2±3.0 bc	13.4±6.8 bc	14.0±3.2 bc	15.1±3.2 b	19.6±3.2 a	10.1±1.7 c
Ethyl 2-phenylacetate	2.3±0.4 a	2.0±0.4 ab	2.3±0.6 a	2.0±0.3 ab	2.4±0.4 a	1.5±0.3 b
Ethyl 3-methylbutanoate	23.5±5.2 bc	27.8±9.9 b	26.0±7.1 b	28.7±6.7 b	35.7±5.2 a	18.0±4.1 c
Ethyl butanoate	270±49 b	270±60 b	248±70 b	292±26 b	374±106 a	249±29 b
Ethyl decanoate	793±126 b	669±138 b	723±135 b	988±276 a	815±50 b	678±137 b
Ethyl hexanoate	1445±240 ab	1264±163 bc	1114±232 c	1530±59 a	1623±203 a	1309±189 b
Total Ethyl esters	7466	6246	9494	10212	8614	9275
Acetate esters						
Ethyl acetate	25528±3489 b	32603±3005 a	26464±2386 b	23078±3546 b	31178±5647 a	22573±3074 b
Hexyl acetate	7.3±4.2 a	8.8±2.5 a	3.7±3.5 b	4.3±3.0 b	7.9±4.0 a	3.5±0.5 b
Isoamyl acetate	2858±1242 a	2411±654 ab	1367±659 c	1873±818 bc	2409±980 ab	1645±262 bc
2-Phenylethyl acetate	4.5±1.0 ab	4.7±3.0 a	3.0±0.7 bc	3.2±1.4 bc	4.0±0.6 ab	2.4±0.4 c
Total Acetate esters	28398	35028	27838	24959	33599	24224
Alcohols						
1-Butanol	669±114 bc	865±159 a	585±107 c	700±79 b	602±102 bc	586±166 bc
Total Alcohols	669	865	585	700	602	586
Isoprenoids						
Limonene	0.1±0.0 ab	0.1±0.0 ab	0.1±0.0 ab	0.2±0.0 a	0.2±0.0 a	0.1±0.0 b
Linalool	91.8±37.8 b	84.4±29.0 b	91.2±14.4 b	99.1±7.4 b	143±18 a	97.1±37.6 b
α-Terpineol	10.5±1.8 b	11.7±2.0 ab	12.2±1.6 ab	16.4±2.1 a	15.9±2.7 a	9.1±1.5 b
β-Damascenone	2.6±0.6 b	3.2±0.6 b	2.8±0.7 b	5.0±0.7 a	4.8±1.8 a	3.3±0.7 b
Total Isoprenoids	105	99	106	121	164	110

Acids						
Acetic acid	386528±81595 b	434606±81811 ab	370555±43122 b	364664±24921 b	480002±67880 a	377341±61783 b
Total Acids	386518	434606	370555	364664	480002	377341
Carbonyls						
Furfural	12135±4897 ab	17363±8089 a	14549±8021 a	5919±5061 b	7850±2964 b	15158±8449 a
cis-Oak lactone	236±103 ab	272±63 a	251±61 a	100±43.0 d	155±50 cd	172±82 bc
Total Carbonyls	12371	17635	14800	6019	8005	15330

Values are given as mean ± SD (duplicate measurements). Values followed by different letters within a row are significantly different between sub-regions.

Subregions: Margaret River (MR), Regional (R), Wallcliffe (A), and Wilyabrup (W) and Yarra Valley (YV), Regional (R), Dixons Creek (D), and Gladysdale (G).

Finally the reliability of the sub-regional classification was tested by stepwise discriminant analysis. Using the combination of ten variables (α-terpineol, honey aroma, TA, linalool, pH, floral and vegetal aromas, oak lactone, 3-methylbutanol and ethyl butanoate), 100% of the wine set was correctly classified and complete separation of MR and YV Chardonnay wines could be achieved. With leave one out cross-validation it was possible to predict the sub-regions with 84% accuracy. This result is promising for identifying sensory and chemical markers to monitor regional authenticity of MR and YV Chardonnay wines, although chemical compositional differences based on the measured components may not pair with perceivable sensory differences, as reflected in Figure 1 and Figure 2 and discussed above.

3.2. Shiraz

3.2.1. The flavour profile of fine Australian Shiraz wines

Panellists identified a total of 41 sensory attributes that defined the sensory properties of the 31 Shiraz wines selected from (BV) and (MV), of which 17 attributes differed significantly among the wines (Table A.2). These attributes were dark fruit, dried fruit, herbaceous, olives, cooked vegetable, sweet oak, chocolate, smoky, wood, savoury, alcohol, barnyard, sweet spice aromas; astringent, tannin texture (from fine to coarse) mouthfeel; and dried fruit, and sweet oak flavours. Volatiles summarised in Table A.4 (with corresponding sensory descriptors based on Mayr et al. (2014)) were all significantly different for the set of wines except for isoamyl acetate. PCA was performed on the mean data of the significantly different sensory attributes with significant volatiles and chemical data as supplementary variables. The first three factors accounted for 65% of the variation in the data. As shown in the plot of F1 vs F2 in Figure 3, F1 (41%) contrasted the wines based on savoury, cooked vegetables, herbaceous, olives and barnyard on the left side, which has been associated with cooler climate (Heymann & Noble, 1987; Iland, 2009) but BV and MV are warm climate regions and such sensory attributes are likely to be related to reductive winemaking (Cejudo-Bastante, Pérez-Coello, & Hermosín-Gutiérrez, 2011). On the right side of F1,warmer climate Shiraz descriptors such as dried fruit, dark fruit (Iland, 2009; Johnson et al., 2013), oak derived descriptors like sweet oak, wood, sweet spice, and chocolate (San Juan, Cacho, Ferreira, & Escudero, 2012), and mouthfeel attributes such as astringency and coarser tannin texture. F2 (14%) contrasted mouthfeel attributes (astringency and tannin texture), and smoky and wood aromas in the positive direction from dark fruit flavour in the negative direction. F3 (11%) mainly separated wines on the basis of astringency, tannin texture, MCP tannin, alcohol aroma, ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, 3-methyl-1-butanol, 2-phenyl ethanol in the positive direction, and smoky and oak derived attributes in the negative direction (Figure A.2). The perceived sensory attributes corresponded with chemical composition, such as higher astringency and coarser tannin texture relating to higher MCP tannin (Mercurio & Smith, 2008), and similarly for alcohol aroma with alcohol % by volume. Volatile aroma compounds were also generally positioned closely to their corresponding sensory attributes such as guaiacol with smoky aroma (Maarse, 2017), eugenol with sweet spice (included love, cardamom, cinnamon, aniseed) aroma (Towey & Waterhouse, 1996), and cis-oak lactone with sweet oak (included vanilla, caramel, honey, butterscotch, coconut) and chocolate aromas (Mayr et al., 2014).

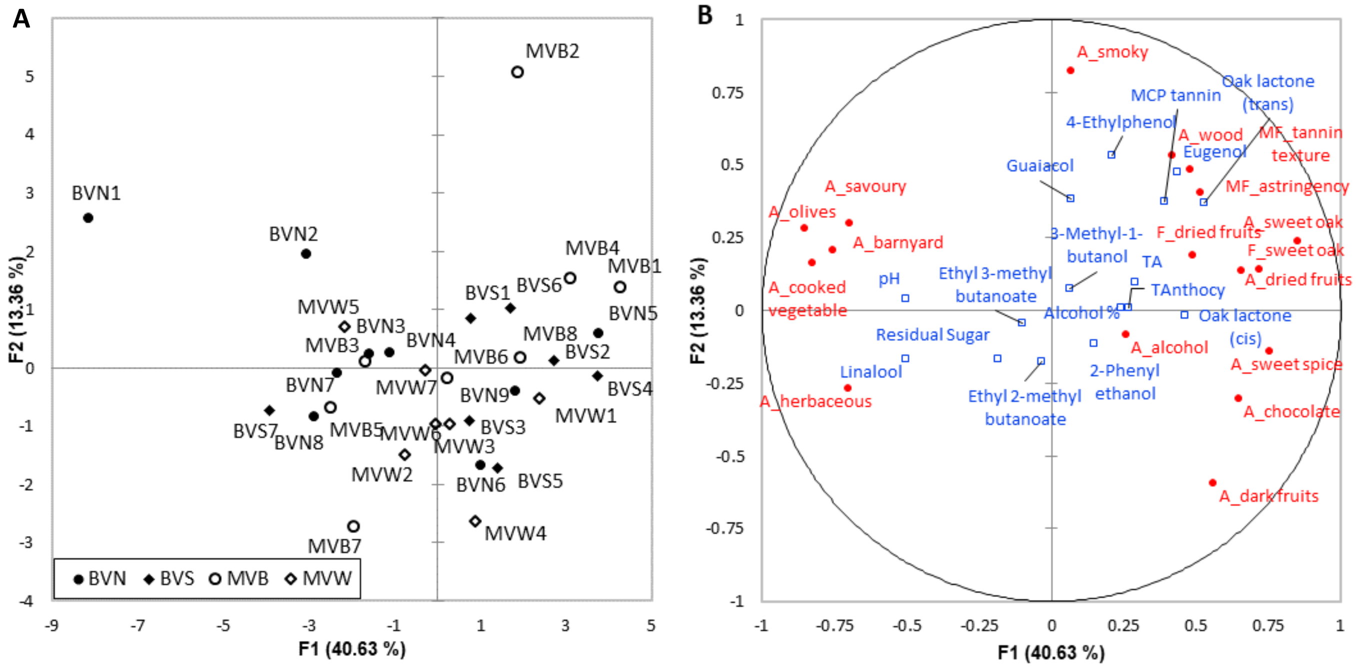

Figure 3. Score-plot (A) and loadings (B) of PCA (F1 & F2) for mean scores of significant sensory descriptive analysis data and supplementary volatile and chemical composition for fine Australian Shiraz wines.

Wine BVN1 separated from the other wines due to its higher ratings in sensory attributes that included savoury, cooked vegetable, herbaceous, olives, barnyard, and smoky to an extent, and also had a higher pH value, and lower ratings in sweet spice, chocolate and dark fruits (Figure 3). The loss of primary fruit aromas is indicative of oak ageing along with the development of non-fruit aromas such as cooked vegetable and barnyard. The presence of cooked vegetable attribute has been associated with dimethyl sulfide (DMS), which develops post-bottling in Shiraz wines possessing higher pH, such as BVN1 (pH = 3.8, (Table A.4)) (Bekker, Smith, Wilkes, & Johnson, 2016). Reductive odours also may arise from late racking or the absence of racking the wine off the lees during ageing (Jackson, 2002). The term barnyard is most commonly used to describe an off-aroma in wine originating from the presence of *Dekkera/Brettanomyces* yeasts, which produce volatile phenols like 4-ethyl phenol and 4-ethyl guaiacol (Suárez, Suárez-Lepe, Morata, & Calderón, 2007). However, 4-ethyl guaiacol concentration was not quantified in the present study and 4-ethyl phenol positively correlated with smoky aroma (r = 0.561), not with barnyard. Wines that were comparable to BVN1 on F1 but less intense were BVN2, BVN3, MVB3, and MVW5. Wine MVB2 also separated from the other wines along F2 due to its higher smoky and wood aromas corresponding with higher 4-ethyl phenol, eugenol and guaiacol concentrations derived from ageing in barrel with higher toasting levels (Maarse, 2017), and also coarser tannin texture and astringency. Eugenol is usually described as spicy/clove in its pure state, however in the complex mixture of barrel-aged wines volatile phenols do not always correlate with their expected sensory attributes (Prida & Chatonnet, 2010). Similarly, guaiacol - a thermal degradation product formed from lignin during toasting of oak barrels - showed only moderately positive correlation (r = 0.345) with its typical smoky aroma. Wines in the top right quadrant (BVN5, BVS1, BVS2, BVS6, MVB1, MVB4, and MVB8) were similar to MVB2 but less intense and characterised by sweet oak, chocolate, sweet spice, and dried fruits and oak lactones, which are usually found together in high quality wines characterised by long ageing in oak barrels (San Juan et al., 2012). In particular MVB1, BVS2, and BVS4 possessed higher astringency and coarser tannin texture with correspondingly higher MCP tannin concentrations. Such characteristics can result from winemaking techniques, such as those that increase the level of phenolic extraction (Gawel et al., 2014; Girard, Kopp, Reynolds, & Cliff, 1997) and wine experts tend to associate them with higher wine quality (Lattey, Bramley, & Francis, 2010; Niimi et al., 2018). Viticultural practices, soil type, and clone can also largely impact wine composition and sensory characters (Bindon et al., 2014; Casassa, Larsen, & Harbertson, 2016; Harbertson et al., 2008). Wines in the lower-left quadrant of the PCA shared similar characters (i.e., savoury, vegetal, and barnyard attributes) but also displayed some dark fruits and chocolate, along with lower concentrations of oak-derived aromas and flavours (sweet oak, wood, sweet spice), and lower astringency. The wines in the lower-right quadrant, consisting of BVN6, BVN9, BVS3, BVS4, BVS5, MVW1, MVW3, MVW4, possessed sensory and volatile profiles somewhat influenced by oak but with more dark fruit and without smoky character. Wines situated closest to the origin of the plot (BVS1, MVB6, MVW3, MVW6, and MVW7) had attributes that were either not prominent, were rated moderately or relatively highly in the characters loaded in both positive and negative directions of F1 and F2. F3 (Figure A.2) further separated MVB3 from all other wines due to its high alcohol aroma, and higher concentrations of ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, 2-phenylethanol and 3-methyl-1-butanol, however the sample configuration did not change dramatically.

The multivariate sensory descriptive data space shows similarities with the sensory categories described by Johnson et al. (2013), in which earthy, savoury, dusty, and meaty wines contrasted a combination of blackberry plum, pepper and spice, and a group of herbal, vanilla, cedar and berry jam wines. In particular, their study found that blackberry, plum, pepper, spice and berry jam fruits discriminated BV wines from other regions, however, jam and pepper did not significantly discriminate between BV and MV Shiraz in the larger intraregional sample set used in the present study. Heymann et al (2015) reported a comparable outcome on Cabernet Sauvignon wines. In their study, BV and MV produced wines possessed similar sensory and chemical composition in comparison to other Australian GIs. In agreement with our findings on Chardonnay wines in section 3.1.2, the PCA by sample revealed variation within the same region and sub-region, which potentially demonstrates a strong impact of wine style and winemaking (Fischer et al., 1999; Johnson et al., 2013). Although the wine samples and sub-regions were selected following experts' advice and the results of previous industry research, the Barossa Grounds Project (Robinson & Sandercock, 2014) encompassed unoaked wines and the Scarce Earth program (Bekkers,

2012) was restricted to Shiraz wines free of overt winemaking influences, such as the use of 100% new oak barrels. Based on our findings, in particular, winemaking techniques such as oak treatment and phenolic extraction seem to have larger impact on sensory and volatile composition of BV and MV Shiraz than region and sub-region and therefore assessing the true regional/intraregional character may only show through under rigorously controlled viticultural and winemaking practices or subtle application of new oak barrels (Johnson et al., 2013). Furthermore, extended maturation after bottling could further diminish oak derived aromas and astringency derived from winemaking (Gambuti et al., 2017), allowing wineries and wine regions to promote GI-focused varietal wines.

3.2.2. Regional typicality of fine Australian Shiraz wines

As with the Chardonnay wines, the typicality associated with each sub-region of fine Shiraz wines was assessed using discriminant analysis of the significantly different attributes according to sub-region. The ANOVA by sub-region significantly differentiated 11 sensory (Table A.2) and 11 volatile attributes (Table 2), which explained 88% variation in the data with the first two factors of discriminant analysis (Figure 4). MV wines tend to separate along F1 and BV wines along F2. F1 (72%) contrasted the wines on the basis of floral character, hexyl acetate, 2-phenylethyl acetate, ethyl butanoate, and ethyl octanoate in the positive direction, α-terpineol, and anthocyanins in the negative direction. F2 (16%) separated the samples based on cooked vegetable, earthy, savoury, and barnyard attributes, 1-butanol, guaiacol, β-damascenone, and pH in the positive direction, and floral, confectionery, and 2-phenylethanol in the negative direction. BVN wines had a combination of savoury, cooked vegetable and barnyard aromas, moderate astringency and tannin texture, and were higher in 1-butanol, β-damascenone, and guaicol. The higher concentration of guaiacol usually indicates ageing in toasted oak barrels (Spillman, Sefton, & Gawel, 2004), however in the presence of 1-butanol (associated with balsamic aroma (Mayr et al., 2014)), it might have enhanced the tasting panel's aroma associations (Polášková, Herszage, & Ebeler, 2008) with savoury, cooked vegetable, barnyard and earthy odours.

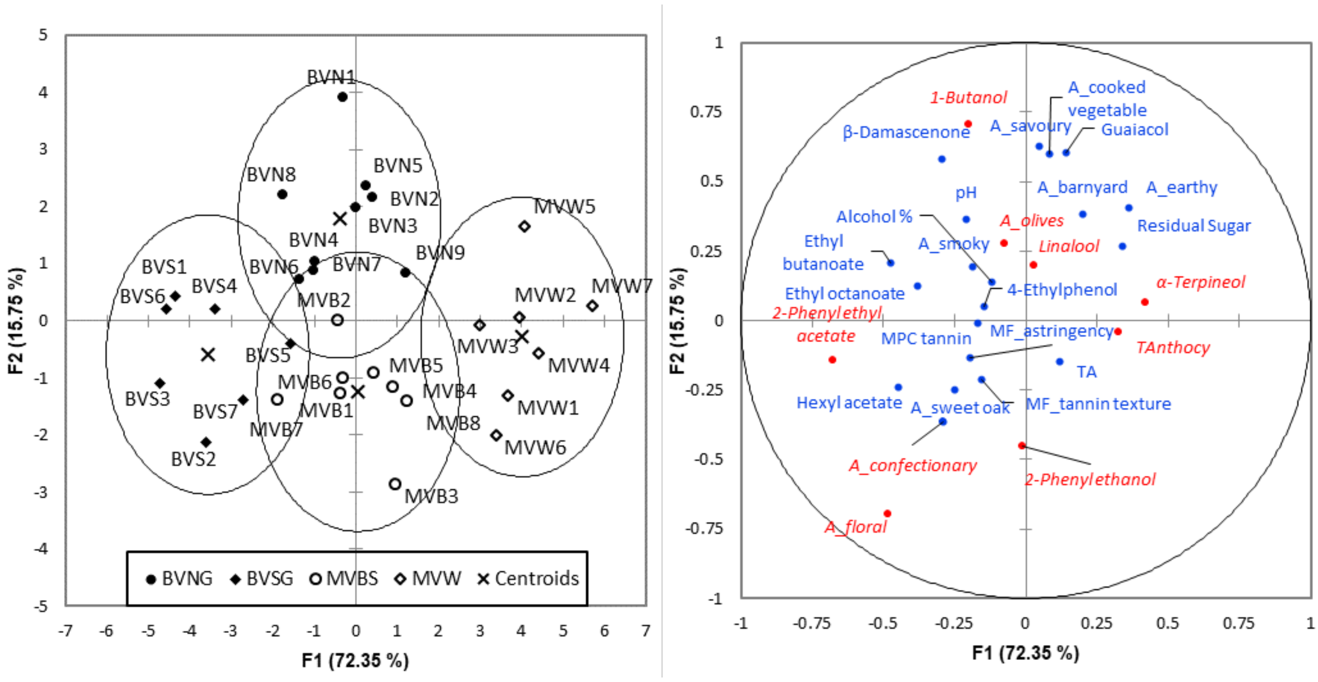

Figure 4. Stepwise discriminant analysis employing sub-region as grouping criterion. Projection of Chardonnay wine samples on the discriminant space selecting the first two discriminant functions as axes. The italicised attributes were used in the model.

Contrasting with BVN, BVS wines were described by sweet oak, floral, and confectionery aromas and hexyl acetate, 2-phenylethanol, and ethyl octanoate (Figure 4), as well as moderate astringency and moderately coarse tannin texture. These findings partly align with the Barossa Grounds study that found BVN wines to be more savoury with astringent, coarse tannins and BVS were more floral with lower astringency and smoother tannins (Robinson & Sandercock, 2014). However, BVN and BVS wines in this study possessed similar astringency qualities, which might have resulted from winemaking techniques pursuing moderate phenolic extraction wine style (Gawel et al., 2014; Girard et al., 1997). MVB wines were characterised by higher astringency, coarser tannin texture (with corresponding MCP tannin), sweet oak, confectionary, and floral aromas, and 4-ethylphenol. MVW wines were moderate in savoury, floral and oak-related descriptors and had lower astringency with finer tannins. MVW wines had the lowest ethyl ester concentrations, which is likely to be affected by lower fermentation temperature or the yeast strain used for alcoholic fermentation (Swiegers, Bartowsky, Henschke, & Pretorius, 2005). Although the wines of the MVB and the MVW districts were still well separated from BVN and BVS (Figure 4), a complete differentiation of MV and BV was not possible.

Table 2. Mean concentrations (µg/L) of the significant volatile compounds detected in fine Australian Shiraz wines across sub-regions.

Compound	BVN	BVS	MVB	MVW
Ethyl esters				
Ethyl butanoate	267±58 a	281±74 a	227±40 b	213±24 b
Ethyl octanoate	671±161 a	688±179 a	607±181 ab	511±111 b
Total Ethyl esters	938	969	834	724
Acetate esters				
Hexyl acetate	12.6±2.8 b	16.6±3.0 a	14.1±1.8 b	13.5±1.6 b
2-Phenylethyl acetate	4.5±1.4 b	6.3±1.2 a	4.5±0.5 b	3.6±0.8 b
Total Acetate esters	17.1	22.9	18.6	17.1
Alcohols				
1-Butanol	1592±301 a	1244±258 b	1233±145 b	1136±120 b
2-Phenylethanol	32126±13643 b	40060±8557 ab	43761±14052 a	38688±11076 ab
Total Alcohols	33718	41304	44994	39824
Isoprenoids				
Linalool	6.2±1.5 a	6.6±4.4 a	4.3±1.4 b	6.8±1.8 a
α-Terpineol	8.9±2.8 ab	7.5±2.7 b	8.7±1.7 ab	10.3±1.6 a
β-Damascenone	1.9±0.6 a	1.6±0.4 a	1.0±0.4 b	1.2±0.3 b
Total Isoprenoids	17.0	15.7	14.0	18.3
Carbonyls				
Guaiacol	27.4±11.2 a	14.9±3.1 b	17.6±6.2 b	18.8±4.4 b
4-Ethylphenol	50.6±42.7 c	86.3±127.7 b	106±151 a	47.0±92.3 c
Total Carbonyls	78.0	101	124	65.8

For each means±SD (duplicate measurements for each sample). Barossa Valley Northern Grounds (BVN), Barossa Valley Southern Grounds (BVS), McLaren Vale Blewitt Springs (MVB) and McLaren Vale Willunga (MVW).

The reliability of the sub-regional classification for the Shiraz wines was tested by means of stepwise discriminant analysis. Eight variables (α-terpineol, linalool, 2-phenylethyl acetate, 2-phenylethanol, 1-butanol, total anthocyanin, and floral and olive aromas) correctly classified 97% of the wine set. In fact, sub-regional classifications were 100% correct except for BVS (85.7%), whereby BVS5 was classified as MVB. With leave one out cross-validation it was possible to predict the sub-regions with 84% accuracy. Similarly to our findings on Chardonnay in section 3.1.2, and of Heymann et al. (2015) on Australian Cabernet Sauvignon and Argentine Malbec, sensory markers and predominantly volatile profiles allowed the building of regional authenticity models, which is promising, however, consumers may not perceive sub-regional differences based on sensory attributes. Perceivable sensory differences between sub-regions may be subtle due to climatic similarities of BV and MV on one hand, and similar winemaking techniques pursuing the style of South Australian Shiraz on the other. Therefore, the area of regional typicality of fine Australian Shiraz clearly warrants further study.

4. Conclusions

Establishing a fine wine image according to regional typicality has been of interest for New World wine countries like Australia to extend beyond single variety and brand associations. Previous research mainly involved wine without winemaking influence (e.g., Barossa Grounds) or with minimal winemaking influence (e.g., Scarce Earth), and this study encompassed the largest sample set to investigate intraregional typicality of commercially available fine Australian wines by using a blend of sensory and chemical analyses. Fine Chardonnay wines could be grouped by region to some extent as the PCA separated the samples on the basis of the cooler climate YV possessing more stock, and vegetal sensory attributes in contrast to the fruit and oak-driven MR wines. The sensory analysis by sub-region partially discriminated YVG and MRA wines on the basis of citrus, vanilla and oak descriptors. Data analysis showed that a differentiation could be made between YVG, YVD, and YVR wines, although not completely between MRA, MRW, and MRR wines. Even though regional wines (i.e., blends from within the GI) MRR and YVR possessed significantly different sensory and volatile profiles, the Chardonnay wines from MR and YV in this study generally seemed to be categorised by wine styles such as “oaky”, “fruity/crisp” rather than by region. Shiraz wines showed some similar properties across regions as the PCA tended to separate the samples on the basis of BV possessing more savoury, cooked vegetables sensory attributes in contrast to the fruit and oak dominated MV wines. The DA revealed subtle differences by sub-region, and contrasted BVN from BVS in partial agreement with the Barossa Grounds study, furthermore MVB from MVW as per the Scarce Earth study. In our hypothesis, sub-regions within regions were expected to produce more similar wines, however Shiraz wines had similarities across region as well, which might derive from similarities in climate and winemaking tradition of the two South Australian wine regions.

The variation observed among wines from the same region and sub-region demonstrated the sensory and chemical variability within the same GI. Based on the outcomes of this study, commercial Australian Chardonnay and Shiraz wines might best be described by wine styles as wineries seemed to produce similar wines across geographic origins. There are many factors encompassing regional/sub-regional typicality, however in this study, it is implied that winemaking in particular seemed to influence sensory and chemical composition of the wines. Perhaps, commercial wines made with less oak influence would convey the outcome of industry research projects (e.g., Scarce Earth, Barossa Grounds) and thus regional typicality, although consumers perceive the presence of oak as high quality and thus may be risky for wineries. On the other hand, sensory differences between BV and MV Shiraz wines may be less pronounced regardless of winemaking influence due to their similar climate. Future research should include wine regions that differ more in terms of climate and proximity to each other, and use a combination of unoaked experimental and commercial wine samples to understand the influence of winemaking on regional typicality. Being limited in scope, this study cannot be representative of all variation emerging across wine regions, vintages, and viticultural and winemaking practices but it has created a preliminary sensory and chemical map for future research.

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SUPPORTING INFORMATION FOR

Matter of place: sensory and chemical characterisation of fine Australian Chardonnay and Shiraz wines of provenance

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Tables

Figures

Table A1. List of sensory attributes developed by the panel and scored in the descriptive analysis of fine Australian Chardonnay wines with definitions and reference standards.

Attribute	Definition (reference standard)	Significance by product	Significance by sub-region
Aroma	Aroma of		
Citrus	Lemon, lime, orange, grapefruit (2 cm peel of fresh lemon, orange, and grapefruit)	ns	ns
Beer	Stale beer (West End Draught (lager), Lion Beer Australia) left open overnight)	< 0.0001	ns
Confectionery	Candy, lolly, fruit drops (fruit drops and gummy bears (The Natural Confectionery Company, Melbourne, Australia) soaked in 20 mL white wine*)	< 0.0001	< 0.0001
Dried apricot	Dried apricot (half fresh apricot cut into 0.5 cm cubes and soaked in 20 mL white wine*)	ns	ns
Floral	Rose, violet, jasmine (2 drops of rose essence in 20 mL white wine*)	< 0.0001	0.006
Green apple	Freshly cut green apple (fresh green apple cut into 0.5 cm cubes and soaked in 20 mL white wine*)	ns	ns
Honey	Honey (0.5 tsp honey (Capilano, Richlands, QLD, Australia) in 20 mL white wine*)	ns	ns
Oak	Toasted bread, wood, pencil shaving, nuts (2 cm toasted bread piece (Woolworths Home brand, Bella Vista, NSW, Australia), halved roasted hazelnut, pencil shaving)	< 0.0001	< 0.0001
Pineapple	Fresh pineapple (quarter ring of canned pineapple in 20 mL white wine* and 1 tsp pineapple juice)	0.001	0.025
Solvent	Penetrating, pungent smell (5 mL 95% v/v ethanol)	ns	ns
Stock	Vegetable stock (0.5 tsp vegetable stock powder (Massel Australia) in 20 mL white wine*)	< 0.0001	ns
Stone fruit	Peach, nectarine, apricot (small wedges of fresh peach, nectarine, apricot in 0.5 cm cubes and 20 mL white wine*)	0.046	ns
Toffee	Toffee, butterscotch, milk candy (0.25 of butterscotch candy (Werther's Original, August Storck KG, Berlin, Germany) in 20 mL white wine*)	< 0.0001	ns
Tropical fruit	Passionfruit, rock melon, lychee, mango (equal parts of canned lychee, passion fruit, mango and rock melon (John West, Mentone, VIC, Australia) in 20 mL white wine*)	< 0.0001	0.008
Vanilla	Vanilla bean (2 drops of vanilla essence in 20 mL white wine*)	< 0.0001	< 0.0001
Vegetal	Capsicum, cut grass, lettuce (thin slice of fresh capsicum and lettuce in 20 mL white wine*)	0.001	0.006
Dough	Fresh yeast, bread dough (0.5 tsp dry yeast (Lowan Whole Foods, Glendenning, NSW, Australia) in 20 mL white wine*)	ns	0.006

Taste	The taste associated with …		
Acidity	Sour taste (tartaric acid (McKenzie's, Altona, VIC, Australia) in water: low =0.5 g/L, medium = 1.5 g/L, high = 3 g/L)	< 0.0001	< 0.0001
Bitter	Bitter taste (quinine sulfate (Sigma Aldrich, St Louis, MO, USA) in water 5 mg/L, 10 mg/L, 20 mg/L)	ns	ns
Sweet	Sweet taste (sucrose (Woolworths Home brand, Bella Vista, NSW, Australia) in water 2 g/L, 4 g/L, 10 g/L)	ns	0.001
Mouthfeel			
Astringency	Drying/puckering sensation (grapeseed extract (Tarac Technologies, Nuriootpa, SA, Australia) in white wine*: low= 0 g/L, medium = 0.15 g/L, high = 0.3 g/L)	ns	ns
Body/Weight	Perceived viscosity from thin to viscous (water, skimmed milk, full fat milk)	ns	ns
Heat	Warming sensation in the mouth (ethanol (Tarac Technologies) in white wine*: low = 12% ABV, high = 14% ABV)	ns	0.001
Flavour	Flavour of…		
Beer	Stale beer (see Aroma)	0.011	ns
Citrus	Lemon, lime, orange, grapefruit	< 0.0001	< 0.0001
Confectionery	Candy, lolly, fruit drops (see Aroma)	< 0.0001	0.001
Dried apricot	Dried apricot (see Aroma)	ns	ns
Floral	Rose, violet, jasmine (see Aroma)	0.0002	ns
Green apple	Freshly cut green apple (see Aroma)	0.0002	ns
Honey	Honey (see Aroma)	ns	ns
Oak	Toasted bread, wood, pencil shaving, nuts (see Aroma)	< 0.0001	< 0.0001
Pineapple	Fresh pineapple (see Aroma)	ns	ns
Stonefruit	Peach, nectarine, apricot (see Aroma)	ns	ns
Toffee	Toffee, butterscotch, milk candy (see Aroma)	ns	ns
Tropical fruit	Passionfruit, rock melon, lychee, mango (see Aroma)	< 0.0001	< 0.0001
Vanilla	Vanilla bean (see Aroma)	< 0.0001	< 0.0001
Vegetal	Capsicum, cut grass, lettuce (see Aroma)	0.003	0.001
Dough	Fresh yeast, bread dough (see Aroma)	ns	ns
Flavour length	The time that flavours persist in the mouth after expectoration	0.0004	ns

* white wine: Berry Estate Traditional Dry White NV

Table A2. List of sensory attributes scored in the descriptive analysis of fine Australian Shiraz wines with definitions and reference standards.

Attribute	Definition (reference standard)	Significance by product	Significance by sub-region
Aroma	Aroma of		
Alcohol	Ethanol (10 mL ethanol (Tarac Technologies))	0.005	ns

S-4

Barnyard	Band aid, medicinal, barnyard (2 cm piece of band aid (Leukoplast GMBH, Hamburg, Germany))	< 0.0001	0.036
Chocolate	Milk/dark chocolate (dark and milk chocolate shavings (Lindt, Kilchberg, Switzerland))	0.0001	ns
Confectionery	Candy, lolly, fruit drops (one of each raspberry and fruit drops (Allen's, Nestle Australia) in 20 mL red wine*)	ns	0.049
Cooked vegetable	Cooked cabbage, root vegetables (2 slices of Cooked cabbage and carrot in 20 mL red wine*)	< 0.0001	< 0.0001
Dark fruits	Plum, dark cherry, blueberry, black berry, black currant (one cut up fresh black berry, blueberry and plum in 20 mL red wine*)	0.031	ns
Dried fruits	Prune, fig, raisin (one cut up dried prune, fig and raisin sliced in 20 mL red wine*)	< 0.0001	ns
Earthy	Dry and wet soil (1 tsp of soil and one fresh mushroom sliced in 10 mL red wine*)	ns	0.016
Floral	Rose, violet, jasmine (2 drops of rose essence in 20 mL red wine*)	ns	0.004
Herbaceous	Capsicum, cut grass, eucalyptus (3 of 1 × 1 cm fresh capsicum slice and one crushed mint leaves in 20 mL red wine*)	0.001	ns
Herbal	Tobacco, oregano, rosemary (pinch each of dry tobacco, oregano and rosemary in 20 mL red wine*)	ns	ns
Jammy	Fruit jam, stewed fruits (1 tsp plum jam (Cottee's, Melbourne, Australia) in 20 mL red wine*)	ns	ns
Olives	Black olives, tapenade (2 slices of canned black olive (Woolworths Home brand, Bella Vista, NSW, Australia))	0.001	0.0003
Pepper	Ground white and black pepper (pinch of each ground black and white pepper (Woolworths Home brand, Bella Vista, NSW, Australia) in 20 mL red wine*)	ns	ns
Red fruits	Strawberry, raspberry, red cherry (crushed fresh strawberry and raspberry in 20 mL red wine*)	ns	ns
Savoury	Meat, leather (0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather)	< 0.0001	< 0.0001
Smoky	Bushfire, charred wood, toasted bread (White toast bread (Woolworths Home brand, Bella Vista, NSW, Australia), heavily toasted and crumbled)	0.018	0.047
Sweet oak	Vanilla, caramel, honey, butterscotch, coconut (2 drops of vanilla essence, 0.25 of butterscotch candy (Werther's Original, August Storck KG, Berlin, Germany) in 20 mL red wine*)	< 0.0001	0.002
Sweet spice	Clove, cardamom, cinnamon, aniseed (One whole clove crushed and soaked in 20 mL red wine*)	0.04	ns

S-5

Wood	Pencil shaving, raw wood (pencil shaving and one pinch of heavy toast oak chips)	0.005	ns
Taste	Taste associated with…		
Acidity	Sour taste (tartaric acid (McKenzie's, Altona, VIC, Australia) in water: low =0.5 g/L, medium = 1.5 g/L, high = 3 g/L)	ns	ns
Bitter	Bitter taste (quinine sulfate (Sigma Aldrich, St Louis, MO, USA) in water 5 mg/L, 10 mg/L, 20 mg/L)	ns	ns
Sweet	Sweet taste (sucrose (Woolworths Home brand, Bella Vista, NSW, Australia) in water 2 g/L, 4 g/L, 10 g/L)	ns	ns
Mouthfeel			
Astringency	Drying/puckering sensation (grapeseed extract (Tarac Technologies, Nuriootpa, SA, Australia) in red wine*: low= 0 g/L, medium = 0.15 g/L, high = 0.3 g/L)	< 0.0001	0.001
Body/Weight	Perceived viscosity from thin to viscous (skimmed milk, full fat milk, 50/50 mixture of heavy cream and full fat milk (Woolworths Home brand, Bella Vista, NSW, Australia))	ns	ns
Heat	Warming sensation in the mouth (ethanol (Tarac Technologies) in water 15% ABV)	ns	ns
Tannin texture	Coarseness, chewiness of astringent sensation associated with tannins (from fine to coarse)	< 0.0001	0.001
Flavour	Flavour of		
Chocolate	Milk/dark chocolate (as above)	ns	ns
Confectionery	Candy, lolly, fruit drops (as above)	ns	ns
Dark fruits	Plum, dark cherry, blueberry, black berry, black currant (as above)	ns	ns
Dried fruits	Prune, fig, raisin (as above)	0.004	ns
Herbaceous	Capsicum, cut grass, eucalyptus (as above)	ns	ns
Herbal	Tobacco, oregano, rosemary (as above)	ns	ns
Jammy	Fruit jam, stewed fruits (as above)	ns	ns
Pepper	Ground white and black pepper (as above)	ns	ns
Red fruits	Strawberry, raspberry, red cherry (as above)	ns	ns
Savoury	Meat, leather (as above)	ns	ns
Smoky	Bushfire, charred wood, toasted bread (as above)	ns	ns
Sweet oak	Vanilla, caramel, honey, butterscotch, coconut (as above)	0.012	ns
Sweet spice	Clove, cardamom, cinnamon, aniseed (as above)	ns	ns
Flavour length	The time that flavours persist in the mouth after expectoration	ns	ns

* red wine: Berry Estate Traditional Dry Red NV

S-6

Table A3. Sample information and basic chemical composition of fine Australian Chardonnay wines from Yarra Valley (YV) and Margaret River (MR) sub-regions.

Sample	pH	TA (g/L)	Alcohol % (v/v)	Residual Sugar (g/L)
MRR1	3.2	6.7	12.9	1.9
MRR2	3.2±0.1	6.4	12.8	1.5
MRR3	3.4	5.3±0.1	13.3	2.2±0.1
MRR4	3.1±0.1	6.5	13.0	3.3
MRR5	3.3	6.2	12.7	1.3
MRA1	3.2±0.1	7.4±0.1	13.5	1.9
MRA2	3.3±0.1	6.6±0.1	13.0	2.6
MRA3	3.1	7.5±0.1	12.9	2.5
MRA4	3.1	7.5	12.9	3.0
MRA5	3.2±0.1	7.3±0.1	13.4	1.4
MRA6	3.3	6.9±0.1	12.9	1.0
MRW1	3.2	8.7±0.5	13.6	2.2
MRW2	3.2	8.1±0.1	13.4	1.4±0.1
MRW3	3.3±0.1	7.4±0.1	13.2	1.4±0.1
MRW4	3.5±0.1	6.2±0.1	13.3	1.8
MRW5	3.2	7.4	12.2	1.4
YVR1	3.2	6.2±0.1	13.7	2.6
YVR2	3.3	6.3	13.1	1.3
YVR3	3.3±0.1	6.2±0.2	13.6	2.1
YVR4	3.2±0.1	6.5±0.1	13.4	1.9
YVR5	3.3	6.5±0.2	13.6	1.7
YVR6	3.2	5.9±0.1	13.5	1.0±0.1
YVD1	3.2	6.0±0.2	12.6	1.5
YVD2	3.3±0.1	6.5±0.1	14.1	0.8
YVD3	3.2±0.1	6.2±0.1	13.5	1.9
YVD4	3.2	7.9	14.0	1.5
YVD5	3.2±0.1	6.3±0.1	14.6	1.3
YVG1	3.2±0.1	8.1	12.8	1.5
YVG2	3.3±0.1	7.3	13.4	1.3
YVG3	3.2	6.8	13.3	1.5
YVG4	3.2	6.5	13.6	1.5
YVG5	3.2±0.1	7.1±0.1	13.1	1.6

All data are expressed as the mean ± standard deviation (duplicate measurements). Where SD is not shown, the value was 0. Sub-regions: Margaret River (MR) with Regional (R), Wallcliffe (A), and Wilyabrup (W); Yarra Valley (YV) with Regional (R), Dixons Creek (D), and Gladysdale (G).

Table A4. Sample information and basic chemical composition of fine Australian Shiraz wines from Barossa Valley (BV) and McLaren Vale (MV) sub-regions.

Sample	pH	TA (g/L)	Alcohol % (v/v)	Residual Sugar (g/L)	Total anthocyanins (mg/L)	MCP tannin (mg/L)
BVN1	3.8	6.1	14.3	0.8	245±9.5	2192±284
BVN2	3.6	6.3±0.1	15.0	0.7	246±3.8	2350±93
BVN3	3.6	6.3	14.9	1.2±0.1	268±7.7	3118±152
BVN4	3.4	7.7±0.1	13.4	0.9	228±1.1	1637±211
BVN5	3.3	6.8	15.5	0.8	245±7.5	2754±379
BVN6	3.5	6.8	15.0	1.0	325±7.7	3055±316
BVN7	3.6	5.5	13.8	0.9±0.1	221±6.3	1833±164
BVN8	3.6	6.5	14.9	0.6	265±1.9	2498±169
BVN9	3.5±0.1	6.4	14.7	0.9	235±5.3	2092±172
BVS1	3.6	6.1	14.5	0.4	224±2.5	1980±226
BVS2	3.6	5.9	14.3	0.6±0.1	262±9.6	3594±63
BVS3	3.5	6.5	14.7	0.7	230±18.7	1824±183
BVS4	3.5	6.7	15.0	0.8	326±4.2	2875±60
BVS5	3.5	6.8	14.9	0.6	247±7.5	2129±314
BVS6	3.7	6.0	14.7	0.5±0.1	217±6.3	1948±137
BVS7	3.5	6.8	14.6	0.7	211±5.7	1442±7
MVB1	3.3±0.1	6.9	14.5	0.5	239±4	3370±374
MVB2	3.4±0.1	7.1	14.4	0.6±0.1	303±3.1	3418±683
MVB3	3.3±0.1	7.2	14.6	0.7	269±4.1	2793±247
MVB4	3.5	6.6±0.1	15.7	0.9	256±8.7	2088±308
MVB5	3.6	5.4	14.4	1.1±0.1	283±9.1	2001±48
MVB6	3.5±0.1	6.8±0.1	14.7	0.5	261±5	2378±160
MVB7	3.5±0.1	6.1±0.1	14.8	0.7±0.1	197±1.9	1116±229
MVB8	3.4	7.0	14.1	0.8	238±6.6	2332±341
MVW1	3.5±0.1	6.4	14.3	0.5	318±60.2	1623±205
MVW2	3.5±0.1	6.3	14.6	0.8	258±10.3	1874±170
MVW3	3.4	6.5	14.4	1.1	240±1.3	1804±228
MVW4	3.4±0.1	6.8	14.4	1.2±0.1	308±14.8	2272±263
MVW5	3.5±0.1	6.5	15.1	1.7	255±14.9	1172±388
MVW6	3.5	6.7	14.3	0.7	265±4.4	2091±19
MVW7	3.6	6.4±0.1	14.0	0.4	277±8.3	2272±134

All data are expressed as the mean ± standard deviation (duplicate measurements). Where SD is not shown the value was 0. Subregions: Barossa Valley Northern Grounds (BVN), Barossa Valley Southern Grounds (BVS), McLaren Vale Blewitt Springs (MVB) and McLaren Vale Willunga (MVW).

Table A5. Concentrations (µg/L of volatile compounds determined in 32 fine Australian Chardonnay wines and corresponding aroma descriptors based on Gambetta et al. (2014).

Compound	Mean	SD	Significance by product	Significance by sub-region	Aroma descriptor(s)
Ethyl esters					

Ethyl butanoate	283	75.3	< 0.0001	0.002	fruity, strawberry
Ethyl 2-methylbutanoate	14.1	4.7	< 0.0001	0.001	strawberry, berry
Ethyl hexanoate	1378	257	< 0.0001	< 0.0001	green apple, pineapple, strawberry
Ethyl octanoate	3617	646	ns	ns	fruity, sweet
Ethyl 2-furoate	15.5	3.5	0.05	ns	balsamic
Ethyl decanoate	783	198	< 0.0001	0.002	oily, fruity, floral
Diethyl succinate	6147	1940	< 0.0001	< 0.0001	caramel
Ethyl 2-phenylacetate	2.1	0.5	0.05	0.017	floral, honey
Ethyl 3-methylbutanoate	26.7	8.4	< 0.0001	0.0003	red fruit
Acetate esters					
Ethyl acetate	26771	5208	0.001	< 0.0001	solvent
Isoamyl acetate	2065	968	< 0.0001	0.005	banana
Hexyl acetate	5.8	3.9	< 0.0001	0.001	apple
2-Phenylethyl acetate	3.6	1.6	< 0.0001	0.024	rose, tropical
Alcohols					
2-Methyl-1-propanol	43084	13654	< 0.0001	ns	green, fresh, fusel
3-Methyl-1-butanol	123642	17310	< 0.0001	ns	alcohol, harsh
1-Hexanol	1673	389	< 0.0001	ns	fruity
1-Butanol	667	157	< 0.0001	0.0001	banana
2-Ethyl-1-hexanol	28.6	10.3	ns	ns	citrus, floral
1-Octanol	14.2	7.2	< 0.0001	ns	metallic, natural gas
2-Phenylethanol	23163	8276	< 0.0001	ns	rose
Benzyl alcohol	153	35.9	< 0.0001	ns	fruity, floral
Isoprenoids					
Limonene	0.1	0.02	ns	0.041	citrus
Linalool	101	32	ns	0.016	fruit, citrus
α-Terpineol	12.7	3.3	ns	0.016	floral, musty, orange
Citronellol	1.9	2.6	ns	ns	floral
β-Damascenone	3.6	1.3	0.01	< 0.0001	stewed fruit, apple, peach
Acids					
Acetic acid	400114	74566	0.03	0.02	vinegar
Hexanoic acid	3334	586	< 0.0001	ns	rancid, pungent, green
Decanoic acid	2172	267	< 0.0001	ns	vinegar, animal, fatty
Carbonyls					
Furfural	12042	7763	< 0.0001	0.003	almond
Benzaldehyde	2.3	0.5	0.05	ns	sharp, almond
Methional	580	207	ns	ns	cooked vegetables
cis-Oak lactone	196	92.5	< 0.0001	< 0.0001	coconut

Table A6. Concentrations (µg/L) of volatile compounds determined in 31 fine Australian Shiraz wines and corresponding aroma descriptors based on Mayr et al. (2014).

Compound	Mean	SD	Significance by product	Significance by sub-region	Aroma descriptor(s)
Ethyl esters					
Ethyl butanoate	247	56.2	< 0.0001	0.006	fruity, pineapple

Ethyl 2-methylbutanoate	38	13	< 0.0001	ns	candy, apple
Ethyl 3-methylbutanoate	57.3	16.2	< 0.0001	ns	red berry, violet
Ethyl hexanoate	367	80.7	< 0.0001	ns	fruity, minty
Ethyl octanoate	622	165	< 0.0001	0.038	melon, almond, wood
Acetate esters					
Ethyl acetate	116740	22003	< 0.0001	ns	fruity
Isoamyl acetate	2090	275	ns	ns	fruity, banana
Hexyl acetate	14.1	2.8	< 0.0001	0.001	red berry, solvent
2-Phenylethyl acetate	4.7	1.4	0.001	ns	jammy, plum, floral
Alcohols					
3-Methyl-1-butanol	163795	27344	< 0.0001	ns	sweaty
1-Hexanol	2198	530	< 0.0001	ns	waxy, earthy
1-Butanol	1318	287	< 0.0001	< 0.0001	balsamic
2-Methyl-1-propanol	69359	22747	< 0.0001	ns	metallic, chemical, fruity
2-Phenyl ethanol	38402	12240	< 0.0001	0.046	floral, rose
Isoprenoids					
Linalool	5.9	2.7	< 0.0001	0.041	floral, lemon
α-Terpineol	8.9	2.3	< 0.0001	0.042	spicy
β-Damascenone	1.5	0.5	< 0.0001	< 0.0001	rose, candy, citrus
Acids					
Acetic acid	393229	85781	0.047	ns	vinegar
Hexanoic acid	683	206	< 0.0001	ns	leafy, wood, varnish
Decanoic acid	261	64.8	0.0004	ns	earthy, caramel
Carbonyls					
Furfural	194	55.8	< 0.0001	ns	earthy, wood
Methionol	1683	497	< 0.0001	ns	savoury, potato
Guaiacol	20.1	8.7	0.0002	0.001	smoky, medicinal
Eugenol	23.4	10.7	< 0.0001	ns	spicy
4-Ethylphenol	72.2	105	< 0.0001	< 0.0001	smoky, savoury
Oak-related					
cis-Oak lactone	666	438	< 0.0001	ns	smoky, wood
trans-Oak lactone	75.8	43.5	< 0.0001	ns	coconut, wood

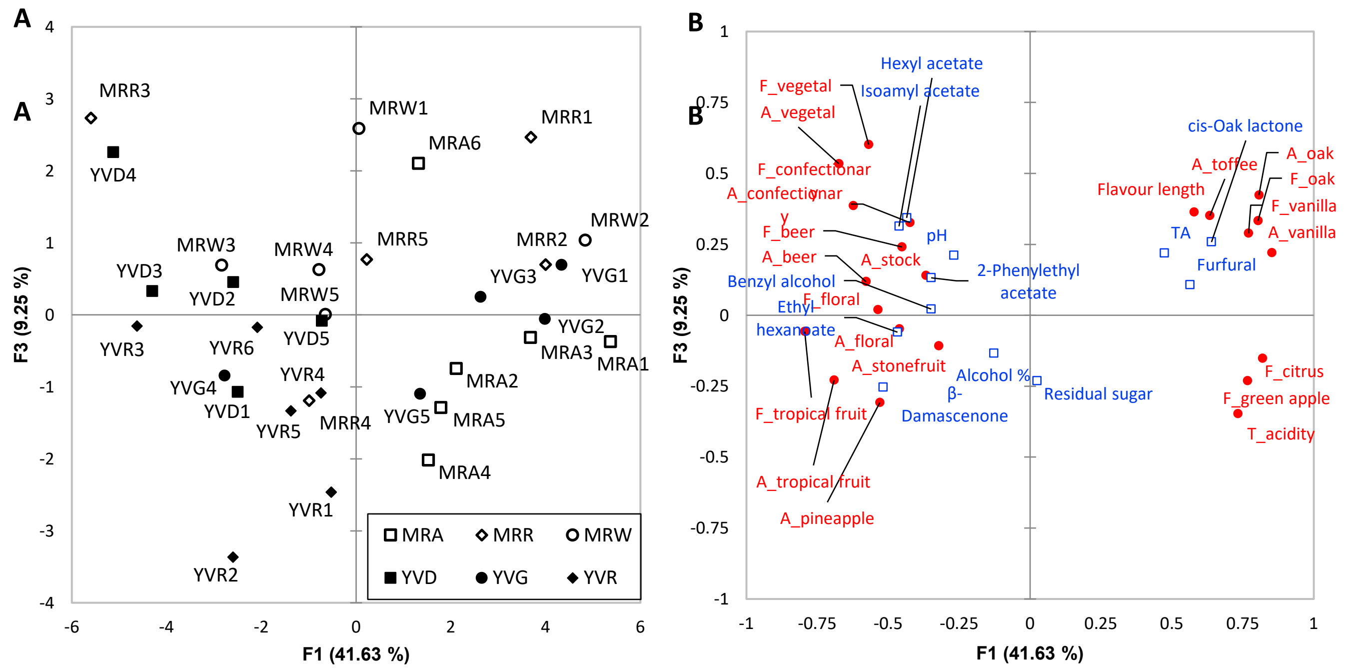

Figure A 1. Score-plot (A) and loadings (B) of PCA (F1 & F3) for mean scores of significant sensory descriptive analysis data and supplementary volatile and chemical composition for fine Australian Chardonnay wines.

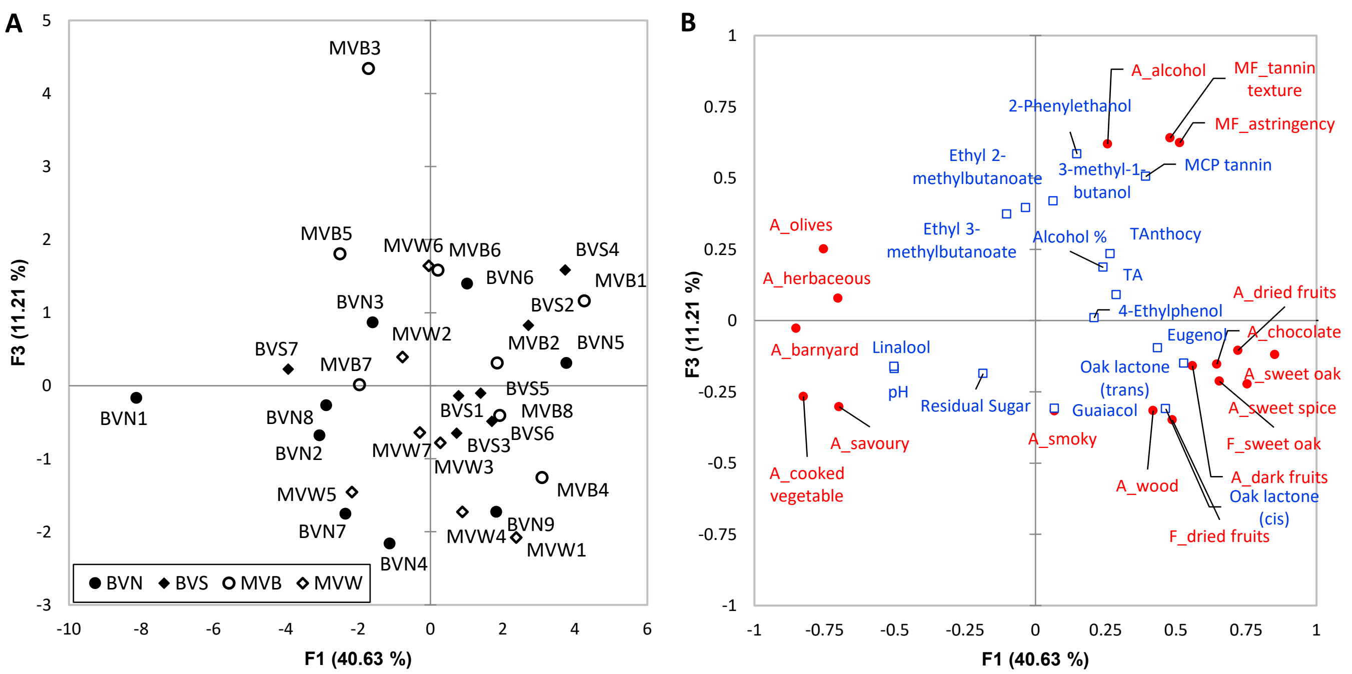

Figure A 2. Score-plot (A) and loadings (B) of PCA (F1 & F3) for mean scores of significant sensory descriptive analysis data and supplementary volatile and chemical composition for fine Australian Shiraz wines.

Chapter 4

Inter(t)wined: what makes food and wine pairings appropriate?

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Principal Author

Name of Principal Author (Candidate)	Marcell Kustos		
Contribution to the Paper	Designed experiments, performed all sample preparation and wine non-volatile analyses, trained panels for sensory descriptive analysis of food (n = 7), wine (n = 8), and pairing (n = 16) samples. Recruited consumers (n = 108) and completed consumer trials, analysed and interpreted the data, drafted and constructed the manuscript.		
Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	7/5/19

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Hildegarde Heymann		
Contribution to the Paper	Supervised the work, assisted with sensory analysis design, consumer trials, data analysis, interpretation of the data and edited the manuscript.		
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Contribution to the Paper	Contributed to the research idea, assisted sample selection, interpretation of the data and editing of the manuscript.		
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Contribution to the Paper	Contributed to the research idea, interpretation of the data and editing of the manuscript.		
Signature		Date	7/5/19

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Contribution to the Paper	Supervised the work, contributed to the research idea, sensory analysis design, sample selection, and interpretation of the data and editing of the manuscript and acted as corresponding author.		
Signature		Date	7.5.19

Abstract

This study sought to identify sensory attributes of the most appropriate food and wine pairings and relate them to wine balance, consumer liking, sensory complexity, and expected price. A descriptive analysis panel (n=8) evaluated four Australian Shiraz wines along with four complex food samples, yielding 16 wine and food combinations. Based on the sensory profiles, distinct food and wine pairings (n=6) were selected for consumer preference tests, comprising a real life, pseudo-three course meal with two wines. According to American consumers (n=108), in the most appropriate pairings, the flavour intensities increased and wine taste attributes changed in relation to the individual components. Appropriate pairings positively correlated with liking, sensory complexity, and expected price to pay, and negatively with balance as slight wine dominance was preferred in pairings. Most importantly, the pairings had an increase in liking and sensory complexity over the individual wine but not the food component. To account for individual variability, consumers were segmented by their liking of the pairing. The key drivers of successful pairings across consumer clusters were similar to the average consumer results, however, the preferred pairings differed by cluster. The findings suggest, the quality of food and wine pairings might be more effectively measured with a combination of direct (dominance/balance, appropriateness of pairing) and indirect methods (sensory complexity, liking), instead of a single scale, and consumer segmentation may better account for the variability of results. The outcome of this study enhanced the understanding of the relationship between consumer behaviour and food and wine pairings.

Key words

Descriptive sensory analysis; Consumer segmentation; Food and Wine pairing; Pairing liking; Flavour match

1 Introduction

1.1 Food and wine pairing research

Food pairings relate to the consumption of a food and a beverage together which yields different sensory properties compared to consumption of that food or beverage in isolation (Lahne, 2018). There is an array of theories in the culinary literature for pairing food and wine, and the most explained ideas to date investigate interactions between the key elements of food and wine (Harrington, 2007). Experts and researchers agree that taste, texture, aroma, and overall flavour should be taken into account for successful pairings (Harrington, 2007), however they tend to disagree on which element is the most important. Paulsen and others (2015) published a review of important books on the topic and found that a balance of overall flavour intensities, and taste balance between food and wine were the most commonly mentioned principles. Other studies investigated pairings on the basis of chemical composition (Fujita et al., 2010; Tamura et al., 2009), taste (Koone, Harrington, Gozzi, & McCarthy, 2014), body (Harrington & Hammond, 2006a), aroma similarity (De Klepper, 2011; Eschevins, Giboreau, Allard, & Dacremont, 2018), and expert opinions (Bastian et al., 2009; King & Cliff, 2005), but they are generally unable to reach strong conclusions as to which beverage and food should or should not pair well. Furthermore, some of the conclusions were drawn from more preliminary research, which conducted sensory descriptive analysis (DA) without replicates (Harrington & Hammond, 2006b), or used less conventional approaches such as consumer tests with training as a hybrid methodology between DA and affective testing (Koone et al., 2014). Both approaches go against the fundamentals of sensory evaluation and consumer research (Lawless & Heymann, 2010), therefore it is difficult to rely on these results. It’s been suggested that consumers might perform similarly to trained panellists if a suitable method is used (Varela & Ares, 2012), however, considering the complexity of the task to objectively evaluate food and wine pairings, more specific methods are required.

More productive findings have come from analytical approaches that focused on how specific attributes of wine were changed by food pairings (Bastian et al., 2010; Madrigal-Galan & Heymann, 2006), which stemmed from Nygren and colleagues (2003) empirical discovery that within pairings, food has a substantial impact on wine sensory characteristics. Essentially, wine is an aqueous solution, and mixing it with food in the mouth increases viscosity resulting in suppression of wine flavour, taste, and mouthfeel intensities (Bastian et al., 2010; Kokini, Bistany, Poole, & Stier, 1982; Pangborn, Gibbs, & Tassan, 1978). Following the principles of taste interactions (Keast & Breslin, 2003), the combination of wine and food can potentially result in attribute suppression and also enhancement, but the question is whether the suppression or enhancement is pleasant for consumers. For instance, it is unlikely that the increase of bitterness or harsh acidity of a wine be favourable in a pairing. However, fat and protein rich foods can reduce wine astringency and bitterness enhancing consumer liking for wine (Bastian et al., 2010; Madrigal-Galan & Heymann, 2006).

Another concern is the lack of systematic approach in sample selection of what foods and wines and on what basis were investigated in pairings. Previous food pairing studies attempted to disprove anecdotal rules of food and wine pairings (Harrington, McCarthy, & Gozzi, 2010; Harrington & Seo, 2015) but these studies chose supposedly “good” and “bad” pairings without evidence. A more viable approach has been to select pairings based on experts’ recommendations (Bastian et al., 2009; Harrington & Hammond, 2006b; Harrington et al., 2010), however, those expert suggestions do not necessarily overlap with foods and wines that consumers may couple together (Harrington, 2007). For instance, most studies involved cheese, chocolate and other singular food items rather than a complex course or dish as occurs in real life meals. In terms of wine selection, studies favoured contrasting wine styles (e.g., dry white wine against sweet port wine) to generate large sensory differences between pairings (Harrington & Seo, 2015), however neglected the weak or strong cultural associations of the selected wines to the evaluated food samples. Furthermore, evaluating one wine per grape variety/appellation without a pre-selection process assumes that all wines within a variety share the same sensory characteristics, irrespective of their origin and style. The flaw in this assumption is apparent from the significant sensory and quality differences within an intentionally chosen set of 10 diverse Shiraz wines paired with the same cheddar cheese (Bastian et al., 2010). Indeed, it is well known that wine sensory characteristics such as flavour intensity, astringency, acidity, body, etc. can be altered by winemaking techniques, as well as influenced by the growing season (Iland, 2009). So instead of examining pairings based on anecdotal varietal assumptions, generating pairings for research purposes based on a detailed understanding of the actual sensory properties of pairing components could be a more effective approach.

After a review of the food pairing research, Lahne (2018) stated that it is important to better define how the perceived quality of food pairings should be measured. Some limitations of the analytical studies have been the use of scales which assume that an ideal match is one in which neither the food nor the wine dominates (King & Cliff, 2005). Flavour is the overall perception of taste, mouthfeel and aromas in food or wine (Spence, Smith, & Auvray, 2015), therefore assuming the balance of flavour intensities as a measure of ideal pairings is seemingly logical. However, the main contention seems to be whether an ideal or appropriate food pairing is a balance of intensities or a synergistic relationship between the flavours of food and beverage (Eindhoven & Peryam, 1959; Harrington, 2006). If the balance theory is true, pairings in which neither the food nor the wine dominates would be the most liked, although the research findings contradict that popular belief (Bastian et al., 2010;

Donadini, Fumi, & Lambri, 2012). However, if we accept synergy between food and wine as driving ideal matches, there should be a measurable increase in the liking of the pairing from the individual elements (Lahne, 2018). To confirm or not whether synergy theory may explain ideal pairings, studies involving DA of food, wine and subsequent pairings are required to identify the sensory attributes of balanced pairings and/or an observed increased liking of pairings from the individual food and wine in consumer testing.

1.2 Consumer research in food and wine pairing

The existing literature on food and wine pairing tends to base the success of a pairing on consumer liking. One of the first studies on the subject by Eindhoven and Peryam (1959) found that the liking of foods alone were non-predictors of how much the pairings were liked. However, many subsequent papers based on the combination of descriptive sensory analysis and consumer preference testing found the opposite, namely that individual liking for the beverage in a pair was strongly predictive of liking for the pairing (Bastian et al., 2010; Donadini et al., 2012; Harrington & Seo, 2015). One apparent finding across all studies is the variability across trained judges, consumers, and even experts (King & Cliff, 2005). Thus, if consumer liking is taken as the key predictor of successful pairings, then the heterogeneity of consumers' taste preferences and behaviours cannot be neglected. Consumers should be segmented using multivariate analyses upon various bases including psychographic measures, e.g., hedonic scores, demographics, wine and food consumption behaviour, neophobia, and levels of consumer knowledge, involvement and interest, so that consumers with similar traits are grouped together (Kotler, Keller, Brady, Goodman, & Hansen, 2009) to obtain consumer targeted insights.

Although, it is widely assumed that the sensory characteristics of products can explain consumers' preferences, other subjective and complex dimensions might influence consumer decisions (Masson, Delarue, Bouillot, Sieffermann, & Blumenthal, 2016). Among such factors, perceived complexity; comprising sensory, cognitive, and emotional dimensions, seems important, especially due to its ability to arouse (Palczak, Blumenthal, Rogeaux, & Delarue, 2019). As a new direction in food and wine pairing research, we were interested in investigating food and wine pairing perceived sensory complexity and its relationship with appropriate pairings.

The primary aim of this study was to explore if the appropriateness of pairing is driven by the balance of intensities between food and wine or if it is a synergistic relationship. We hypothesised that appropriate food and wine pairings will have positive relationships with liking, sensory complexity and expected price to pay for the wine. We also hypothesised that the liking of appropriate food and wine pairings will be greater than liking of the food or wine element alone. The second objective was to determine sensory attribute changes in food and wine with pairing and if they drive perceived appropriateness and liking of pairing.

2 Methods and Materials

The experimental design included a series of DAs followed by a consumer test. A panel of trained assessors evaluated singular foods and complex dishes, wine samples, and finally pairing of the food and wine samples in three separate, consecutive, DAs. Details of all stages are outlined below.

2.1 Sensory Analysis

2.1.1 Food DA panel

Seven sensory assessors (three female, four male) with previous DA experience were recruited as panellists. Three 120 minute training sessions were held, in which seven foods were presented and panellists generated descriptors and defined aroma standards upon consensus (Lawless & Heymann, 2010). The final training session was performed under identical conditions to the formal sessions. Once no judge by sample interaction was significant, assessors proceeded to evaluate the samples. A total of 34 sensory attributes, including 9 aroma, 15 taste and mouthfeel and 10 flavour attributes were rated for each food on a 10 cm scale with anchors of low and high placed at 10% and 90% of the line, respectively (Lawless & Heymann, 2010). Reference standards for the aroma attributes (Table A.1) were provided prior to evaluation in covered glasses. The foods were assessed in duplicate with seven foods presented individually in each session in 4-digit coded, clear plastic containers with 5 minutes break after four foods and 60 s between samples.

2.1.2 Wine DA panel

The training and evaluation procedure was identical to that used for the food panel. A total of 25 sensory attributes were agreed upon, comprising 9 aroma, 7 taste and mouthfeel and 9 flavour attributes (Table A.2). The wines were assessed in duplicate with 8 wines presented individually in a randomised order during each session, with a 60s pause between samples and a 5 min break after four samples.

2.1.3 Food and wine pairing DA panel

The panel was instructed to taste food and wine combinations following the mixed tasting method (Nygren, Gustafsson, & Johansson, 2003). Four training sessions of 120 min were held. Samples were presented as outlined above in Section 2.1. Each bite of food was evaluated with a mouthful (8 mL) of wine. Panellists decided to assess the pairings based only on flavour, taste and mouthfeel attributes, hence the list of attributes was generated accordingly. A total of 21 sensory attributes were agreed upon, comprising 11 taste and mouthfeel and 10 flavour attributes (Table A.3). The pairings were assessed in duplicate in a randomised order during each session, with a 60 s pause between samples.

All sensory evaluations were conducted at University of Adelaide, Waite campus using RedJade Sensory Software (RedJade Software Solutions, LLC). The study was performed in accordance with the ethical guidelines for scientific research at The University of Adelaide and approved by the Human Research Ethics Committee (approval number: H-2016-150).

2.2 Sample selection and characterization

2.2.1 Food and meal sample selection

The meal selection for the food and wine pairings under study was based on an online consumer survey specific to fine Australian Shiraz wines (Kustos, Goodman, Jeffery, & Bastian, 2019). The food samples and recipes were finalised after a benchtop evaluation of creamy pasta, braised beef, braised lamb, Greek salad, fresh goat cheese, brie, camembert, two types of cheddar cheese, Italian prosciutto, apple pie, and chocolate mousse with experts (n=4, sommeliers, winemaker, wine educator) (Parr, White, & Heatherbell, 2004). Seven dishes and foods that represented distinct flavours and styles (pasta with cheese sauce, braised beef with potato puree, chocolate mousse, fresh goat cheese, clothbound cheddar cheese, prosciutto ham, and spicy salami (cacciatore)) were chosen for the DA (Table A.4). Principal component analysis (PCA) of the DA data provided an effective tool for selecting four food samples that possessed very different sensory attributes in flavour, taste and mouthfeel, such as pasta with cheese sauce (dairy, mouth-coating), braised beef with potato puree (intense flavour, savoury, complex mouthfeel), chocolate mousse (smooth, sweet, sweet spice), and spicy Italian salami (spicy, intense flavour, meaty) to evaluate with wine pairings (Figure 1). The number of food samples was reduced from seven to four to prevent DA panellist and consumer fatigue and the final food samples for food and wine descriptive profiling and consumer tests were selected to cover items of a regular meal: starter/entrée, main, and dessert. As the spicy hot salami dominated all pairings in the DA, it was eliminated, and consumers evaluated three foods (pasta with cheese sauce, braised beef with potato puree, and chocolate mousse) in pairings. The pasta and beef dishes were prepared for the study according to the recipes in Table A.5. The mousse was prepared from a powdered mix according to the instructions on the packet (Aeroplane chocolate flavoured mousse, McCormick Foods Australia).

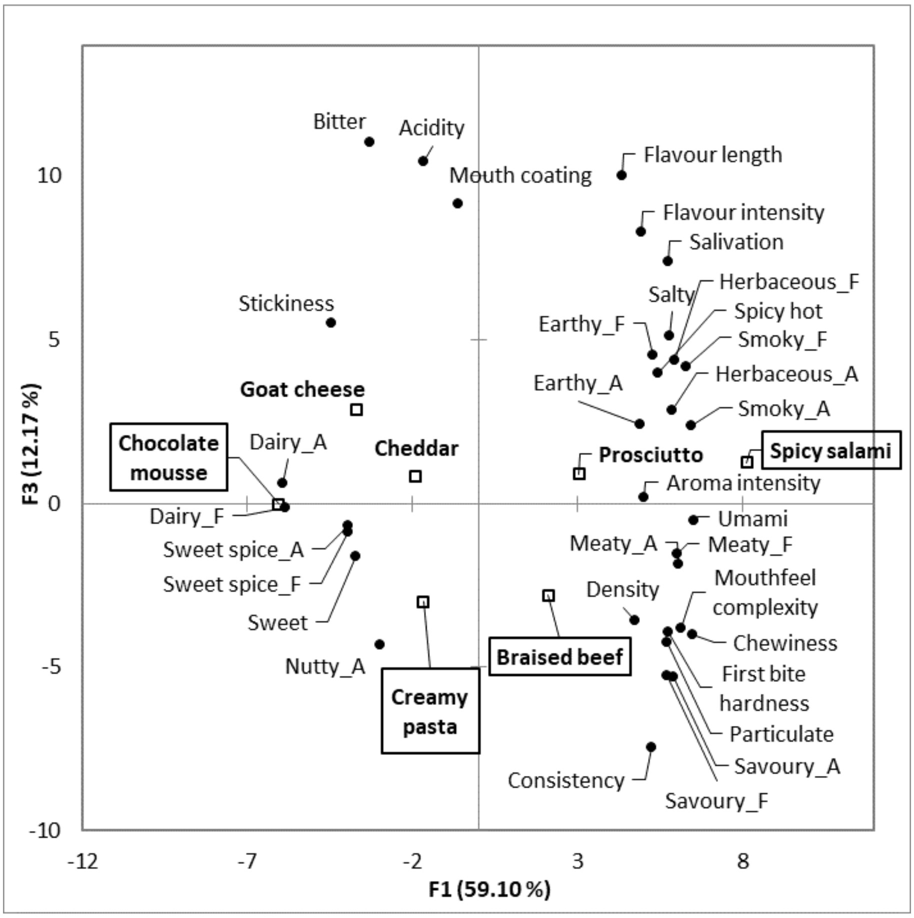

Figure 1. Scores of the food samples (n=7) with loadings of sensory properties on the first two principal components explaining the variability in sensory data. Boxed products marks the selected samples for food and wine pairings.

2.2.2 Wine samples and selection

The ultimate aim was to select two clearly different Australian Shiraz wines for the consumer testing that represent the stylistic diversity of the variety available on the retail market. From a larger group of eight fine Shiraz wines (Kustos et al., 2019), which underwent DA (Table A.6, (Lawless and Heymann, 2010)), four wines that possessed very different aroma, taste, mouthfeel and flavour attributes were chosen to be evaluated in the food and wine pairing DA (Figure 2). BV2 and CB2 were not used further due to vintage unavailability. For the consumer test, two Shiraz wines, one from a warm climate region (McLaren Vale, MV) and one from a cooler climate region (Canberra District, CB) were chosen by three wine experts (Parr et al., 2004). These wines displayed very distinct sensory characteristics, differed in retail price (MV AU$65 and CB AU$36), were made in the same vintage (2015), and were both awarded 97 points by wine critics (see Table A.6 for technical information). Wines were stored at 15 °C prior to all sensory experiments, and equilibrated at room temperature (22-23°C) for two hours prior to serving. The wines were assessed in duplicate presented individually in a randomised order during each session, with a 60s pause between samples.

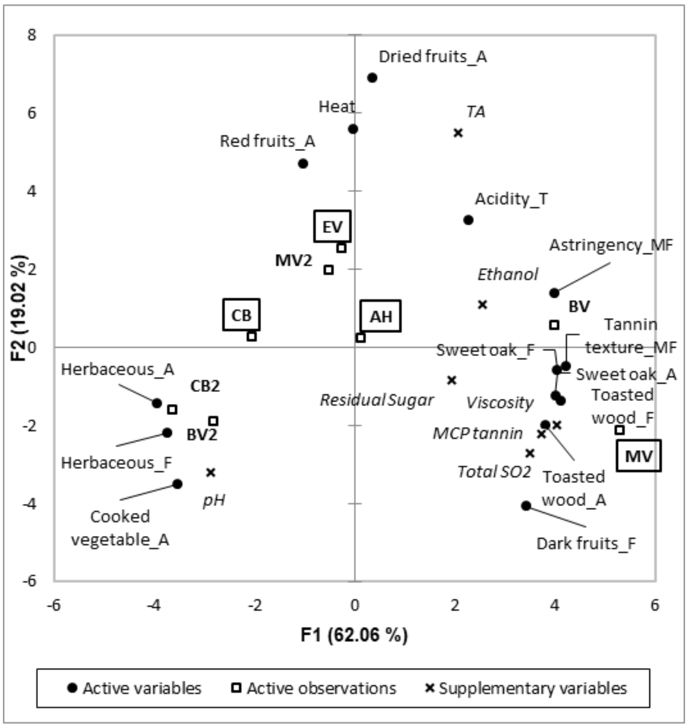

Figure 2. Scores of the Shiraz wines (n=8) with loadings of sensory properties and chemical composition as supplementary variables on the first two principal components explaining the variability in sensory data. Boxed wines mark the selected samples for food and wine pairings.

2.3 Consumer preference test

The consumer testing took place at University of California, Davis campus in individual tasting booths. Participants (n = 108) gave written informed consent prior to the first tasting session and received an US$10 gift voucher to an online store upon completion. First, consumers received the food samples in sequentially monadic order. Food samples were presented in uncoded, clear plastic containers. The presentation order of food samples was constant across consumers and intended to represent a real life dinner with starter/entrée, main, and dessert course items. Secondly, consumers received the two wine samples in duplicate. Participants were not made aware that they received the same samples twice and were only told that they were going to receive four red wine samples in this study. All wine samples (15 mL) were presented in clear 215 mL ISO glasses coded with 3-digit codes for each food sample, under white light. After tasting the food and wine samples, consumers were given a 15 min break, and were asked to complete a demographic questionnaire. No scale has been developed to measure consumer interest in food and wine pairings so food neophobia (FN, (Bell & Marshall, 2003)) and fine wine instrument (FWI, (Johnson & Bastian, 2015)) scales were included as bases for consumer segmentation beyond demographics. Lastly, consumers evaluated food and wine pairings (n = 6). Pairings were ordered by food (starter, main, dessert) and each food was evaluated with two randomised wines presented one at a time. Consumers received both verbal and written instruction about the mixed-tasting method (Nygren, Gustafsson, & Johansson, 2003); subjects were told to take a small bite of food and then a sip of wine, slowly chew and savour the flavours, expectorate the samples and then evaluate the wine and food pairing. In all stages, participants were asked to evaluate the liking, number of flavours perceived, expected price to pay for wine (except when food was evaluated alone), and when assessing the pairings, the appropriateness of the pairing, and balance as well. Liking and appropriateness of pairing were rated on 9 point scales and the other measures on 7 point scales. The balance scale ranged from food dominates highly (1) to wine dominates highly (7), with balance in the middle (4). The number of flavour attributes was used as an indirect measure of sensory complexity (Meillon et al., 2010) and the scale ranged from few (1) to many (7). Distilled water and crackers were provided as palate cleansers, and panellists were required to have a 1 min break between samples.

The consumer testing was carried out using FIZZ (Biosystèmes, France). The study was performed in accordance with the ethical guidelines for scientific research at the University of California, Davis by the Institutional Review Board (approval number: 1228622-1).

2.4 Statistical analysis and calculations

The DA data were analysed by three-way analysis of variance (ANOVA) with a mixed model with product and replicate as fixed factors and judge as random factor, as well as all interactions (product × judge, product × replicate, judge × replicate) were performed for all attributes. When product by judge or product by replicate interaction effects and the product main effect were significant ($p < 0.05$), a pseudomixed model (Næs & Langsrud, 1998) was used to determine the importance of the interaction effect. If the new F-value was still significant at $p < 0.05$, the interaction was not important and the product effect was still significant. However, if the new F-value was not significant, the interaction effect was significant and the product effect was not anymore. Fisher's least significant difference (LSD) was used to calculate the pair-wise comparison of the mean values.

The pairing-induced changes on food and wine were calculated by subtracting significant food and wine sensory attributes from the corresponding significant pairing attributes. For example, change in food savoury = food savoury - pairing savoury. As the DA panel did not assess aromas for food and wine pairings, therefore only in mouth attributes (flavours, taste and mouthfeel) were used for this method. Partial-Least-Square-Regression (PLS2) was performed to predict which sensory changes and consumer measures of food and wine (X) drive the appropriateness of pairing and consumer liking (Y) on each consumer cluster resulting in four models. VIPs below 0.8 were discarded from the PLS2 model in order to retrain on the most important predictors. All statistical analyses were performed with, XLSTAT version 2018.5 (Addinsoft, New York, USA) at 5% level of significance.

3 Results and Discussion

3.1 Sensory profile and consumer ratings of food samples

Table 1 shows the results of the DA for the three selected foods. Twenty-four out of 34 attributes significantly differed across sensory modalities by product (Table 1). As expected for the dessert, the mousse was the sweetest and the pasta (starter) and beef (main) were more salty and umami (Table 1). Pasta had intense dairy and savoury aromas and savoury flavour. Beef was characterized by intense savoury, meaty, smoky, earthy aromas; hard texture, high density, chewy, lumpy, coarse and complex mouthfeel, and intense and long flavours of savoury, meaty, and earthy. Mousse had dairy and sweet spice aromas, very intense flavour, in particular sweet spice, and long flavour length.

Consumers perceived the beef dish to have the highest sensory complexity and significantly preferred it to mousse or pasta (Table 1). Furthermore, consumers' sensory complexity rating showed high correlation (r = 0.787) with mouthfeel complexity in DA. Consumer liking was positively correlated with meaty (r = 0.865) and smoky (r = 0.706) aromas, mouthfeel complexity (r = 0.775), flavour intensity (r = 0.832), length (r = 0. 795), and meaty flavour (r = 0.870), and showed negative correlation with dairy aroma (r = -0.722).

Table 1. Descriptive analysis intensity rating scores of sensory attributes and consumer sensory and hedonic scores for food samples.

	A_dairy	A_savoury	A_meaty	A_smoky	A_herbaceous	A_earthy	A_sweet spice
Beef	41.8 b	48.1 a	79.1 a	20.2 a	17.3 a	25.1 a	11.3 b
Mousse	58.4 a	5.0 b	5.4 b	9.2 b	5.3 b	7.4 c	67.0 a
Pasta	53.3 a	49.7 a	10.9 b	12.8 b	11.5 ab	16.8 b	9.5 b

	MF_hardness	MF_density	MF_chewiness	MF_consistency	MF_particulate	MF_heat	MF_complexity
Beef	50.2 a	58 a	58.4 a	69.3 a	57.4 a	7.1 a	62.3 a
Mousse	8.2 b	8.5 b	6.5 c	10.3 c	10.9 c	4.9 b	25.3 b
Pasta	35.1 b	58.5 a	34.8 b	59.9 b	32.5 b	5.8 ab	33.9 b

	T_sweet	T_salty	T_umami	F_intensity	F_savoury	F_meaty	F_smoky
Beef	13.8 b	40.8 a	49.3 a	60.4 a	44.9 a	80.4 a	16.5 a
Mousse	76.8 a	10.4 c	5.3 c	60.4 a	5.1 b	5.2 b	7.9 b
Pasta	16.3 b	28.9 b	27.8 b	42.0 b	47.6 a	9.9 b	12.1 ab

	F_earthy	F_sweet spice	F_flavour length	C_overall liking	C_nr flavours
Beef	20.3 a	11.2 b	63.4 a	7.3 a	4.6 a
Mousse	7.3 c	67.4 a	64.1 a	6.8 b	3.8 a
Pasta	14.1 b	10.0 b	54.4 b	6.4 c	3.2 a

The "A" prefix denotes aroma, "MF" mouthfeel, "T" taste, "F" flavour, and "C" consumer rated attributes. C_nr flavours denotes the number of flavours perceived by consumers. The letters following the scores show the result of Fisher pair-wise comparison within the column for given attribute $p < 0.05$. Consumer attributes were measured on 9 point scales and sensory attributes on 100 point scale.

3.2 Sensory profile and consumer ratings of wine samples

Nine of the 25 sensory attributes differed significantly across the two Shiraz wines, namely red fruits, sweet oak and toasted wood aromas; astringency and tannin texture; and dark fruits, sweet oak, savoury, and smoky flavours (Table 2). In most cases MV was more intense than CB, except for red fruits aroma and savoury flavour (Table 2), and the more intense sensory attributes of MV corresponded with higher consumer ratings of liking and sensory complexity (Meillon et al., 2010) and consumers expected to be charged a 13% higher price than for CB (Table 2). Such sensory differences were expected between these two wines, as CB originated from the cooler Canberra district region, whereas MV was from the warmer McLaren Vale region (1410 and 1910 heat degree days, respectively) (Gladstones, 2011). MV had aromas and flavours that could be ascribed to extended maturation in oak barrels, such as sweet oak and smoky, in combination with higher astringency and coarser tannins, which can be found in McLaren Vale Shiraz wines (Kustos et al., unpublished). CB possessed red fruit aromas and savoury flavour, which are common descriptors for cool climate Shiraz wines (Iland, 2009). The two Shiraz wines represented the diversity that exists within this grape variety, possibly related to their region of origin and/or production practices.

Table 2. Descriptive analysis intensity rating scores of sensory attributes evaluated for Shiraz wines evaluated in the consumer test.

Wine	A_red fruits	A_sweet oak	A_toasted wood	MF_astringency
CB	42.6 a	17.1 b	19.1 b	44.5 b
MV	20.9 b	54.3 a	44.6 a	75 a
	MF_tannin texture	F_dark fruits	F_sweet oak	F_savoury
CB	35.6 b	64.4 b	17.3 b	25.8 a
MV	63.6 a	73.1 a	44.6 a	16.1 b
	F_toasted wood	C_overall liking	C_nr flavours	C_price bottle
CB	25.0 b	5.4 b	4.6 b	2.3 b
MV	50.4 a	6.3 a	4.9 a	2.6 a

The “A” prefix denotes aroma, “MF” mouthfeel, “T” taste, “F” flavour, and “C” consumer rated attributes. C_nr flavours denotes the number of flavours perceived by consumers. The letters following the scores show the result of Fisher pair-wise comparison within the column for given attribute $p < 0.05$. Consumer attributes were measured on 9 point scales except "C_price bottle" (7 point) and sensory attributes on 100 point scale.

3.3 Sensory profile and consumer ratings of food and wine pairings

Sensory profile of food and wine pairings

From the 21 sensory attributes (Table A.6), 15 differed significantly across the pairings, namely overall sensation dominance, sweet spice, savoury, smoky, and meaty flavours, all taste attributes, mouthfeel complexity, chewiness, body, astringency and heat (Table 3). The overall sensation dominance was measured to indicate whether the intensity of food or wine dominated the pairing with no dominance (balance) in the middle of the scale. BeefCB was the closest to the centre point as neither the food nor the wine dominated the pairing (mean = -2.7) and in BeefMV the wine slightly dominated (mean = 6.8), however the difference was not statistically significant (Table 3), suggesting appropriate pairings (King & Cliff, 2005). MousseCB (mean = 13.7) and MousseMV (mean = 13.9) pairings were equally slightly dominated by the wines. PastaCB (mean = 17.1) and PastaMV (mean = 28.5) deviated the most from neutral, inferring they are the least appropriate pairings based on King's study (2005). Beef and wine pairings were intense in most descriptors, savoury, smoky, meaty flavours, salty and umami tastes, they were the chewiest and the most complex in mouthfeel. BeefCB was more savoury than BeefMV (means = 65.6 vs 54.9), which mirrors the individual wine characteristics of CB and MV (means = 25.8 vs 16.1, Table 2). Although wine sensory characteristics was expected to be supressed by the food (Nygren et al., 2002), the savoury flavour similarity with beef (mean = 44.9 (Table 1)) might have been enhanced by the wine component.

Intense sweet spice flavour described the mousse pairings along with sweet taste, acidity, heat and the lack of savoury, meaty flavours, salty, umami taste, chewiness and mouthfeel complexity. Pasta and wine pairings possessed high acidity, and scored low on most attributes. The sensory differences between pairings (Table 3) resembled the results of the food DA (Table 1), and the pair-wise comparison suggested a significant food effect on the majority of sensory descriptors as per Nygren's findings (2001), and also a partial wine effect was observed for smoky flavour, body, astringency and heat. In particular, MV and food pairings were higher than pairings with CB (Table 3). The mousse and pasta pairings were perceived significantly more acidic than beef pairings, which partially fits with the culinary literature that proposes food sweetness level should be less than or equal to wine sweetness level to avoid harsh pairings (Keast & Breslin, 2003; Paulsen et al., 2015), however, the cause seems unclear as pasta was not sweet. Bitterness was not significant for foods or wines alone (data not shown) but differed between BeefCB and BeefMV pairings. Foods containing high levels of umami, without adequate levels of salt can make wines with oak or skin contact become surprisingly bitter and unbalanced (Fielden & Robinson, 2009). Among the major sensory attributes of wines distinguishing BeefCB and BeefMV, the more astringent, oaky and smoky MV seemingly increased bitterness in pairing with the high umami and moderately salty beef (Table 3). This result seems to support expert opinions (Fielden & Robinson, 2009), however, Brannan et al. (2001) did not find interactions between moderate levels of salt and umami and astringency. Furthermore, food and wine pairings are multi-taste matrices in which the compressive function of taste interactions (salty, umami, sour) is expected to decrease bitterness (Keast & Breslin, 2003). A more likely scenario from the sensory science stand point is that the combination of savoury and smoky aromas of beef and MV perceivably enhanced bitter taste due to cross-modal interactions (Labbe, Damevin, Vaccher, Morgenegg, & Martin, 2006; Noble, 1996).

Table 3. Intensity rating scores of sensory attributes evaluated for food and Shiraz wine pairings that were included in the consumer test.

	Overall sensation dominance	F_sweet spice	F_savoury	F_smoky	F_meaty
BeefCB	-2.7 c	10.6 cd	65.6 a	12.9 b	74.4 a
BeefMV	6.8 bc	13.3 c	54.9 b	37.3 a	73.1 a
MousseCB	13.9 b	65.4 a	4.4 d	6.3 b	5.1 b
MousseMV	13.7 b	65.6 a	5.8 d	39.4 a	5.0 b
PastaCB	17.1 ab	5.3 d	44.9 c	12.4 b	5.6 b
PastaMV	28.5 a	19.8 b	40.9 c	32.1 a	5.4 b
	T_acidity	T_sweet	T_salty	T_bitter	T_umami
BeefCB	52.2 b	20.4 b	43.7 a	10.2 c	54.9 a
BeefMV	56.6 b	20.2 b	45.8 a	23.9 ab	56.6 a
MousseCB	68.6 a	48.4 a	8.1 c	19.9 abc	5.6 c
MousseMV	69.9 a	49.9 a	9.3 c	28.1 a	5.6 c
PastaCB	68.6 a	18.5 b	25.2 b	13.2 c	14.1 b
PastaMV	70.4 a	22 b	25.1 b	17.4 bc	13.8 b
	MF_complexity	MF_chewiness	MF_body	MF_astringency	MF_heat
BeefCB	66.5 a	75.8 a	53.4 ab	33.1 c	62.6 b
BeefMV	70.5 a	76.0 a	60.8 a	44.8 bc	62.5 b
MousseCB	36.9 c	6.6 c	48.4 bc	45.2 bc	63.1 ab
MousseMV	38.3 c	5.8 c	54.3 ab	60.6 a	71.4 a
PastaCB	44.8 bc	56.6 b	41.9 c	39.9 c	53.6 c
PastaMV	48.6 b	57.4 b	52.6 ab	56.4 ab	64.9 ab
	C_overall liking	C_pairing	C_balance	C_nr flavours	C_price bottle
BeefCB	6.6 a	6.4 a	0.0 c	5.2 a	2.8 a

BeefMV	6.6 a	6.4 a	0.5 b	5.1 ab	2.9 a
MousseCB	6 bc	5.9 ab	0.6 b	4.6 cd	2.4 b
MousseMV	6.3 ab	6.3 a	0.6 b	4.8 bc	2.7 a
PastaCB	5.6 c	5.5 b	1.0 a	4.5 d	2.4 b
PastaMV	5.6 c	5.4 b	1.0 a	4.7 cd	2.6 ab

The "A" prefix denotes aroma, "MF" mouthfeel, "T" taste, "F" flavour, and "C" consumer rated attributes. C_nr flavours denotes the number of flavours perceived by consumers. The letters following the scores show the result of Fisher pair-wise comparison within the column for given attribute $p < 0.05$. Consumer attributes were measured on 9 point scales except "C_price bottle" and "C_nr flavours" (7 point) and sensory attributes on 100 point scale. "Overall sensation dominance" and "C_balance" mark the deviation from balance towards food (negative) or wine (positive).

The astringency difference between wines remained significant in pasta and mousse pairings, however it was suppressed with beef and potato puree pairings (Table 3). The latter pairing supports the theory that astringent wines pair with foods that are high in fat and protein (Madrigal-Galan & Heymann, 2006), however only partially as BeefMV was not significantly less astringent than PastaMV, possibly due to the buttery cheese sauce in the pasta pairing (Bastian et al., 2010) (Table A.2).

Consumer hedonic ratings of food and wine pairings

Consumers were asked to rate the overall liking of the pairings on a 9 point hedonic scale. BeefCB and BeefMV rated the highest in liking; however, they were not significantly different from MousseMV (Table 3). MousseCB, PastaCB and PastaMV were only slightly liked. Liking had a high positive correlation with meaty flavour (r = 0.814), umami (r = 0.724) and body (r = 0.738) and a high negative correlation with acidity (r = -0.798). Most importantly, we measured whether liking of the pairings increased or decreased relative to food or wine alone. Interestingly, foods alone were more liked than in pairings (Table 4), but wine liking did not change by pairing except for CB, which was significantly preferred in pairing with beef and mousse, and MV, which was, less liked with pasta than alone. This latter finding with CB and MV contradicts previous studies using simple foods (e.g. cheese, chocolate), in which the liking of the beverage drove the liking of the pairing (Bastian et al., 2010; Harrington & Seo, 2015). Our study involved a realistic meal scenario, and the type of food (simple vs. complex) might have influenced the hedonic relationship between food, wine and pairings. In theory, food and wine pairing has a synergistic relationship if the pairing is liked more than food or wine alone (Lahne, 2018), but it ignores that the food impacts the pairing more than the wine (Nygren et al., 2001) and thus either pair inducing improvement or deterioration of the wine is potentially possible.

Overall none of the pairings were disliked by consumers. A one point difference on a 9-point scale between the most (beef) and least (pasta) liked pairings was less than the authors anticipated as it does not reflect the expert opinions during the recipe and pairing development process (data not shown). Pasta pairings (starter) were slightly liked, and this small hedonic contrast might have affected consumer affective responses to the beef pairings (main course) resulting in only a slight increase of liking (Lahne, Pepino, & Zellner, 2017). Although, the decrease of pairing liking relative to food liking, may have arisen from the within subject experimental design. All consumers rated the foods first followed by the same food paired with wines. As food seemed to drive the sensory characteristics of pairings, perhaps the sensory perception of pairings were rather similar to those of the single foods, which affected consumer hedonic responses to the pairings (Lahne et al., 2017). In other words, even if a pairing was liked, hedonic contrast occurred and consumers perceived the pairings as less ideal than the individual foods (Lahne et al., 2017). This hedonic contrast effect could be reduced by pairing wines with foods of distinct cuisines (e.g.: Italian vs Thai) (Lahne et al., 2017) in multi-course meals. The exact mechanism of hedonic contrast is not understood in the food and wine pairing context and warrants further research. However, the slight difference in consumer liking might be due to a heterogeneous consumer cluster effect, which might further explain food and wine pairing.

Table 4. Pairing induced changes in liking and perceived sensory complexity of food and wine.

Liking	BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
Food	7.3 a	7.3 a	6.8 a	6.8 a	6.4 a	6.4 a
Wine	5.4 c	6.3 b	5.4 c	6.3 b	5.4 b	6.3 a
Pairing	6.6 b	6.6 b	6.0 b	6.3 b	5.6 b	5.6 b
Complexity	BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
Food	4.6 b	4.6 b	3.8 b	3.8 b	3.2 b	3.2 b
Wine	4.6 b	4.8 ab	4.6 a	4.8 a	4.6 a	4.8 a
Pairing	5.2 a	5.1 a	4.6 a	4.8 a	4.5 a	4.7 a

The role of balance in food and wine pairings

Consumers also rated whether the food and the wine were in balance, or whether either the food or wine dominated the pairing (Table 3). Consumer perceived balance also highly positively correlated (r = 0.936) with the overall sensation of dominance attribute of the DA, meaning consumers and trained panellists rated the pairings similarly. Balance had a high negative correlation with liking (r = -0.885) and appropriateness of pairing (r = -0.854), as did overall sensation dominance (r = -0.867; r = -0.846). This is taken to mean that consumers preferred, and deemed food and wine pairings to be more appropriate, when the wine slightly dominated the pairing. This is in agreement with and extends the other studies in the food pairing domain (Bastian et al., 2010; Donadini et al., 2012) and indicates that the "balance" construct alone is a poor predictor of liking (Lahne, 2018) as unbalanced pairings were favoured over balanced ones as long as they had positive hedonic valence.

The role of sensory complexity in food and wine pairings

The consumer-rated sensory complexity of the food and wine pairings showed a positive correlation with liking (r = 0.902), appropriateness of pairing (r = 0.829), and the mouthfeel complexity attribute from DA (r = 0.851). The beef pairings were rated significantly higher in complexity than the pasta followed by mousse pairings, in agreement with the DA panel (Table 3). On the other hand, when the sensory complexity of pairings was compared with the food and wine alone, only BeefCB was significantly more complex, echoing the improvement of hedonic ratings (Table 4). In the wine dominated pairings (PastaCB, PastaMV, MousseCB, MousseMV (Table 3)), the complexity of pairings was driven by wine complexity and was greater than food complexity. The increase of sensory complexity in BeefCB might have come from flavour similarities between Beef and CB further explaining consumer preferences and the synergistic nature of food pairings beyond liking. Flavour and aromatic similarity might be important for appropriate pairings (Eschevins et al., 2018) as long as the pairing is in balance between flavour intensities and has a positive hedonic valence.

Drivers of appropriate food and wine pairings

Consumers rated how well the food and the wine paired, as a measure of how appropriate the pairing was (Table 3). The appropriateness of pairing had a high positive correlation with liking (r = 0.984), meaty flavour (r = 0.708), umami taste (r = 0.604), body (r = 0.684) and negative correlation with acidity (r = -0.697) echoing the findings driving consumer's hedonic scores. Consequently, consumers considered BeefCB, BeefMV and MousseMV significantly more appropriate pairings than PastaCB and PastaMV. This finding is important for hospitality operators when selecting wines as although savoury wines, such as CB, may be less favoured on their own (Johnson et al., 2013; Lattey et al., 2010) (Table 2), they can comprise appropriate food pairings that consumers enjoy (Table 3). Based on our study, appropriate pairings had an increase in liking and sensory complexity over the individual wine but not the food component, indicating that the food improves the wine and not the other way around (Bastian et al., 2010; Harrington & Seo, 2015) (Table 4). The implication for the hospitality industry is that when offering food and wine pairings, wine should be served and tasted prior to food in order to provide the best consumer experience.

Furthermore, instead of trying to select wines that complement foods, designing recipes based on the wine's sensory profile might enhance the pairing.

Expected price to pay for wine in appropriate pairings

Consumers also rated how much they expected to pay for a bottle of wine in the pairing (Table 3). The expected price of the wine had strong positive relationships with the liking ($r = 0.818$), appropriateness of the pairing ($r = 0.754$), and sensory complexity ($r = 0.926$). Consequently, consumers expected to pay the most for wines in BeefCB, BeefMV and MousseMV. More specifically, consumers valued MV equally across all pairings, however they expected to pay significantly more for CB in the most appropriate food pairing (BeefCB) (Table 3). These findings are in agreement with previous research that consumers value food and wine pairing (Bastian et al., 2010) and sensory complexity (Palczak et al., 2019), and extend with the importance of offering appropriate pairings to enhance the consumer experience and improve profitability.

3.3.1 Consumer clusters

Neither wine involvement nor food neophobic traits had significant effects on; consumer wine and food pair liking ($F = 2.817$, $p = 0.633$; $F = 1.797$, $p = 0.582$), appropriateness of pairings ($F = 3.018$, $p = 0.408$; $F = 2.033$, $p = 0.734$), sensory complexity ($F = 2.477$, $p = 0.841$; $F = 2.419$, $p = 0.129$) or balance ($F = 4.166$, $p = 0.817$; $F = 4.023$, $p = 0.592$). However, both did have an effect on the expected price ($F = 4.765$, $p = 0.0001$; $F = 1.648$, $p = 0.039$). This is surprising as both involvement (Johnson & Bastian, 2015) and neophobia (Arvola, Lähteenmäki, & Tuorila, 1999) have demonstrated influence on consumer preferences when wine and food were rated separately. The individual characteristics of products were possibly suppressed in pairings (Nygren et al., 2002) to the extent that they were not significantly perceivable as a function of involvement or neophobia.

As this paper focuses on hedonics of wine and food pairing, consumers were segmented based on their pairing liking scores, and an Agglomerative Hierarchical Clustering (AHC) resulted in four hedonic clusters (HC); HC1 (n=18), HC2 (n=36), HC3 (n=22), HC4 (n=32) (Table A.7). There was a significant cluster effect on the appropriateness of pairing and balance, but not on sensory complexity and expected price (Figure 3), which means each cluster described the preferred pairings as equally complex, and expected to pay equally for the wine in the preferred pairings. This is not surprising as liking has positive relationships with price and sensory complexity (Palczak et al., 2019).

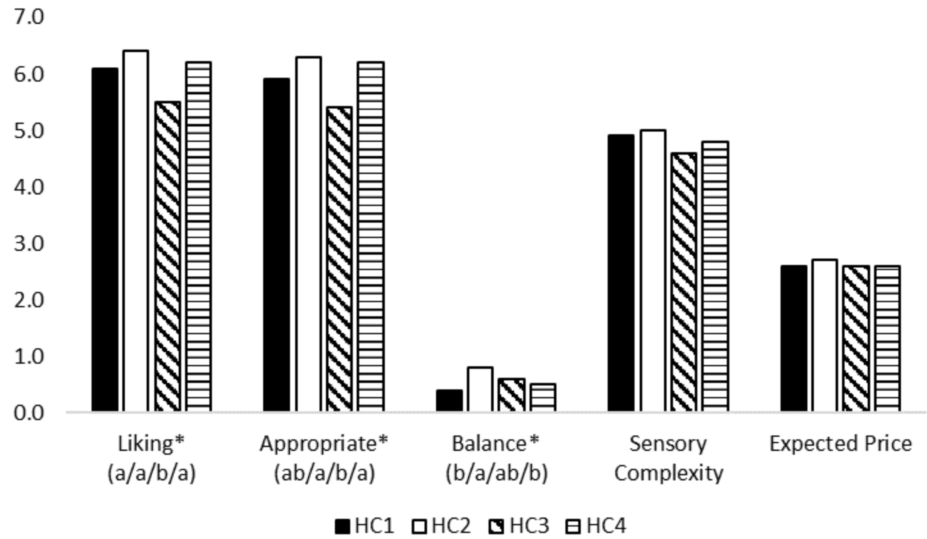

Figure 3. Hedonic cluster (HC) effect on consumer perceptions in relation to food and wine pairings. Asterisk indicates significant ($p < 0.05$) HC effect and the letters following show the result of Fisher pair-wise comparison across clusters.

All clusters were female dominant except HC4 (male = 62.5% and female = 37.5%) (Table A.7). In terms of household income, cluster HC3 had the highest percentage (31.8%) earning over US$150,000, although they tend not to spend more on wine than other clusters. Consumers in all clusters were highly educated and they would spend similar amounts on a bottle of wine on different occasions.

Consumers in HC1 had clear preferences for MV wine paired with mousse and pasta, but preferred CB with beef, which they disliked with mousse (Table 5). HC2 preferred CB to MV with beef and pasta foods, liked both mousse pairings, and slightly disliked the PastaMV pairing. HC3 did not prefer one wine over the other with either beef or pasta, however, they preferred beef pairings the most and clearly did not like mousse with either of the wines. HC4 had a moderate to high liking for BeefMV, MousseCB, MousseMV, and had a general preference for MV pairings. HC4 was the only male dominated cluster (Table A.7), which might be explained by their preference for fuller bodied red wine pairings opposed to female consumers who reportedly like lighter and medium bodied red wines (Bruwer, Saliba, & Miller, 2011), possibly confirming a gender bias for red wine styles.

Overall, the most liked food and wine pairings across consumer clusters were more appropriate, had greater sensory complexity and higher expected wine prices. The only exception was HC2, who did not differentiate on sensory complexity and found all pairings moderately complex (Table 5). The most balanced pairings (least deviation from balance) were highly liked and deemed appropriate across segments, however the less balanced pairings did not differ significantly (Table 5). This further confirms our previous observation on the consumer cohort in section 3.3 and reinforces the notion that equal intensities of food and wine flavour alone is a poor indication of the emergent quality of the pairing (Bastian et al., 2010). The high positive correlation between liking and sensory complexity (except for HC2) might be an important underlying factor to predict consumer preference alongside with appropriateness of the pairing (Masson et al., 2016). Moreover, instead of measuring food and wine pairing on a single scale, a combination of direct (appropriateness of pairing, balance) and indirect (liking, sensory complexity) measures might result in deeper understanding of the phenomenon. Although the hedonic clustering revealed different consumer perceptions for food and wine pairing, with the exception of gender ratio the demographics were not significantly different (Table A.7).

Table 5. Consumer ratings for food and Shiraz wine pairings by hedonic cluster (HC).

Cluster	BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
Liking						
HC1	7.3 a	5.9 bc	4.3 d	7.1 ab	5.1 cd	6.7 ab
HC2	7.4 a	5.8 b	6.8 a	6.9 a	7.1 a	4.4 c
HC3	6.6 ab	7.2 a	4.0 d	3.6 d	5.5 c	6.2 bc
HC4	5.2 b	7.3 a	7.5 a	7.1 ab	4.2 c	5.9 b
Appropriateness of pairing						
HC1	6.8 ab	5.7 bc	4.2 d	7.1 a	5.0 cd	6.7 ab
HC2	7.2 a	5.7 b	6.7 a	6.9 a	6.8 a	4.2 c
HC3	6.7 a	7.1 a	4.0 c	3.6 c	5.1 b	5.6 b
HC4	5.1 bc	7.2 a	7.3 a	7.1 a	4.4 c	5.8 b
Sensory complexity						
HC1	5.7 a	4.8 b	4.1 c	4.9 ab	4.7 bc	5.1 ab
HC2	5.4 a	4.9 a	5.0 a	5.0 a	4.8 a	4.8 a
HC3	5.5 a	5.5 a	3.9 b	4.2 b	4.3 b	4.5 b
HC4	4.8 ab	5.3 a	5.1 a	4.9 ab	4.1 c	4.5 bc
Expected price of wine						
HC1	2.9 a	2.5 ab	2.0 c	2.9 a	2.3 bc	2.9 a
HC2	3.1 a	2.7 abc	2.6 bc	2.9 ab	2.9 ab	2.3 c
HC3	3.0 ab	3.2 a	1.9 c	2.1 c	2.4 bc	2.9 ab
HC4	2.2 bc	3.2 a	2.7 ab	2.9 a	2.0 c	2.7 ab
Deviation from balance						
HC1	0.1 b	0.4 ab	0.7 ab	0.1 b	1.1 a	0.2 ab
HC2	0.0 c	0.8 b	0.8 b	0.8 b	0.8 b	1.8 a
HC3	-0.1 c	0.2 bc	0.9 ab	0.7 ab	1.1 a	1.0 a
HC4	0.1 c	0.4 bc	0.3 bc	0.5 abc	1.1 a	0.8 ab

The letters following the scores show the result of Fisher pair-wise comparison across rows.

3.3.2 Pairing induced changes in food and wine

To predict which sensory changes and consumer measures of food and wine (X) drive the appropriateness of pairing and consumer preferences (Y), PLS2 was performed on each consumer liking cluster resulting in four models (Figure 4). In each model, the first component explained over 95% of the variance in consumer liking towards the appropriateness of the pairing and sensorial changes in food and wine. All four models showed a good separation of pairings, although the configurations changed depending on the hedonic cluster. Consumers in HC1 (Figure 4a) described pairings appropriate when the pairing increased both the food's smoky flavour and heat, and the wine's savoury and smoky flavours, and heat, and decreased acidity of wine, and the liking of pairing was higher than of food or wine alone. Such pairings were BeefCB, MousseMV and PastaMV whereas pasta and mousse with CB were shown to be poor pairings. HC2 (Figure 4b) found pairings to be appropriate when the pairing had little to no change on the wine's smoky flavour and sweet taste, food's smoky flavour, acidity, mouthfeel complexity, chewiness. BeefCB was the most appropriate whereas PastaMV, in particular, was not. Appropriate pairings for HC3 (Figure 4c) occurred when the pairing slightly increased the food's, chewiness, sweetness, and saltiness, and especially increased acidity. For wine, increased savoury flavour, unchanged acidity and decreased sweetness determined the appropriate pairings. Such pairings involved CB and MV with the beef whereas mousse with either wine was not appropriate. For HC4 (Figure 4d), appropriate pairing occurred when there were increases in both the food's, heat, and bitterness, and the wine's sweetness, bitterness, and heat but decreases in food chewiness and sweetness. This was the case for BeefMV, and both wines with the mousse whereas PastaCB was not well paired.

The traditional concepts of food and wine pairing, such as red meat with red wine (Harrington, 2007) and the weight matching theory (Werlin, 2003) applied only to HC3, who favoured beef with both red wines. Other clusters seemed to freely express their ideas of a suitable pair, even deeming red wine with chocolate mousse to be a suitable pairing in the case of HC4 (in stark contrast to HC1 and HC3).

Pairing evidently influenced the flavour, taste and mouthfeel attributes of the initial food and wine items, confirming the complex nature of food and wine pairing (Bastian et al., 2010). None to slight increases in intensities of flavour and taste attributes of food and wine were generally preferred and rated appropriate, which reiterates the prominence (but not the reign) of flavour intensity balance in successful pairings (Paulsen et al., 2015). Extending beyond previous studies with single items like cheese (Bastian et al., 2010) and chocolate (Donadini et al., 2012) that found consumers liked pairings in which wine slightly dominated, within a meal-like context as in our study, consumers deemed none to slight dominance of food or wine to be more appropriate. As pointed out in section 3.3.1, the most appropriate pairings cannot be predicted solely on dominance of food or wine though, as in many cases consumers rated unbalanced pairings just as appropriate as balanced ones. In particular, balance only moderately correlated with the pairing scores of HC3 (r = -0.665) and HC4 (r = -0.494) clusters. Furthermore, the liking of appropriate pairings was greater than of wine alone, indicating a synergistic relationship between food and wine (Lahne, 2018). For instance, CB Shiraz was neither liked nor disliked on its own (Table 2) but was moderately to highly liked when paired with beef for all clusters except HC4, who preferred it with mousse (Table 5). HC4 had a predominance of males and desired pairings which increased the bitterness of food and wine. Males tend to be less sensitive to bitter taste than females (Tepper, 2008); the results quite likely reflect differences in sensitivity to bitter tastes among the participants (Garcia-Bailo, Toguri, Eny, & El-Sohemy, 2009; Mennella, Pepino, & Reed, 2005).

Although there were trends in liking increase and sensory characteristics across clusters with respect to appropriate pairings, consumers liked different pairings in each cluster. This phenomenon aligns with the heterogeneous nature of consumers (Kotler et al., 2009), meaning it is important to evaluate food and wine pairings with appropriate consumer segmentation.

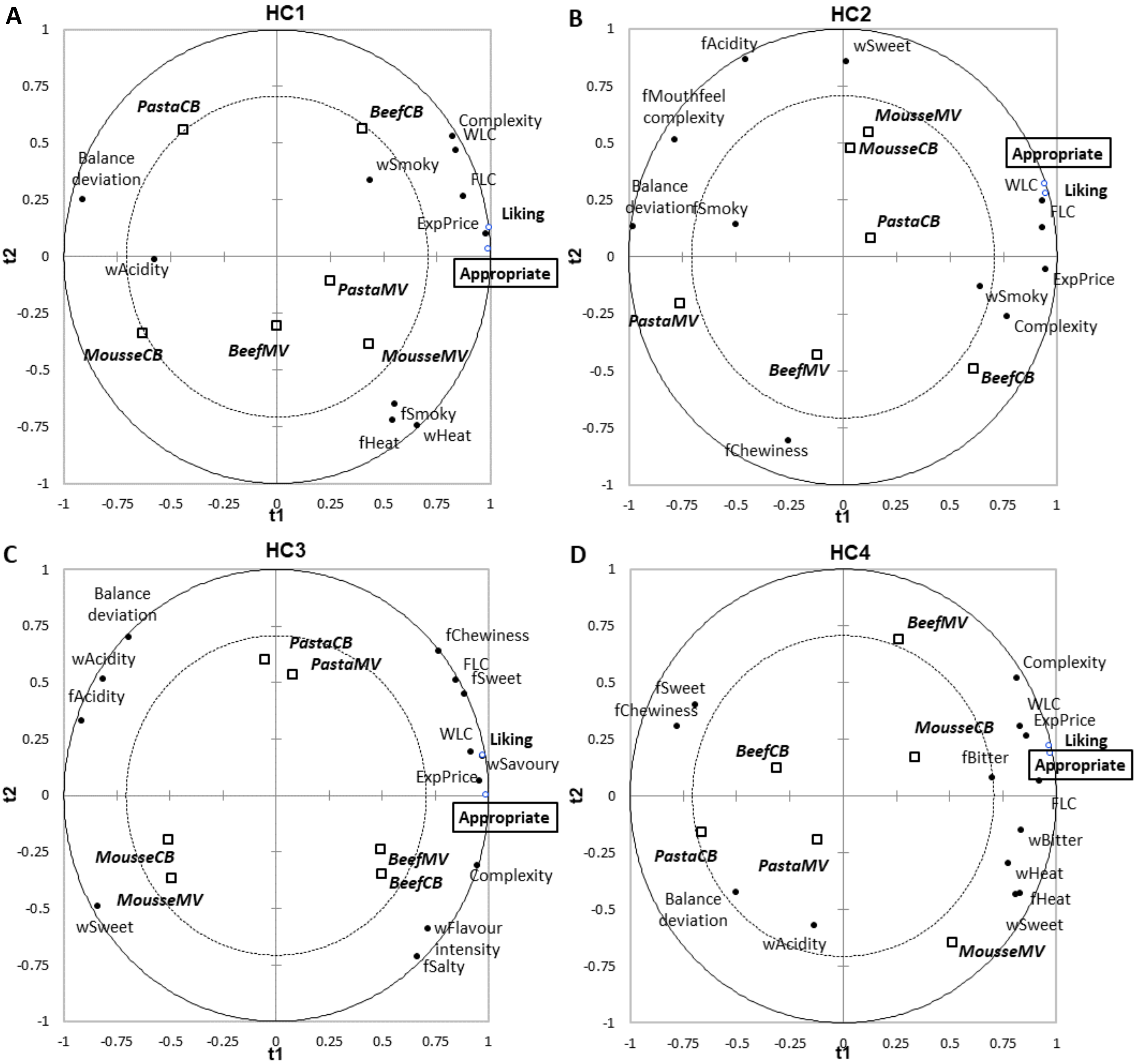

Figure 4. Attribute profile of pairings (PastaCB, PastaMV, BeefCB, BeefMV, MousseCB, MousseMV) by consumer liking clusters (HC). The 'w' prefix indicates pairing induced changes on the wine, and the 'f' prefix indicates pairing induced changes on the food attributes. Open circles signify consumer responses. FLC is the pairing induced change of food liking, WLC is the pairing induced change of wine liking.

4 Limitations and future perspectives

The tasting in a laboratory setting might have been perceived unrealistic by some consumers, however, Danner et al. (2016), showed no difference in liking of Shiraz wine between laboratory, home and restaurant, but there was an emotional difference that might be worth exploring in food and wine pairing context as well. Although consumers received verbal and written instructions about the tasting procedure, they may not have interpreted the instructions similarly. As there are individual differences in bitterness perception, it might be worth screening consumers based on PROP sensitivity as well as other phenotypic traits as a basis for further segmenting and understanding consumer liking. As a consequence of sensory heterogeneity between consumers, their concept of appropriate food and wine pairing may differ too, thus would be worth exploring what construct they use to assess pairings. Furthermore, a better understanding of the motivational factors behind consumer preferences requires future research that segments consumers based on their interest in food and wine pairings.

5 Conclusion

This study explored consumer ratings and sensory drivers for appropriate food and Shiraz wine pairings. The wines presented some of the climatic and stylistic diversity of Australian Shiraz and the selected foods nominally comprised a three course meal, representing a real life scenario of pairing wine with food. On average, the liking and appropriateness of pairings were driven by food, confirming that food suppresses wine attributes in a pairing situation that are typically found in hospitality settings; this is significant to hospitality and winery cellar door operators, suggesting that the consumer experience is likely to be great if the wine is tasted before the food. Another implication might be to design recipes and create courses that complement the wines, not the other way around. In the most appropriate pairings, the intensities of food and wine flavours increased, wine taste attributes changed, there was a positive relationship with liking, sensory complexity, expected price to pay for the wine and a negative relationship with balance as slight wine dominance of the pairing was preferred. Most importantly, the pairings had an increase in liking and sensory complexity over the individual wine, but not the food component. It may be that food impacts pairings more so than wine, which might have led to hedonic contrast due to the within-subject experimental design. Nevertheless, the pairing induced increase of wine liking and sensory complexity indicates that food and wine pairing is a synergistic interaction of foods. The balance theory may still be an important predictor for successful food and wine pairings; however cannot be solely relied upon as it was not significantly preferred over pairings in which food or wine slightly dominated. In fact, it is most likely that appropriate food and wine pairings are synergistic and balanced as well. Measuring food and wine complexity could represent a valid predictor of appropriate pairings and an underlying factor to explain consumer preference beyond sensory attributes (Masson et al., 2016). Even so, food and wine pairing is a complex phenomenon and there is no guarantee that two subjects assess the same construct. Therefore, instead of direct single scale measurements, a combination of direct (balance, appropriateness of pairing) and indirect methods (sensory complexity, liking) might be more effective. To account for the individual variability, consumers were segmented by liking of the pairing, which revealed greater differences between pairings. Importantly, even though consumers across clusters seem to agree on the sensory drivers of appropriate pairings, their matched pairings varied so although universal methods to measure food pairing may be desirable, appropriate consumer segmentation could better account for the variability of results. In terms of segmentation methods, neither wine involvement nor food neophobia had significant effects on consumers' food and wine pairing related behaviour, which warrants the development of a specific food and wine pairing related scale.

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SUPPORTING INFORMATION FOR

Inter(t)wined: what makes food and wine pairings appropriate?

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Table of Contents

Table A. 1. Sensory attributes of food samples with agreed definitions and reference standards. Asterisk marks the significant attributes by product.

Attribute	Definition	Reference
Aroma	Aroma of	
Aroma intensity	Weak to strong overall food aroma	
*Dairy	Milk, yoghurt, sour cream, butter	1 tsp of full fat sour cream (Woolworths Home brand, Bella Vista, NSW, Australia)
*Savoury	Onion, olives	Fried onion, 1 thin slice of carrot and 1 black olive
*Meaty	Cooked beef, pork, stock, broth	0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather
*Smoky	Toasted bread and smoke	Toast (Woolworths Home brand, Bella Vista, NSW, Australia), burnt in a toaster and crumbled
*Herbaceous	Capsicum, tomato leaf	Capsicum, diced
*Earthy	Earth, mushroom, barnyard, leather, sweat	Potato peel, soil, mushroom slices
*Sweet spice	Aniseed, cinnamon, nutmeg, clove, vanilla, and cocoa	Mixture of cinnamon, nutmeg, clove, vanilla, and cocoa
Nutty	Roasted nuts	Hazelnut (Woolworths Home brand, Bella Vista, NSW, Australia) roasted in 200 C oven for 7 minutes
Palate		
Mouthfeel		
*First bite hardness	From soft to hard	From cream cheese to peanuts
*Density	From light/airy to dense	From mousse to hard cheese
*Chewiness	From tender to chewy/tough	From roast chicken slices (Primo Smallgoods, Chullora, NSW, Australia) to beef jerky (Jack Link's, Wisconsin, United States)
*Consistency	From smooth to lumpy	From full fat cream to pearl tapioca
*Particulate	From fine to coarse	From flour to polenta
Stickiness	Tendency to adhere to contacting surfaces, especially the palate, teeth and tongue during mastication	From water to peanut butter
Salivation	Sensation resulting in increased saliva production	
*Heat	Sensation perceived in the mouth as warming, irritation, burning or stinging	
*Mouthfeel complexity	The sensation of simultaneously occurring sensations and textures	
Mouth coating	Sensation of a coating film in the mouth	From water to oil
Taste	Taste associated with	
*Sweet	The basic taste sweet	Taste of sucrose

*Salty	The basic taste salty	Taste of table salt (NaCl)
Sour	The basic taste sour	Taste of lemon juice
Bitter	The basic taste bitter	Taste of quinine
*Umami	Monosodium glutamate	Taste of Monosodium glutamate
Flavour	Flavour of	
*Flavour intensity	Dilute to concentrated	
Dairy	Milk, yoghurt, sour cream, butter	1 tsp of full fat sour cream (Woolworths Home brand, Bella Vista, NSW, Australia)
*Savoury	Onion, olives	Fried onion, thin slices of carrots and olives
*Meaty	Cooked beef, pork, stock, broth	0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather
*Smoky	Toasted bread and smoke	Toast (Woolworths Home brand, Bella Vista, NSW, Australia), burnt in a toaster and crumbled
Herbaceous	Capsicum, tomato leaf	Capsicum, diced
*Earthy	Earth, mushroom, barnyard, leather, sweat	Potato peel, soil, mushroom slices
*Sweet spice	Aniseed, cinnamon, nutmeg, clove, vanilla, and cocoa	Mixture of cinnamon, nutmeg, clove, vanilla, and cocoa
Nutty	Roasted nuts	Hazelnut (Woolworths Home brand, Bella Vista, NSW, Australia) roasted in 200 C oven for 7 minutes
*Flavour length	Duration of lingering flavours after swallowing the sample that does not differ from the sensations perceived when it was in the mouth	

* Asterisk indicates the significant attributes by product.

Table A. 2. Sensory attributes of wine samples with agreed definitions and reference standards. Asterisk marks the significant attributes by product.

Attribute	Definition	Reference
Aroma	Aroma of	
Aroma intensity	Weak to strong overall wine aroma	
Dark fruits	Plum, dark cherry, blueberry, black berry, blackcurrant	One of each fresh black berry, blueberry and plum in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
*Red fruits	Raspberry, strawberry, red cherry	One of each frozen raspberry, strawberry, cherry in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
Dried fruits	Prune, fig, and raisins	One dried prune, fig and raisin sliced in 20 mL red wine
Herbaceous	Capsicum, tomato leaf, cut grass, and eucalyptus	Capsicum, diced in 20 mL red wine
Cooked vegetable	Cooked cabbage, and green beans	Two slices of cooked cabbage and carrot cubes in 20 mL red wine

*Sweet oak	Cinnamon, nutmeg, vanilla, and cocoa	Two drops of vanilla essence, dark chocolate shavings (Lindt, Kilchberg, Switzerland) and a pinch of cinnamon powder in 20 mL red wine
*Smoky	Toasted bread, wood, and smoke	Burnt toast (Woolworths Home brand, Bella Vista, NSW, Australia) crumbles
Savoury	Meaty, leather, olives	0.5 tsp beef stock powder (Massel Australia), 1 cm piece of leather, and two slices of canned black olive (Woolworths Home brand, Bella Vista, NSW, Australia)
Pepper	White and black pepper	Pinch of each ground black and white pepper (Woolworths Home brand, Bella Vista, NSW, Australia) in 20 mL red wine
Palate		
Mouthfeel		
*Astringency	The dry puckering mouthfeel sensation	
*Tannin texture	From fine/smooth to coarse/rough tactile sensation	
Mouth coating	The sensation of a coating layer on oral tissues	
Heat	Sensation perceived in the mouth as warming, irritation, burning or stinging	
Taste	Sensation in the mouth associated with	
Acidity	The basic taste sour	Taste of lemon juice
Sweet	The basic taste sweet	Taste of sucrose
Bitter	The basic taste bitter	Taste of quinine
Flavour	Flavour of	
*Dark fruits	Plum, dark cherry, blueberry, black berry, black currant	Fresh black berry, blueberry and plum in 20 mL red wine
Dried fruits	Prune, fig, and raisins	One dried prune, fig and raisin sliced in 20 mL red wine
Herbaceous	Capsicum, tomato leaf, cut grass, and eucalyptus	Capsicum, diced in 20 mL red wine
*Sweet oak	As above	As above
*Smoky	Toasted bread, wood, and smoke	Burnt toast (Woolworths Home brand, Bella Vista, NSW, Australia) crumbles
*Savoury	Onion, garlic, potato, carrot, olives, and meat	0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather
Pepper	White and black pepper	Pinch of each ground black and white pepper (Woolworths Home brand, Bella Vista, NSW, Australia) in 20 mL red wine
Flavour length	Duration of lingering flavours after swallowing the sample that does not differ from the sensations perceived when it was in the mouth	

* Asterisk indicates the significant attributes by product.

Table A. 3. Sensory attributes of food and wine pairing samples with agreed definitions and reference standards. Asterisk marks the significant attributes by product.

Attribute	Definition	Reference
Flavour	Flavour of	
*Overall sensation dominance	Flavours of the food or wine dominates the overall sensation of the combination	
Flavour intensity	Dilute to concentrated	
Red fruits	Raspberry, strawberry, red cherry	One of each frozen raspberry, strawberry, cherry in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
Dark fruits	Plum, dark cherry, blueberry, black berry, blackcurrant	One of each fresh black berry, blueberry and plum in 20 mL red wine
*Sweet spice	Cinnamon, nutmeg, vanilla, and cocoa	2 drops of vanilla essence, dark chocolate shavings (Lindt, Kilchberg, Switzerland) and a pinch of cinnamon powder in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
Hot spice	Chilli, black pepper	Pinch of each ground black pepper (Woolworths Home brand, Bella Vista, NSW, Australia) in 20 mL red wine
*Savoury	Onion, garlic, potato, carrot, olives	Fried onion, 1 thin slice of carrots and 1 black olive
*Smoky	Toasted bread and smoke	Burnt toast (Woolworths Home brand, Bella Vista, NSW, Australia) crumbles
Dairy	Milk, yoghurt, sour cream, butter	1 tsp of full fat sour cream (Woolworths Home brand, Bella Vista, NSW, Australia)
*Meaty	Cooked beef, pork, stock, broth	0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather
Taste	Taste associated with	
*Acidity	The basic taste sour	
*Sweet	The basic taste sweet	
*Salty	The basic taste salty	
*Bitter	The basic taste bitter	
*Umami	Flavour enhancer	
Mouthfeel		
*Mouthfeel complexity	The sensation of simultaneously occurring sensations and textures	
*Chewiness	From tender to chewy/tough	From roast chicken slices (Primo Smallgoods, Chullora, NSW, Australia) to beef jerky (Jack Link’s, Wisconsin, United States)
*Body	Sensation of fullness in the mouth	Water, skimmed milk, full fat milk

Mouth coating	Sensation of a coating film in the mouth	From water to oil
*Astringency	The dry puckering mouthfeel sensation	Grapeseed extract (Tarac Technologies, Nuriootpa, SA, Australia) in white wine (Berry Estates Traditional Dry White Cask, SA, Australia) 0.5 g/L, 1 g/L, 2 g/L
*Heat	Sensation perceived in the mouth as warming, irritation, burning or stinging	

* Asterisk indicates the significant attributes by product.

Table A. 4. Detailed information of the food samples used in this study.

Food	Properties	Serving size
*Pasta with cheese sauce	Cooked from ingredients purchased at Foodland Supermarkets, Australia	8 pieces of penne pasta and 30 g of sauce
*Braised beef with potato puree	Cooked from ingredients purchased at Foodland Supermarkets, Australia	30 g of beef and 50 g of potato puree
*Chocolate mousse	Aeroplane, McCormick Foods, Australia	50 g
Fresh goat cheese	Fromagerie P. Jacquin, France	1 cm thick cut into half, 20 g
Cheddar cheese	Quicke's Traditional Ltd., UK, aged 18 months	2 pieces of 2 cm × 2 cm cubes, 20 g
Prosciutto ham	San Nicola Prosciuttificio del Sole S.p.A., Italy, aged 18 months	1 thin slice cut into half, 10 g
Spicy salami	Cacciatore (hot), Fabbris Smallgoods, Australia	2 thin slices cut into half, 10 g

*Asterisks indicate items tasted by the consumers.

Table A. 5. Recipes of the food samples used in this study.

Pasta

500g Penne (Barilla S.p.A., Italy)

30g unsalted butter (Foodland Australia PTY Ltd)

30g wheat flour (Foodland Australia PTY Ltd)

30g Parmigiano Reggiano, grated (Zanetti S.p.A., Italy)

1 clove garlic, minced

260ml chicken stock (Massel Australia PTY Ltd)

260ml whole milk, (Foodland Australia PTY Ltd)

4g salt (Foodland Australia PTY Ltd)

Preparation

1. In a pot, bring water to boil .
2. Add the pasta and cook for 8 minutes (al dente).
3. Remove the pasta from the boil, cool under cold running water, and reserve until required.
4. In a heated medium size pot, melt the butter, add the minced garlic, and cook until slightly golden in colour.
5. Whisk in the flour and add the milk and chicken stock while continuously whisking the mixture.
6. When the mixture starts thickening, add the salt and Parmigiano Reggiano.
7. Reheat the pasta and serve it with sauce on top.

Braised beef

800g beef gravy meat, diced into 2,5 cm

200g onion, quartered

10g salt (Foodland Australia PTY Ltd)

500ml beef stock (Massel Australia PTY Ltd)

1tsp corn starch (Foodland Australia PTY Ltd)

600g red potato, peeled, coarsely diced

120g unsalted butter (Foodland Australia PTY Ltd)

180g whole milk (Foodland Australia PTY Ltd)

4g salt (Foodland Australia PTY Ltd)

Preparation

1. In a soup pot, cover the potatoes with water, bring to boil and cook until soft (about 20 min), strain water and reserve.
2. In a hot pressure cooker, add 2 Tbsp vegetable oil and gently sweat the onion until tender.
3. Gently add the beef, stock and salt.
4. Secure lid and bring cooker to high pressure.
5. Reduce heat to stabilise pressure and cook for 35 minutes.
6. Release pressure according to manufacturer's instructions and remove lid.
7. Set aside the beef and blend the cooking liquid and onion with corn starch until smooth.
8. Bring the mixture to boil until the gravy thickens.
9. Add the beef back to the gravy and allow to cool.
10. Using a stick mixer, puree the potatoes, butter, milk and salt.
11. Reheat beef and potato puree if needed. Plate up the potato puree and spoon over beef and gravy.

Table A. 6. Composition of the Shiraz wines used in this study.

Wine	Vintage	Region	Degree days (°C)[a]	pH	TA (g/L)	Residual Sugar (g/L)	MCP tannin (mg/L)	Viscosity (m^2/s)	Ethanol (% ABV)	FreeSO2 (mg/L)	BoundSO2 (mg/L)
AH	2015	Adelaide Hills	1270	3.6	6.2	0.3	2011	1.63	14.8	16.8	24.8
BV	2014	Barossa Valley	1710	3.3	6.8	0.8	2754	1.70	15.1	4	60
BV2	2014	Barossa Valley	1710	3.8	6.1	0.8	2192	1.61	13.9	13.6	14.4
*CB	2015	Canberra District	1410	3.8	6.6	0.18	1423	1.59	14.1	17.6	35.2
CB2	2015	Canberra District	1410	3.6	6.1	0.4	1729	1.60	14.4	12.8	23.2
EV	2015	Eden Valley	1390	3.5	7.2	0.3	2049	1.61	14.2	7.2	18.4
*MV	2015	McLaren Vale	1910	3.5	6.7	1.01	3572	1.73	14.4	24.8	67.2
MV2	2014	McLaren Vale	1910	3.4	6.8	1.2	2272	1.63	14.3	15.2	28

*Asterisks indicate wines tasted by the consumers. [a] Classifies the climate of wine regions based on heat summation or growing degree-days

Table A. 7. Demographic information of the participating consumers across hedonic clusters (HC).

Demographics	HC1 n=18 (%)	HC2 n=36 (%)	HC3 n=22 (%)	HC4 n=32 (%)
Gender				
Male	*33.3 a*	*38.9 ab*	*36.4 ab*	*62.5 b*
Female	*66.7 a*	*61.1 ab*	*63.6 ab*	*37.5 b*
Education				
Finished High School	16.7	11.1	4.5	6.3
Community College	11.1	2.8	0	12.5
Bachelor's Degree	33.3	38.9	36.4	43.8
Postgraduate Degree	38.9	44.5	54.6	37.6
N/A	0	2.8	4.5	0
Household income (USD)				
Less than $15000	11.1	8.3	4.5	6.3
$15000-$25000	16.7	13.9	4.5	9.4
$25001-$35000	11.1	22.2	13.6	15.6
$35001-$50000	11.1	2.8	4.5	12.5
$50001-$75000	5.6	11.1	13.6	9.4
$75001-$100000	*5.6 ab*	*16.7 a*	*9.1 ab*	*0.0 b*
$100001-$150000	22.2	8.3	13.6	21.9
More than $150000	*16.7 ab*	*8.3 b*	*31.8 a*	*15.6 ab*
N/A	0	8.3	4.5	9.4
Spent on a bottle of wine (USD)		**Home**		
Under $10	5.6	8.3	4.5	6.3

$10-$15	16.7	36.1	31.8	31.3
$16-$25	55.6	41.7	31.8	34.4
$26-$40	5.6	11.1	27.3	25.0
$41-$60	*16.7 a*	*2.8 ab*	*0.0 b*	*0.0 b*
$61-$80	0	0	4.5	3.1
		Friends' house		
Under $10	5.6	0	0	0
$10-$15	5.6	22.2	13.6	25.0
$16-$25	55.6	50.0	50.0	31.3
$26-$40	27.8	25.0	31.8	28.1
$41-$60	5.6	2.8	4.5	12.5
More than $80	0	0	0	3.1
		Casual restaurant		
Under $10	0	8.3	4.5	3.1
$10-$15	*33.3 a*	*8.3 b*	*22.7 ab*	*25.0 ab*
$16-$25	33.3	44.4	36.4	40.6
$26-$40	27.8	30.6	27.3	21.9
$41-$60	5.6	8.3	9.1	9.4
		Fine restaurant		
$16-$25	11.1	8.3	9.1	9.4
$26-$40	33.3	47.2	36.4	40.6
$41-$60	44.4	27.8	40.9	25
$61-$80	5.6	13.9	9.1	21.9
More than $80	5.6	2.8	4.5	3.1

S-11

Chapter 5

Food and wine pairing: a tool for developing memorable dining experiences

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Principal Author

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Contribution to the Paper	Designed experiments, performed all sample preparation, trained panels for sensory descriptive analysis 16 food and wine pairings, recruited consumers (n = 151) and completed consumer trials, analysed and interpreted the data, drafted and constructed the manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Abstract

This study explored food and wine pairing-related gastronomic experience under blind and informed (wine provenance) conditions. Based on descriptive analyses, specific food and wine pairings (n=8) were selected for consumer tastings, which explored the pre-consumption, core (actual) consumption, and post-consumption experience in relation to the sensory profiles of food and wine pairings. During core consumption, information level significantly impacted ratings for sensory complexity and 15 emotion terms. Appropriate pairings corresponded with increased liking, sensory complexity, and expected prices for wine, and emotions of positive valence, but no pairing by information level interactions were evident. In the post-consumption experience, information level affected the vividness of the tasting, whereas the most appropriate pairings commanded significant vividness, remembered liking, memorability and loyalty ratings. The significant pairing by information level interaction on remembered liking may be beneficial for the word-of-mouth effect. Appropriate pairings may be important for positive gastronomic experiences, and could provide businesses with higher customer satisfaction and spending.

Key words

Sensory Descriptive Analysis; Consumer Experience; Food and Wine Pairing; Emotion; Memory

1 Introduction

1.1 Food and wine pairing as a marketing tool

Food and beverage pairing is valued by consumers and represents an innovative and profitable strategy for the hospitality and wine sectors to meet consumers' demands (Bastian, Collins, & Johnson, 2010; Pettigrew & Charters, 2006). Good food and wine pairing recommendations may lead to an estimated 45% increase in wine sales in the hospitality setting (Wansink et al., 2006); and food recommendations are an important consideration for consumers when buying wine on the retail market (Lockshin and Corsi, 2012). As a strategy designed to generate revenue and profit, many Australian wineries have adopted food and wine pairing themed tastings as part of their cellar door (tasting room) experience (Alant and Bruwer, 2004), where nearly 20% of expenditure is on food/dining-related purchases (Bruwer et al., 2014).

Food and wine pairing and the related gastronomic experience of consumers have also attracted the attention of researchers in the hospitality, marketing and sensory science disciplines. Most studies based the success of a food and wine pairing on hedonic responses to how specific attributes of food and wine are changed by pairings (Bastian et al., 2010; Donadini, Fumi, & Newby-Clark, 2015; Harrington & Seo, 2015). However, this disregards the holistic approach of understanding the contemporary consumption society (Demir et al., 2009), especially in the co-value created servicescape. Nowadays, consumers want more than just the delivery and consumption of a product or service, and instead seek to immerse themselves in experiences on an emotional level (Walls et al., 2011). In particular, foods and wines are seen as experiences rather than possessions: they are transformed into an experience after purchase (Gómez-Corona and Valentin, 2019). This is especially important in the hospitality sector where the growing trend has been to deliver experiences through a unique consumption context and service. The goal of this trend is to alter consumers' overall quality perception of the product through the consumer experience (Lefebvre and Orlowski, 2019) and in turn, their willingness to pay for goods and services and possibly for them to disseminate positive word-of-mouth recounts (Carpio and Isengildina-Massa, 2009). However, no specific studies addressing how wine sensory attributes and food and wine pairing affect the overall dining experience exist. Hence, the present research study aims to generate insight for the hospitality, wine and tourism service providers by evaluating the power of food and wine pairing on gastronomic experiences.

1.2 Literature review

1.2.1 Consumer experience

In the wine and hospitality industries, where competing operations offer very similar 'products', Pine and Gilmore (1999) suggest that businesses need to provide "experiences" that go beyond mere customer satisfaction. Hemmington (2007) goes even further, stating "customers do not buy service delivery, they buy experiences; they do not buy service quality, they buy memories." While the concept of consumer experience has no clear definition, it is arguably more than just a one-time transaction or simple linear journey (Laming and Mason, 2014). Instead, successful experiences are built around pre-consumption, core consumption and remembered/post-consumption moments (Mäkelä and Simpura, 1985). Whilst this is accepted 'theory and practice', there is little experimental work conducted to develop the science of consumer experience of food and wine pairing.

Pre-consumption expectations are paramount for product or service success and may be based on extrinsic cues such as price, packaging, labelling, brand name, origin, tasting notes and/or consumers' previous experience (Danner et al., 2017; Iaccarino et al., 2006; Laureati et al., 2013; Napolitano et al., 2010). Expected sensory attributes can be confirmed or refuted by tasting (Deliza and MacFie, 1996). Confirmed expectations lead to satisfaction, and also refuted expectations when a positive disconfirmation occurs; however, negative disconfirmation will lead to product rejection (Deliza and MacFie, 1996). The result of both events (confirmation or disconfirmation) will affect the hedonic liking of the product and also the next experience with the product, contributing either to raising or lowering a consumer's expectations (Yeomans, Chambers, Blumenthal, & Blake, 2008).

As a pre-consumption cue, European wine provenance in particular, has been an associated with wine quality expectations and in turn, consumers learned to rely on it and to pay a premium for it (Benfratello et al., 2009; Casini et al., 2009). Establishing a fine wine image according to provenance has been of interest for Australia to extend beyond single variety and brand associations. As consumers increasingly give importance to where their food and wine come from (Bruwer and Johnson, 2010; Easingwood et al., 2011; Feldmann and Hamm, 2015; Skuras and Vakrou, 2002), it is paramount for the hospitality, tourism and wine industries to provide local goods and services e.g., food and wine pairing recommendations to meet consumer expectations and extend regional marketing.

During core consumption, consumers' perceive intrinsic product cues (sensory characteristics) and their interactions as flavour. Furthermore, multiple external product cues (e.g., texture of serving bowl, weight of the glass, colour of lighting) create sensory expectations due to cross-modal correspondences, which in turn influence perceived flavour (Spence and Piqueras-Fiszman, 2014). The sensory experience of products is widely assumed to explain consumers acceptability and/or liking (Köster, 2009). Yet flavour perception does not end at the interactions between our sensory modalities of sight, hearing, smell, taste, and touch, there are intrinsic consumer characteristics (e.g., memories, emotions, genetics, cultural impacts) involved as well (Charters and Pettigrew, 2008; Danner et al., 2017). This is also known as the "Proustian moment", a vivid nostalgic journey taken upon dipping madeleine cake into tea (Sutton, 2001).

Based on our past experiences, we tend to couple memories with certain aromas and flavours (King and Meiselman, 2010), and memories evoke emotions, which will impact the perceived flavour and thus the gastronomic experience. Wine in particular is strongly bonded with emotional concepts evoked by sensory attributes, social associations and memories (Ristic et al., 2019). Arousing a consumer's involuntary memory through suggestions from staff communication during the experience of wine tasting might therefore prove to be a defining moment in the consumer adopting and generating positive word-of-mouth for the wine brand (Famularo et al., 2010). The interaction of extrinsic and intrinsic cues involved in building an experience influences the arousal potential (Lévy et al., 2006) and also the sensory complexity of food and wine (Masson et al., 2016). Studies have been carried out to link food and wine sensory attributes with emotions (Danner et al., 2016; Pham et al., 2008; Porcherot et al., 2012) but evoked emotions of food and wine pairings in the context of consumer experience has not been explored. As consumers are becoming more adventurous and seek experiences, good pairing recommendations may be crucial for the market success of foods and beverages, both in the retail and hospitality sector and in a financial and marketing sense (Paulsen et al., 2015; Wansink et al., 2006).

Post-consumption or remembered consumption experiences are particularly important for the wine and hospitality sectors because developing emotional bonds with customers improves loyalty and stimulates customers to advocate the brand/service to others (Schuler et al., 2011). Measures of post-consumption behaviour such as vividness, remembered liking, satisfaction, repeat intention, and memorability are believed to reflect the overall consumer experience and can provide an avenue for recommendations, positive word-of-mouth as well as repeat interaction (Krishna, 2012; Laming and Mason, 2014; Schuler et al., 2011; Wiedmann et al., 2013). For example, tourism research has emphasised tourist satisfaction and memorable experiences as driving revisits and found that tourists recall past experiences when deciding to travel and search for specific destinations (Kim et al., 2010).

In particular, consuming local food while exploring the local culture was demonstrated to generate positive memories and further enhance strong attachment to memorable experiences of travel destination (Tsai, 2016). Furthermore, a recent study by Saayman and van der Merwe (2015) identified factors that contributed to memorable wine-tasting experience at wineries, such as attributes of the winery, themes and activities, education, and novelty. In the dining experience context, the providers of unique, novel and imaginative products/services could gain a competitive advantage over those hospitality operators who continue to offer food and wine pairings based on outdated guidelines.

Food and wine pairing has been a valuable tool for the hospitality and wine industries to increase consumer satisfaction and spending; however, to address more contemporary experience-driven consumer needs, this study set out to investigate pre-consumption effect on core and post-consumption consumer experiences of food and wine pairings. As consumers are interested in wine and food provenance and extrinsic information is known to impact the consumption experience, it was hypothesised that information provided about wine provenance during pre-consumption will positively influence the consumers' core consumption experience (liking, sensory complexity, evoked emotions, expected price to pay) and post-consumption experience (vividness, remembered liking, memorability, and loyalty). The hypothesis that positive core consumption experience will be followed by positive post-consumption experience was also tested.

2 Methods and Materials

2.1 Experimental overview

The experiments consisted of three separate sensory descriptive analysis (DA) panels with trained assessors to obtain detailed sensory profiles of singular foods and complex dishes, wine, and then food and wine pairings.. Selected food and wine pairings identified from the food and wine pairing DA were utilised in a three-stage consumer test, which aimed to define the gastronomic experience related to the sensory characteristics of the food and wine pairings and to examine the relationships between level of wine provenance information with gastronomic related consumer emotions, consumption experience and behaviour parameters. Details of all stages are outlined below. All sensory evaluations and the consumer testing were conducted using RedJade Sensory Software (RedJade Software Solutions, LLC). The study was performed in accordance with the ethical guidelines for scientific research at The University of Adelaide and approved by the Human Research Ethics Committee (approval number: H-2016-150).

2.2 Food samples

Foods that scored highly to go well with Shiraz were considered, based on an online consumer survey specific to fine Australian Shiraz wines (Kustos et al., 2019). The food samples and recipes were finalised after a benchtop evaluation of creamy pasta, braised beef, braised lamb, Greek salad, fresh goat cheese, brie, camembert, two types of cheddar cheese, Italian prosciutto, apple pie, and chocolate mousse by experts (n=4, sommeliers, winemaker, wine educator) (Parr et al., 2004). Seven dishes and singular foods (pasta with cheese sauce, braised beef with potato puree, chocolate mousse, fresh goat cheese, clothbound cheddar cheese, prosciutto ham, and spicy salami (cacciatore)) were chosen for the DA by the expert panel (Table A.1). The number of samples was capped at four due to the complexity and fatigue of the food and wine pairings task and the preparation of food samples. The final food samples were selected to cover items of a regular meal representing a normal consumption experience for consumers: savoury snack, starter, main, and dessert. The pasta and beef dishes were prepared for the study according to the recipes in Table A.2, stored at 7 ˚C and reheated at 60 ˚C for 1 hour before serving. The mousse was prepared from a powdered mix according to the instructions on the packet (Aeroplane chocolate flavoured mousse, McCormick Foods Australia) and stored at 7 ˚C overnight. The spicy salami was sliced prepared into individual portions two hours prior the tasting sessions and stored at room temperature. The foods were assessed in duplicate and presented individually in each session in 4-digit coded, clear plastic containers with 60 s between samples.

2.3 Wine Samples

From a larger group of eight Shiraz wines (Table A.3), which underwent DA (Lawless and Heymann, 2010), four wines that possessed very different aroma, taste, mouthfeel and flavour attributes were chosen to be evaluated in the food and wine pairing DA (Figure A.2). For the consumer test, two Shiraz wines, one from a warm climate region (McLaren Vale, MV) and one from a cooler climate region (Canberra District, CBR) of which vintage was available in larger quantities were chosen by three wine experts (Parr et al., 2004). These wines displayed very distinct sensory characteristics, differed in retail price (MV AU$65 and CBR AU$36), were made in the same vintage (2015), and were both awarded 97 points by wine critics (see Table A.3 for technical information). Wines were stored at 15 °C prior to all sensory experiments, and equilibrated at room temperature (22-23 °C) for two hours prior to serving. The wines were assessed in duplicate and presented individually in a randomised order during each session, with a 60 s pause between samples.

2.4 Sensory Descriptive Analysis of food and wine pairings

Seven sensory assessors (three female, four male) with previous DA experience were recruited as panellists. The panel was instructed to taste food and wine combinations following the mixed tasting method (Nygren, Gustafsson, & Johansson, 2003). Four training sessions of 120 min were held, in which four foods and four wines were presented in pairings (n=16). Samples were presented as outlined above in the food and wine samples sections. Each bite of food was evaluated with 8 mL (i.e., a mouthful) of wine. Some pairings underwent duplicate evaluations to examine the reproducibility of the panel. The final training session was carried out under identical conditions to the formal sessions, and the formal evaluation commenced once there were no significant judge-by-sample interactions. Panellists decided not to assess the aroma of pairings, and a list of 22 sensory attributes including 5 taste, 6 mouthfeel and 11 flavour attributes were rated for each pairing on a 10 cm scale with anchors of low and high placed at 10% and 90% of the line, respectively. Reference aroma standards (Table A.4) for the flavour attributes were provided prior to evaluation in covered glasses. The 8 pairings were assessed individually in duplicate and presented in a randomised order in each session, in 4-digit coded, clear plastic containers with 5 min breaks after four foods and 60 s intervals between samples. The final evaluation sessions were held on the same day with a 30 min break in between sessions.

2.5 Consumer preference test

Wine consumers were recruited using an in-house wine consumer database and via social media platforms. Prospective participants were screened against inclusion criteria, requiring them to be of legal drinking age (≥ 18 years of age), permanent Australian residents or citizens, having consumed Shiraz wine at least once a month, and who on average ate at restaurants once a month over the past year. A total recruitment of 151 South Australia based food and wine consumers completed an online survey about their wine related behaviour and demographics via Qualtrics (see Table 1 for basic demographic information of the consumer sample).

Table 1. Demographic characteristics of the consumers completing the preference test (n = 151).

	% of total (n = 151)
Gender	
Male	48.3
Female	51.7
Age	
18-34	13.2
35–49	20.5
50-64	46.4
Over 65	19.9
Education	
No tertiary	24.5
Bachelor degree	31.8
Postgraduate degree	43.7
Household income (AUD)	
<$50,000	18.5
$50,001–$100,000	37.7
$100,001–$200,000	35.8
>$200,000	7.9
Wine consumption frequency	
More than 3 times a week	45.7
2-3 times a week	38.4
Once a week	11.3
Once every 2 weeks	3.3
Once a month	1.3

The consumer testing took place at the Waite Campus sensory laboratory of The University of Adelaide in individual tasting booths. Three tasting sessions were scheduled on each of the tasting days between 4 pm and 7 pm with up to 12 consumers per session. Upon completing the pre-tasting online survey, the first half of the consumers (n = 73) were allocated to blind condition and the second half to informed condition (n = 78). In the blind tasting condition, consumers did not receive any information about the wine samples, while in the informed tasting condition, wine samples were presented with their provenance (Canberra District or McLaren Vale). The presentation order of food samples was standardised across consumers (pasta, beef, mousse, and spicy salami) and intended to represent a real life dinner with starter, main, and dessert course items. As the spicy hot salami dominated all pairings in the DA (Table 2), it was presented last to avoid palate fatigue. With each food sample, consumers received the two wine samples, one at the time. Wine samples (15 mL) were presented in clear 215 mL ISO glasses coded with 3-digit codes for each food sample, under fluorescent white light. Consumers received both verbal and written instructions about the mixed-tasting method (Nygren, Gustafsson, & Johansson, 2003) as follows: subjects were told to take a small bite of food and then a sip of wine, slowly chew and savour the flavours, expectorate the samples and then evaluate the wine and food pairing. Participants were asked to evaluate the liking, appropriateness of pairing, and dominance of either food or wine (as an indirect measure of balance (Bastian et al., 2010)), number of flavours perceived (as an indirect measure of sensory complexity (Meillon et al., 2010)), intensity of evoked emotions (AWEEL (Danner et al., 2016)) and expected price to pay for wine in the pairing. Liking and appropriateness of pairing were rated on 9 point scales and the other measures on 7 point scales. The balance scale ranged from food dominates highly (1) to wine dominates highly (7), with no dominance in the middle (4), and for data analysis and discussion the deviation from no dominance was calculated by subtracting no dominance (4) from the balance score. The number of flavours perceived scale ranged from few (1) to many (7). Distilled water and crackers were provided as palate cleansers, and panellists were required to have a 1 min break between each of the 8 pairing samples.

One week after the consumer test, participants were asked to answer a short questionnaire about their experience during the tasting, to investigate the effect of core consumption measures and wine provenance information on memorability and consumer loyalty to wines.

The questionnaire included retrospective liking and vividness of memories scales adopted from the research of Ali, Hussain, and Ragavan (2014). Participants received an AU$20 gift voucher to an Australian supermarket chain upon completion of both the taste test and follow up questionnaire.

2.6 Statistical analysis

The DA data were analysed by three-way analysis of variance (ANOVA) with main effects (product, judge, and replicate) as well as all interactions (product × judge, product × replicate, judge × replicate) assessed for all attributes. When product by judge or product by replicate interaction effects and the product main effect were significant ($p < 0.05$), a pseudomixed model (Næs & Langsrud, 1998) was used to determine the importance of the interaction effect. If the new F-value was still significant at $p < 0.05$, the interaction was not important and the product effect was still significant. However, if the new F-value was not significant, the interaction effect was significant and the product effect was not anymore. Pair-wise comparison of the mean values was calculated by using Fisher's least significant difference (LSD).

Significant sample attribute means from sensory analysis were subjected to Pearson (n) correlation type principal component analysis (PCA) with the significant emotions and consumer tasting data as supplementary variables. PCA was used to reduce the number of variables and to explain the relationships among the variables and the wines. The number of principal components used for PCA was determined from scree plots.

Two-way ANOVA with pre-consumption information (blind vs informed) and sample (pairings) as main effects, and interactions (information × sample) were carried out on core consumption and post consumption measures to investigate the effect of wine provenance on consumers' gastronomic experience. Pearson correlation was used to explain the relationships between core and post consumption variables. All statistical analyses were performed with, XLSTAT version 2018.5 (Addinsoft, New York, USA) at 5% level of significance.

3 Results and Discussion

3.1 Sensory descriptive analysis of food and wine pairings

The sensory DA panel evaluated pairings based on foods and wines that possessed very different sensory attributes in flavour, taste and mouthfeel (Figure A.1). From the selected food samples, the pasta with cheese sauce was described as dairy and mouth-coating, the braised beef with potato puree possessed intense savour flavour, and complex mouthfeel, the chocolate mousse was smooth, sweet, with sweet spice flavour), and the spicy Italian salami was spicy, with intense meaty flavour. The two Shiraz wines selected for the consumer testing, represented the stylistic diversity of the variety from cool and warm climate regions (Iland, 2009). CBR Shiraz was characterised by herbaceous and red fruits attributes, smooth tannins, low astringency and also the lack of oak derived aromas and flavours (sweet oak, toasted wood). MV Shiraz possessed dark fruits, sweet oak, toasted wood attributes, with coarse tannins and high astringency. Consequently, the selected food and wine samples were evaluated in pairings by the DA panel

All attributes were significant ($p < 0.05$) across the pairings, except for dark fruits ($F = 4.376$, $p = 0.575$) and red fruits ($F = 3.192$, $p = 0.065$), which were not presented further in this study. More specifically, the significant differences were driven by the food element of the pairing except for smoky ($F = 3.052$, $p = 0.158$) and sweet oak ($F = 9.784$, $p = 0.055$), which were highly significant ($p < 0.0001$) by the wine. This result aligns with the findings of Nygren et al (2003) about the dominance of the food element of pairings, and hence it could be preferable to serve wine prior to food during food and wine pairing dinners in order to offer the best experience.

The overall sensation of dominance measured whether the food (negative direction), the wine (positive direction), or neither (zero) dominated the combination. From all pairings (Table 2), Pasta was moderately dominated by both wines, Salami highly dominated over both wines, Mousse was just slightly dominated by both wines, and Beef was on par with the CBR and MV Shiraz. In the pairwise comparison, PastaMV, BeefCBR, SalamiCBR and SalamiMV were significantly different. SalamiCBR and SalamiMV had significantly higher flavour intensity than BeefCBR, MousseCBR, MousseMV, PastaCBR and PastaMV. Sweet spice discriminated MousseCBR and MousseMV whereas hot spice set apart SalamiCBR and SalamiMV from all other pairings (Table 2). BeefCBR was significantly higher and MousseCBR and MousseMV were significantly lower in savoury flavour than other pairings. Smoky described MV wine and food pairings, which were significant in the case of BeefMV and MousseMV (Table 2). Smoky aroma/flavour is commonly ascribed to fermentation and maturation of wine in toasted oak barrels (San Juan et al., 2012), which characterised MV Shiraz in the wine DA (Figure A.2). SalamiCBR and SalamiMV scored significantly lower on dairy flavour than other pairings, which was sensible given that salami was the only food not containing a dairy ingredient. As could be anticipated, BeefCBR and BeefMV were significantly meatier than others. All MV wine and food pairings were dominated by sweet oak flavour (Table 2), which appeared to be significant for PastaMV and SalamiMV, and reflects the higher proportion of new oak (100% vs 30%) and extended oak maturation (17 months vs 12 months) of MV Shiraz (data obtained from the wineries). All pairings were at least moderately acidic, however a suppressing effect of salty Beef and Salami may explain the decreased acidity perceived for both wines compared to Pasta and Mousse (Keast and Breslin, 2003). MousseCBR and MousseMV were significantly sweeter than all pairings, which was to be expected for such a dessert. Beef and Salami wine pairings were significantly more salty and umami and had higher mouthfeel sensation complexity than others, which might have resulted from visual appearance complexity and flavour interactions (Mielby et al., 2013). Pairings ranged from low to slightly bitter and only the Beef pairing was significantly different between wines. SalamiCBR and SalamiMV had significantly higher chewiness and heat, and were significantly lower in body than other pairings. MousseMV was the most astringent, while BeefCBR the least: sweet foods tend to increase dry red wine astringency whereas meat proteins are believed to bind with wine tannins, thereby decreasing astringency perceptions (Madrigal-Galan and Heymann, 2006).

Table 2. Sensory profiles of the food and wine pairings determined by descriptive analysis (n = 7).[a]

	PastaCBR	PastaMV	BeefCBR	BeefMV	MousseCBR	MousseMV	SalamiCBR	SalamiMV
Overall sensation dominance[b]	17.1 ab	28.5 a	-2.7 b	6.8 ab	13.9 ab	13.7 ab	-30.2 c	-30.1 c
Flavour intensity	51.1 d	63.7 c	67.1 bc	70.7 abc	58.5 cd	60.6 cd	77.8 ab	80.4 a
Sweet spice	5.3 c	19.8 b	10.6 bc	13.3 bc	65.4 a	65.6 a	9.2 bc	16.0 bc
Hot spice	6.7 c	6.1 c	15.9 b	10.4 bc	5.5 c	5.7 c	82.1 a	81.4 a
Savoury	44.9 b	40.9 b	65.6 a	54.9 ab	4.4 c	5.8 c	42.1 b	43.0 b
Smoky	12.4 bc	32.1 ab	12.9 bc	37.3 a	6.3 c	39.4 a	27.8 abc	39.0 a
Dairy	33.1 a	33.1 a	30.5 a	33.8 a	36.1 a	38.9 a	6.3 b	5.8 b
Meaty	5.6 c	5.4 c	74.4 a	73.1 a	5.1 c	5.0 c	63.0 b	55.4 b
Sweet oak	8.5 c	29.3 ab	18.0 bc	27.7 ab	23.1 ab	31.2 ab	7.4 c	32.1 a
Acidity	68.6 abc	70.4 a	52.2 bc	56.6 abc	68.6 abc	69.9 ab	51.5 c	56.9 abc
Sweet	18.5 b	22.0 b	20.4 b	20.2 b	48.4 a	49.9 a	23.2 b	19.9 b
Salty	25.2 b	25.1 b	43.7 a	45.8 a	8.1 c	9.3 c	43.5 a	44.4 a
Bitter	13.2 bc	17.4 abc	10.2 c	23.9 ab	19.9 abc	28.1 a	11.6 bc	15.8 abc
Umami	14.1 b	13.8 b	54.9 a	56.6 abc	5.6 b	5.6 b	47.9 a	46.4 a
Mouthfeel sensation complexity	44.8 b	48.6 b	66.5 a	70.5 a	36.9 b	38.3 b	65.6 a	72.1 a
Chewiness	56.6 c	57.4 c	75.8 b	76.0 b	6.6 d	5.8 d	85.3 a	84.6 a
Body	41.9 b	52.6 ab	53.4 ab	60.8 a	48.4 ab	54.3 ab	40.9 b	44.6 b
Mouthcoating	41.9 ab	45.8 ab	48.4 a	55.2 a	44.6 ab	47.6 a	28.9 b	39.0 ab
Astringency	39.9 bc	56.4 ab	33.1 c	44.8 abc	45.2 abc	60.6 a	43.0 abc	50.1 abc
Heat	53.6 c	64.9 bc	62.6 bc	62.5 bc	63.1 bc	71.4 b	87.7 a	91.0 a

[a]Only sensory attributes discriminating between pairings at $p < 0.05$ are presented . Significant differences among means within a row are represented by different lower case letters (post-hoc comparisons, Fisher LSD). [b]A positive number indicates dominance of the wine and a negative number indicates dominance of the food..

3.2 Core consumption experience in relation to sensory profiles of food and wine pairings

Significant sample effect was observed for liking (F = 4.271, p = 0.0001), appropriateness of pairing (F = 10.496, p = < 0.0001), sensory complexity (F = 9.043, p = < 0.0001), expected price (F = 9.599, p = < 0.0001), and deviation from balance (F = 33.622, p = < 0.0001), which means the food and wine pairings impacted the consumers' core consumption experience (Table 3). PCA was performed on the significantly different sensory attributes, with significant emotions and consumer tasting data as supplementary variables. The first three principal components (F1-F3) accounted for 91% of the total variance. The most liked pairings (lower right quadrant in Figure 1a) were described by higher values for savoury (*r* = 0.782), meaty (*r* = 0.803), salty (*r* = 0.749), umami (*r* = 0.813), mouthfeel sensation complexity (*r* = 0.720), chewiness (*r* = 0.636), and body (*r* = 0.537), and were lower in sweet spice (*r* = -0.582), acidity (*r* = -0.678), sweetness (*r* = -0.579), and astringency (*r* = -0.487). Consumers' preference for wines with higher flavour intensity is well known (Jackson, 2016), and although savoury wines may be less favourable on their own (Johnson et al., 2013; Lattey et al., 2010), consumers may enjoy them in a food and wine pairing context. The most liked pairings were also considered more appropriate (*r* = 0.667), had higher sensory complexity (*r* = 0.513), and consumers expected to pay more (*r* = 0.469) for them irrespective of information level. Therefore, the most appropriate pairings were higher in meaty (*r* = 0.625), sweet oak (*r* = 0.422), umami (*r* = 0.560), mouthfeel sensation complexity (*r* = 0.458), body (*r* = 0.779), and mouthcoating (*r* = 0.619). BeefMV was significantly more appropriate than other pairings (Table 3), but it was not significant from BeefCBR, SalamiCBR and PastaMV despite of receiving the highest liking score (Table 3). Thus, liking and appropriateness may correlate (*r* = 0.667), but they measure different information. While the appropriateness of pairing may not be a direct predictor for consumer preferences, it seems to have a highly positive relationship with sensory complexity (*r* = 0.777) and expected price (*r* = 0.856). In fact, consumers expected to pay 21% more for CBR Shiraz and 23% more for MV Shiraz in the most appropriate pairings compared to the least appropriate pairings (Table 3). This result extends the existing literature on the monetary benefits of pairing wine with food (Bastian et al., 2010; Wansink et al., 2006) by showing that if hospitality operators present appropriate food and wine pairings opposed to average, they may expect further financial gain.

Table 3. Mean values and Standard deviations (SD) of core consumption ratings. Lower case letters indicate significant differences across food and wine pairings based on post-hoc comparisons using Fisher's LSD p<0.05.

		Mean	SD	Sig
Liking	BeefMV	6.6	2.0	a
	BeefCBR	6.4	1.7	ab
	SalamiCBR	6.1	1.8	bc
	PastaMV	6.0	1.8	bc
	PastaCBR	5.8	1.7	c
	SalamiMV	5.8	2.1	c
	MousseCBR	5.7	2.1	c
	MousseMV	5.7	2.3	c
Appropriateness of pairing	BeefMV	7.0	2.0	a
	BeefCBR	6.3	2.0	b
	MousseMV	6.1	2.5	bc
	SalamiMV	5.9	2.3	bcd
	MousseCBR	5.8	2.3	bcd
	SalamiCBR	5.6	2.0	cd
	PastaMV	5.4	2.3	de
	PastaCBR	5.1	2.2	e
Deviation from balance*	PastaMV	1.4	1.1	c
	PastaCBR	1.0	1.1	c
	BeefMV	0.5	1.2	bc
	MousseMV	0.4	1.3	bc
	MousseCBR	0.3	1.4	b
	BeefCBR	0.2	1.2	bc
	SalamiMV	-0.7	1.5	a
	SalamiCBR	-0.8	1.5	a
Sensory complexity	BeefMV	4.8	1.3	a
	SalamiMV	4.8	1.6	ab
	SalamiCBR	4.6	1.5	ab
	BeefCBR	4.5	1.1	ab

	MousseMV	4.5	1.4	b
	MousseCBR	4.2	1.4	c
	PastaMV	4.1	1.4	c
	PastaCBR	3.9	1.3	c
Expected price	BeefMV	3.4	1.3	a
	MousseMV	3.2	1.4	ab
	SalamiMV	3.2	1.3	ab
	BeefCBR	3.0	1.1	bc
	SalamiCBR	2.9	1.1	cd
	PastaMV	2.8	1.1	cde
	MousseCBR	2.7	1.2	de
	PastaCBR	2.5	1.1	e

*0 = balance between food and wine, (+) = wine dominates, (-) = food dominates the pairing

Although complexity is not an easily defined concept (Mielby et al., 2013), consumers and trained panellists seemed to agree: sensory complexity positively related to pairings with higher flavour intensity, mouthfeel sensation complexity, chewiness and body, confirming the link between complexity and flavour and texture stimuli (top right quadrant in Figure 1b) (Sunarharum et al., 2014; Weijzen et al., 2008). On the other hand, the balance between food and wine seemed to be a poor predictor for liking (r = -0.032) and appropriateness of pairing (r = -0.205) (Figure 1b), contradicting the anecdotal belief that ideal pairings emerge from equal flavour intensities between food and wine (King and Cliff, 2005). BeefCBR was the most balanced (mean = 0.2), whereas with SalamiCBR (mean = -0.8) and PastaMV (mean = 1.4) the food or wine dominated, respectively, yet consumers similarly liked all three pairings (Table 3).

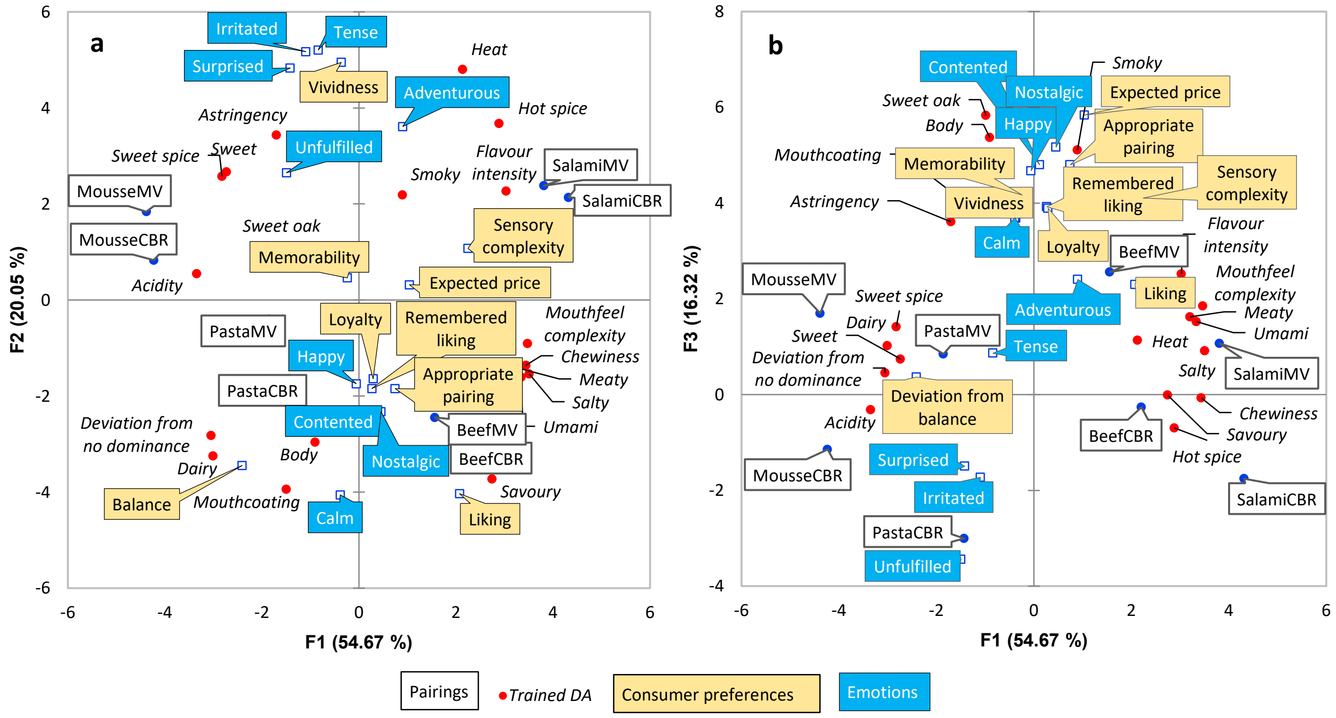

Figure 1. PCA biplots (F1&F2 and F1&F3) of Shiraz wine and food pairings with significant descriptors arising from the descriptive analysis as main variables and consumer preferences and evoked emotions as supplementary variables.

Additionally, liking is the standard measurement to predict product/service success, and appropriateness, but sensory complexity showed higher positive correlation with expected price (r = 0.889), therefore using a combination of these factors might better expresses the complex nature of consumer experience (Schuler et al., 2011). No significant information level by pairing interactions were found.

3.2.1 Pre-consumption information effect on core consumption experience

This study hypothesised that providing pre-consumption information about the provenance of the wine would positively influence the core-consumption experience. Two-way ANOVA was performed to investigate the main and interaction effects of information and sample and their interactions on consumers' core consumption experience, namely, their ratings for liking, appropriateness of pairing, sensory complexity, expected price and balance ratings. Previous studies showed that presenting product information (e.g., provenance, production, tasting notes) can significantly influence liking ratings (Danner et al., 2017; Mueller and Szolnoki, 2010; Siegrist and Cousin, 2009) but providing the provenance of the wines did not impact consumers' scores for liking (F = 0.255, p = 0.614), appropriateness of pairing (F = 0.090, p = 0.765), expected price (F = 1.084, p = 0.298) or balance (F = 0.005, p = 0.943) in the present work. On the other hand, there was a significant inverse effect of information on sensory complexity (F = 10.374, p = 0.001) whereby consumers perceived significantly less aromas and flavours when wine provenance was provided. It is possible that as food suppressed the sensory properties of the wines, consumers could not fully match the perceived wine attributes with the wine region information and their expectations, and the slight negative disconfirmation affected the perceived sensory complexity but not liking (Palczak et al., 2019). Moreover, it is important to note that previous studies assessed information effects on single item products instead of the complex matrices of food and wine pairings (Danner et al., 2017; Iaccarino et al., 2006; Laureati et al., 2013; Napolitano et al., 2010). Describing or assessing wine alone is not easy and evaluating food and wine samples in pairings may be an even more complex task that simultaneously involves multiple sensory modalities (Hopfer and Heymann, 2014). Although pre-consumption information partly affected the perceived sensory complexity of core consumption experience, no significant information level by pairing interactions were found. In the following, consumers across information conditions were considered as one group to explore pairing effect on core consumption experience in relation to DA.

3.2.2 Evoked emotions during the core consumption experience

The two-way ANOVAs revealed a significant information level effect on 14 out of the 19 pairing-evoked emotions, including embarrassed, envious, irritated, lonely, nostalgic, optimistic, panicky, passionate, relaxed, sad, surprised, tense, unfulfilled and warm-hearted (Figure 2). Informed conditions promoted more intense positive emotions of warm heartedness, optimism, passionate and positive surprise, and blind conditions increased the negatively valanced emotions of panicky, sad, tense, irritated, lonely, envious (Figure 2). These results are in agreement with recent studies of an array of extrinsic product attributes such as branding (Spinelli et al., 2015), sensory and producer description (Danner et al., 2017) and congruency (Silva et al., 2017) which can significantly influence product evoked emotions. Extending previous findings that food and wine pairing recommendations can increase wine sales (Danner et al., 2016; Wansink et al., 2006), sensory and producer information of the wine presented by hospitality staff may engage customers on an emotional level, possibly raising the opportunity for upselling wine in restaurants/cellar doors.

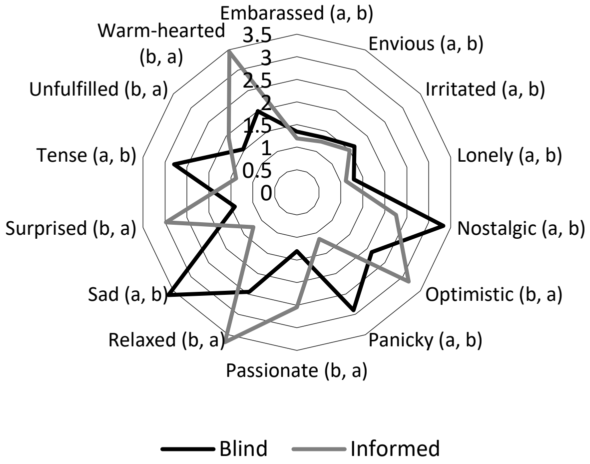

Figure 1. Food and wine pairing experience-evoked emotion profiles for two different information levels (blind or wine provenance information). Emotion intensities were rated on a 9-point scale ranging from 1 = not at all to 9 = extremely. Only emotion terms that discriminate between information conditions ($p < 0.05$) are presented. Lower case letters indicate significant differences in evoked emotion intensities across information levels based on post-hoc comparisons using Fisher's LSD $p < 0.05$.

Out of the 19 emotion terms investigated, 9 were significantly discriminated between pairings (Table 4). When looking at the pairing effect in more detail, the results showed the tasted food and wine pairings evoked weak to moderately intense emotions of positive valence (range 1.9 to 4.1 on a 9 point scale, Table 4). Comparing the pairings, BeefMV evoked significantly more intense emotions of calm, and happy, compared to SalamiCBR, PastaCBR, PastaMV, nostalgic compared to PastaCBR, SalamiCBR, optimistic compared to PastaMV, and contented compared to MousseCB, SalamiMV, SalamiCB, PastaMV, PastaCB. The significant positive valence of emotions has been shown to differentiate warm climate wines from cool climate wines (Coste et al., 2018), and this study positively distinguished the warm climate MV Shiraz in food pairing (BeefMV) as well. BeefMV commanded the highest liking and appropriate pairing scores, and extending the positive correlation between liking and sensory complexity, positive emotions linked with sensory complexity too (Figure 1).

MousseMV evoked the most intense adventurous emotion and was significantly greater than PastaMV. Traditionally, desserts are paired with sweet dessert wines (Harrington, 2007), thus when tasting the unconventional MousseMV (chocolate mousse paired with dry red wine) a positive disconfirmation may have occurred (Deliza and MacFie, 1996) evoking adventurous emotion. Unconventional food and wine pairings can be perceived as novel, which positively influenced hedonic responses (Lévy et al., 2006) and thus it may be a considerable strategy for hospitality operators and cellar doors to induce positive consumer experience. Emotions of negative valence were evoked to a low extent and only tense and unfulfilled discriminated between pairings. Mousse CBR and MousseMV evoked more intense tense emotion than BeefCBR whereas PastaCBR evoked more intense unfulfilled emotion compared to BeefCBR and BeefMV. MousseCBR and MousseMV were significantly less liked than BeefCBR, but not PastaCBR, which on the other hand was the least appropriate with the lowest sensory complexity (Table 3), explaining why consumers felt unfulfilled.

Table 4. Food and wine pairing evoked emotion profiles. Emotions were rated on a 9-point scale ranging from 1 = not at all to 9 = extremely. Lower case letters indicate

significant differences across food and wine pairings based on post-hoc comparisons using Fisher's LSD p<0.05.

Emotions	PastaCBR	PastaMV	BeefCBR	BeefMV	MousseCBR	MousseMV	SalamiCBR	SalamiMV
Adventurous*	2.7 ab	2.6 b	2.8 ab	3.0 ab	2.9 ab	3.2 a	3.1 ab	3.1 ab
Calm*	3.4 b	3.4 b	3.8 ab	4.0 a	3.5 ab	3.7 ab	3.3 b	3.3 b
Contented*	3.3 c	3.4 bc	3.9 ab	4.1 a	3.5 bc	3.8 abc	3.4 bc	3.5 bc
Embarrassed	1.3	1.3	1.1	1.2	1.3	1.3	1.3	1.2
Enthusiastic	2.9	2.9	3.1	3.5	3.2	3.3	3.1	3.2
Envious	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Happy*	3.5 b	3.5 b	3.8 ab	4.1 a	3.7 ab	3.9 ab	3.5 b	3.6 ab
Irritated*	1.6 ab	1.6 ab	1.3 b	1.3 b	1.6 ab	1.7 a	1.7 a	1.6 ab
Lonely	1.3	1.3	1.2	1.1	1.2	1.2	1.2	1.1
Nostalgic*	2.4 b	2.7 ab	3.0 ab	3.2 a	2.7 ab	2.9 ab	2.6 b	2.7 ab
Optimistic	2.5	2.4	2.8	2.9	2.6	2.8	2.5	2.6
Panicky	1.9	1.9	2.0	2.1	1.9	2.2	2.0	2.1
Passionate	1.7	2.0	1.8	2.1	1.9	1.9	2.1	2.0
Relaxed	2.8	3.0	3.2	3.4	3.0	3.3	3.0	3.0
Sad	2.3	2.3	2.5	2.6	2.4	2.5	2.4	2.3
Surprised*	2.1 bcd	2.0 cd	2.0 cd	1.9 d	2.6 a	2.5 ab	2.4 abc	2.2 abcd
Tense*	1.9 ab	2.0 ab	1.7 b	2.0 ab	2.3 a	2.2 a	2.2 ab	2.2 ab
Unfulfilled*	2.0 a	1.9 ab	1.5 b	1.5 b	1.8 ab	1.7 ab	1.7 ab	1.8 ab
Warm hearted	2.7	3.0	2.6	2.8	2.7	2.8	2.8	2.5

* Asterisk indicates the significant emotions by pairing

Significant interactions between pairings and information level were observed for sad (F = 2.457, p = 0.017), surprised (F = 2.646, p = 0.01) and warm-hearted (F = 3.020, p = 0.004). Pairwise comparison indicated that surprised and warm-hearted increased when information was provided whereas the opposite was observed for sad (Figure 4). The interactions between information level and pairings indicate that the wine origin information possibly created expectations in consumers. Expectation were either matched (assimilation) by the pairings and evoked positive emotions like warm-hearted and surprised or were not (rejection) and intensified negative ones like sad (Danner et al., 2017; Deliza and MacFie, 1996). Emphasizing wine provenance could be a useful tool for wine and hospitality industries to improve gastronomic experience by engaging consumers on an emotional level, however for the best result wines are to be paired with food appropriately pairings.

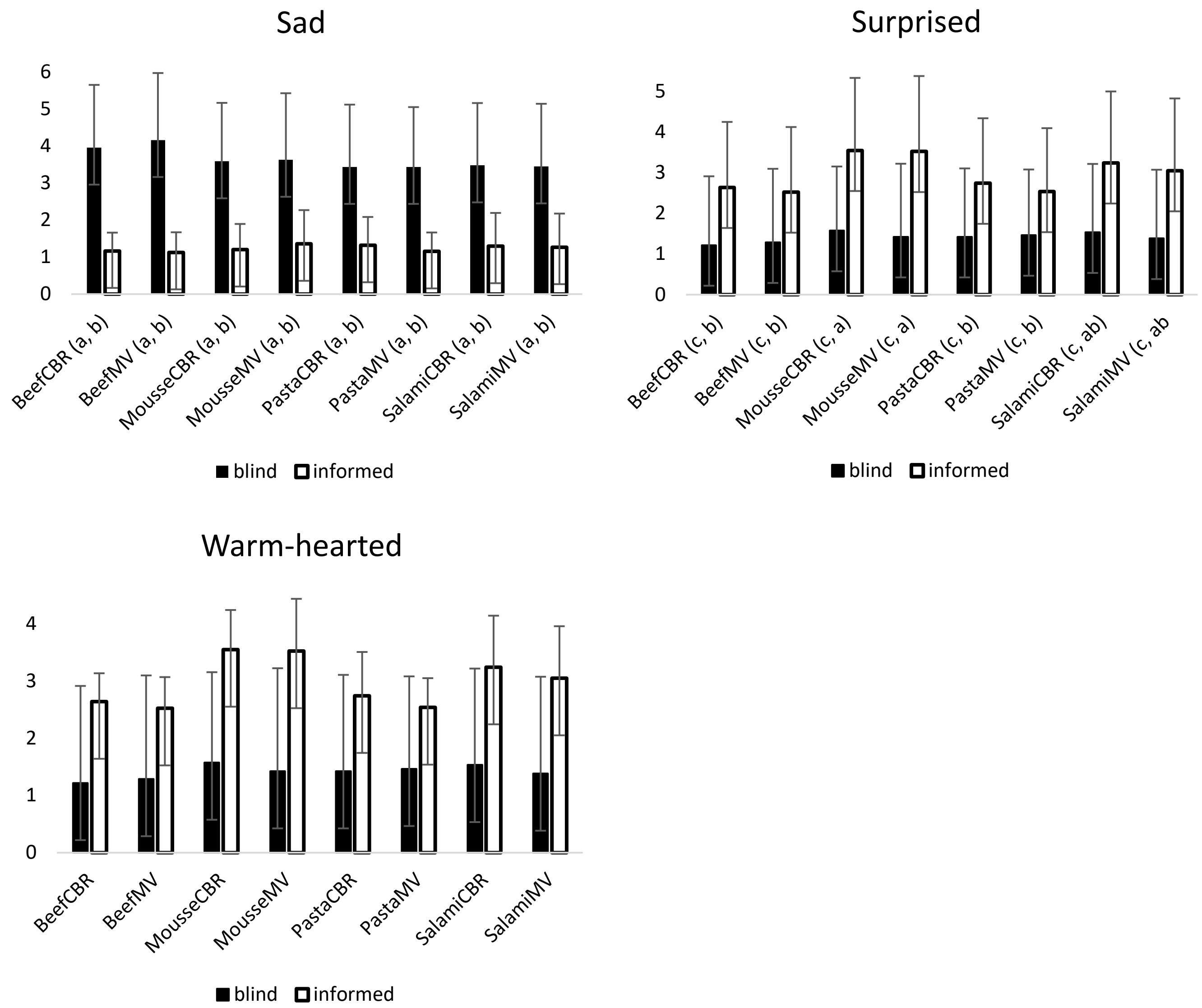

Figure 2. Food and wine pairing evoked emotion profiles for two different information levels (blind, wine provenance information). Emotions were rated on a 9-point scale ranging from 1 = not at all to 9 = extremely. Only emotion terms with significant pairing × information level interaction ($p < 0.05$) are presented. Lower case letters indicate significant differences in evoked emotion intensities across information levels based on post-hoc comparisons using Fisher's LSD $p < 0.05$. Error bars indicate standard error.

3.3 Post consumption experience of food and wine pairings

Wine provenance information resulted in more intensely vivid memories (F = 96.343, p < 0.0001), but did not affect other post experience measures. Significant sample effects were found for vividness (F = 2.537, p = 0.014), remembered liking (F = 11.422, p < 0.0001), memorability (F = 9.612, p < 0.0001), and loyalty (F = 13.779, p < 0.0001). BeefMV was significantly more liked retrospectively and created loyalty compared to MousseCBR, SalamiCBR, SalamiMV, PastaMV, PastaCBR (Table 2). This means BeefMV was not only the most liked, appropriate pairing with the highest sensory complexity and expected price during the core consumption, but also generated positive post-experiences (Schuler et al., 2011) (Figure 1). BeefMV was also coupled with positive emotions, which can explains why consumers found it memorable (Mai and Schoeller, 2009). In particular, remembered liking and loyalty can be important for hospitality operators and wineries as both measures positively correlate with word-of-mouth communication (Coulter and Roggeveen, 2012). MousseMV was significantly more memorable and liked compared to SalamiCBR, SalamiMV, PastaMV, PastaCBR (Table 5), which might be due to its positive disconfirmation (Deliza and MacFie, 1996). As discussed in 3.2.2, desserts are most commonly paired with sweet dessert wines and it is likely that consumer did not expect a dry red wine (MV) to go with chocolate mousse and disproving the concept resulted in adventurous emotion evoked during the tasting as well. Unconventional food and wine pairings can be perceived as a novelty (Cox and Locander, 1987), which positively influences memorability as long as it is coupled with a positive hedonic response (Lévy et al., 2006), thus it may be a considerable strategy for hospitality operators and cellar doors to induce positive consumer experience.

Table 5. Mean values and Standard deviations (SD) of core consumption ratings. Lower case letters indicate significant differences across food and wine pairings based on post-hoc comparisons using Fisher's LSD p<0.05.

		Mean	SD	Sig
Vividness	MousseMV	3.8	1.1	a
	SalamiMV	3.8	1.0	a
	PastaMV	3.6	1.1	ab
	BeefMV	3.6	1.1	ab
	MousseCBR	3.6	1.1	ab
	SalamiCBR	3.6	1.1	ab
	PastaCBR	3.4	1.1	b
	BeefCBR	3.4	1.1	b
Remembered liking	BeefMV	6.7	1.4	a
	BeefCBR	6.3	1.5	ab
	MousseMV	6.2	2.1	b
	MousseCBR	5.9	1.9	bc
	SalamiCBR	5.7	1.9	cd
	SalamiMV	5.6	2.0	cde
	PastaMV	5.3	1.9	de
	PastaCBR	5.2	1.8	e
Memorability	MousseMV	5.2	1.7	a
	BeefMV	5.0	1.5	ab
	BeefCBR	4.8	1.6	abc
	MousseCBR	4.8	1.7	bc
	SalamiMV	4.6	1.6	c
	SalamiCBR	4.5	1.6	c
	PastaMV	4.1	1.5	d
	PastaCBR	4.0	1.5	d
Loyalty	BeefMV	5.8	1.4	a
	BeefCBR	5.5	1.5	ab
	MousseMV	5.4	2.1	bc
	MousseCBR	5.0	1.9	cd
	SalamiCBR	4.8	1.9	d
	SalamiMV	4.7	2.0	de
	PastaCBR	4.3	1.7	f
	PastaMV	4.3	1.8	ef

Significant interactions between pairing and information effects were only observed for remembered liking ($F = 2.189$, $p = 0.033$), but interestingly not for experienced liking during the core consumption. Under blind information condition, BeefCBR obtained the highest remembered liking (mean = 6.52) followed by BeefMV (mean = 6.32). On the other hand, when the provenance of the wines was disclosed, consumers rated remembered liking the highest for BeefMV (mean = 6.99) and even MousseMV (mean = 6.49) scored higher than BeefCBR (mean = 6.15). South Australian consumers' might be just more familiar with South Australian wine regions such as McLaren Vale as it is widely available on the retail market and therefore BeefMV and MousseMV had higher arousal potential than BeefCBR (Lévy et al., 2006). It is also possible that, previous consumption experiences of MV wines influenced consumers' judgements andaltered their post-consumption experience due to judgemental heuristics (Provencher and Jacob, 2016). Familiarity of the product has a positive relationship with memorability (Martí-Parreño et al., 2017) and therefore authors expected MV Shiraz pairings to be more memorable than CBR pairings for consumers, but no statistical differences were found (Table 5). A possible explanation is the effect of context on memorability (Bylinskii et al., 2015). More specifically, the context of food and wine pairing had a larger effect on memorability than provenance as there was a significant sample effect on memorability but not provenance effect.

4 Conclusion

This study explored the relationship between the sensory characteristics of food and wine pairings and consumers' gastronomic experience under blind and informed (wine provenance) conditions. Information about wine provenance, as part of the pre-consumption experience, negatively influenced sensory complexity due to the complication of the evaluating task and information might have exceeded consumers' optimum. This finding suggests that restaurants may increase core consumption experience by presenting the wine on its own before the food is served. The sensory profile of food and wine pairings significantly impacted the core consumption experience as pairings described by high savoury, meaty, salty, umami, mouthfeel complexity, chewiness, and body, and low sweet spice, acidity, sweetness, and astringency attributes were considered more appropriate and liked, had higher sensory complexity and consumers expected to pay up to 21% more for them irrespective of information level. Therefore, not only the concept of food and wine pairing, but the appropriateness of the pairing is valued by consumers and may create further profit for hospitality operators. Appropriate pairings evoked more positive emotions and less negative emotions, which demonstrated consumers' engagement on the emotional level, a key factor for memorable experiences.

Food and wine pairings and hence the core consumption experience impacted consumers' post-consumption experience. Consumers retained vivid memories and reported high remembered liking, memorability and loyalty of experiences included appropriate pairings. Wine provenance information further increased remembered liking of appropriate pairings, which is particularly important for hospitality operators and wineries who rely on word-of-mouth effect.

Overall, this study reinforced the experiential nature of food and wine and revealed relationships between sensory qualities of food and wine pairings and pre-, core-, and post-consumption parts of the gastronomic experience.

Some limitations of this study need to be pointed out too. The tasting in a laboratory setting might have been perceived unrealistic by some consumers, however, Danner et al. (2016), showed no difference in liking of Shiraz wine between laboratory, home and restaurant, but there was an emotional difference that might be worth exploring in food and wine pairing context as well. Future research could further explore pre-consumption experience with more elaborate information levels and measure expected liking, appropriateness of pairing, sensory complexity, memorability, loyalty in relation to core and post-consumption experience. Moreover, including other grape varieties, wine styles, cuisines, and cultures could offer more insights for the hospitality sector. Consumer segmentation based on food/wine involvement could help better understanding of the motivational factors behind consumer preferences.

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SUPPORTING INFORMATION FOR

Food and wine pairing: a tool for developing memorable dining experiences

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Table of Contents

Table A. 1. Detailed information of the food samples used in the sensory descriptive analysis and consumer test.

Food	Properties	Serving size
*Pasta with cheese sauce	Cooked from ingredients purchased at Foodland Supermarkets, Australia	8 pieces of penne pasta and 30 g of sauce
*Braised beef with potato puree	Cooked from ingredients purchased at Foodland Supermarkets, Australia	30 g of beef and 50 g of potato puree
*Chocolate mousse	Aeroplane brand, McCormick Foods, Australia	50 g
Fresh goat cheese	Fromagerie P. Jacquin, France	1 cm thick cut into half (~20 g)
Cheddar cheese	Quicke's Traditional Ltd., UK, aged 18 months	2 pieces of 2 cm × 2 cm cubes (~20 g)
Prosciutto ham	San Nicola Prosciuttificio del Sole S.p.A., Italy, aged 18 months	1 thin slice (~10 g) cut into half
*Spicy salami	Cacciatore (hot), Fabbris Smallgoods, Australia	2 thin slices (~10 g) cut into half

*Asterisks indicate items tasted by the consumers.

Table A. 2. Recipes of the meal samples used in this study.

Pasta

500 g Penne (Barilla S.p.A., Italy)

30 g unsalted butter (Foodland Australia PTY Ltd)

30 g wheat flour (Foodland Australia PTY Ltd)

30 g Parmigiano Reggiano, grated (Zanetti S.p.A., Italy)

1 clove garlic, minced

260 mL chicken stock (Massel Australia PTY Ltd)

260 mL whole milk, (Foodland Australia PTY Ltd)

4 g salt (Foodland Australia PTY Ltd)

Preparation

1. In a pot, bring water to boil.
2. Add the pasta and cook for 8 minutes (*al dente*).
3. Remove the pasta from the boil, cool under cold running water, and reserve until required.
4. In a heated medium size pot, melt the butter, add the minced garlic, and cook until slightly golden in colour.
5. Whisk in the flour and add the milk and chicken stock while continuously whisking the mixture.
6. When the mixture starts thickening, add the salt and Parmigiano Reggiano.
7. Reheat the pasta and serve it with sauce on top.

Braised beef

800 g beef gravy meat, diced into 2.5 cm

200 g onion, quartered

2 Tbsp vegetable oil (Foodland Australia PTY Ltd)

10 g salt (Foodland Australia PTY Ltd)

500 mL beef stock (Massel Australia PTY Ltd)

1 tsp corn starch (Foodland Australia PTY Ltd)

600 g red potato, peeled, coarsely diced

120 g unsalted butter (Foodland Australia PTY Ltd)

180 g whole milk (Foodland Australia PTY Ltd)

4 g salt (Foodland Australia PTY Ltd)

Preparation

1. In a soup pot, cover the potatoes with water, bring to boil and cook until soft (about 20 min), strain water and reserve.
2. In a hot pressure cooker, add 2 Tbsp vegetable oil and gently sweat the onion until tender.
3. Gently add the beef, stock and salt.
4. Secure lid and bring cooker to high pressure.
5. Reduce heat to stabilise pressure and cook for 35 minutes.
6. Release pressure according to manufacturer's instructions and remove lid.
7. Set aside the beef and blend the cooking liquid and onion with corn starch until smooth.
8. Bring the mixture to boil until the gravy thickens.
9. Add the beef back to the gravy and allow to cool.
10. Using a stick mixer, puree the potatoes, butter, milk and salt.
11. Reheat beef and potato puree if needed. Plate up the potato puree and spoon over beef and gravy.

Table A. 3. Composition of the Shiraz wines used in this study.

Wine	Vintage	Region	Degree days (°C)[a]	pH	TA (g/L)	Residual Sugar (g/L)	MCP tannin (mg/L)	Viscosity (m^2/s)	Ethanol (% ABV)	FreeSO2 (mg/L)	BoundSO2 (mg/L)
AH	2015	Adelaide Hills	1270	3.6	6.2	0.3	2011	1.63	14.8	16.8	24.8
BV	2014	Barossa Valley	1710	3.3	6.8	0.8	2754	1.70	15.1	4	60
BV2	2014	Barossa Valley	1710	3.8	6.1	0.8	2192	1.61	13.9	13.6	14.4
*CBR	2015	Canberra District	1410	3.8	6.6	0.18	1423	1.59	14.1	17.6	35.2
CB2	2015	Canberra District	1410	3.6	6.1	0.4	1729	1.60	14.4	12.8	23.2
EV	2015	Eden Valley	1390	3.5	7.2	0.3	2049	1.61	14.2	7.2	18.4
*MV	2015	McLaren Vale	1910	3.5	6.7	1.01	3572	1.73	14.4	24.8	67.2

MV2	2014	McLaren Vale	1910	3.4	6.8	1.2	2272	1.63	14.3	15.2	28

*Asterisks indicate wines tasted by the consumers. [a] Classifies the climate of wine regions based on heat summation or growing degree-days

Table A. 4. Sensory attributes of food and wine pairing samples with agreed definitions and reference standards.

Attribute	Definition	Reference
Flavour	Flavour of	
*Overall sensation dominance	Flavours of the food or wine dominates the overall sensation of the combination	
Flavour intensity	Dilute to concentrated	
Red fruits	Raspberry, strawberry, red cherry	One of each frozen raspberry, strawberry, cherry in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
Dark fruits	Plum, dark cherry, blueberry, black berry, blackcurrant	One of each fresh black berry, blueberry and plum in 20 mL red wine
*Sweet spice	Cinnamon, nutmeg, vanilla, and cocoa	2 drops of vanilla essence, dark chocolate shavings (Lindt, Kilchberg, Switzerland) and a pinch of cinnamon powder in 20 mL red wine (Berry Estates Traditional Dry Red Cask, SA, Australia)
Hot spice	Chilli, black pepper	Pinch of each ground black pepper (Woolworths Home brand, Bella Vista, NSW, Australia) in 20 mL red wine
*Savoury	Onion, garlic, potato, carrot, olives	Fried onion, 1 thin slice of carrots and 1 black olive

*Smoky	Toasted bread and smoke	Burnt toast (Woolworths Home brand, Bella Vista, NSW, Australia) crumbles
Dairy	Milk, yoghurt, sour cream, butter	1 tsp of full fat sour cream (Woolworths Home brand, Bella Vista, NSW, Australia)
*Meaty	Cooked beef, pork, stock, broth	0.5 tsp beef stock powder (Massel Australia) and 1 cm piece of leather
Taste	Taste associated with	
*Acidity	The basic taste sour	
*Sweet	The basic taste sweet	
*Salty	The basic taste salty	
*Bitter	The basic taste bitter	
*Umami	Flavour enhancer	
Mouthfeel		
*Mouthfeel complexity	The sensation of simultaneously occurring sensations and textures	
*Chewiness	From tender to chewy/tough	From roast chicken slices (Primo Smallgoods, Chullora, NSW, Australia) to beef jerky (Jack Link's, Wisconsin, United States)
*Body	Sensation of fullness in the mouth	Water, skimmed milk, full fat milk
Mouth coating	Sensation of a coating film in the mouth	From water to oil
*Astringency	The dry puckering mouthfeel sensation	Grapeseed extract (Tarac Technologies, Nuriootpa, SA, Australia) in white wine (Berry Estates Traditional Dry White Cask, SA, Australia) 0.5 g/L, 1 g/L, 2 g/L
*Heat	Sensation perceived in the mouth as warming, irritation, burning or stinging	

*Asterisk indicates the significant attributes by product.

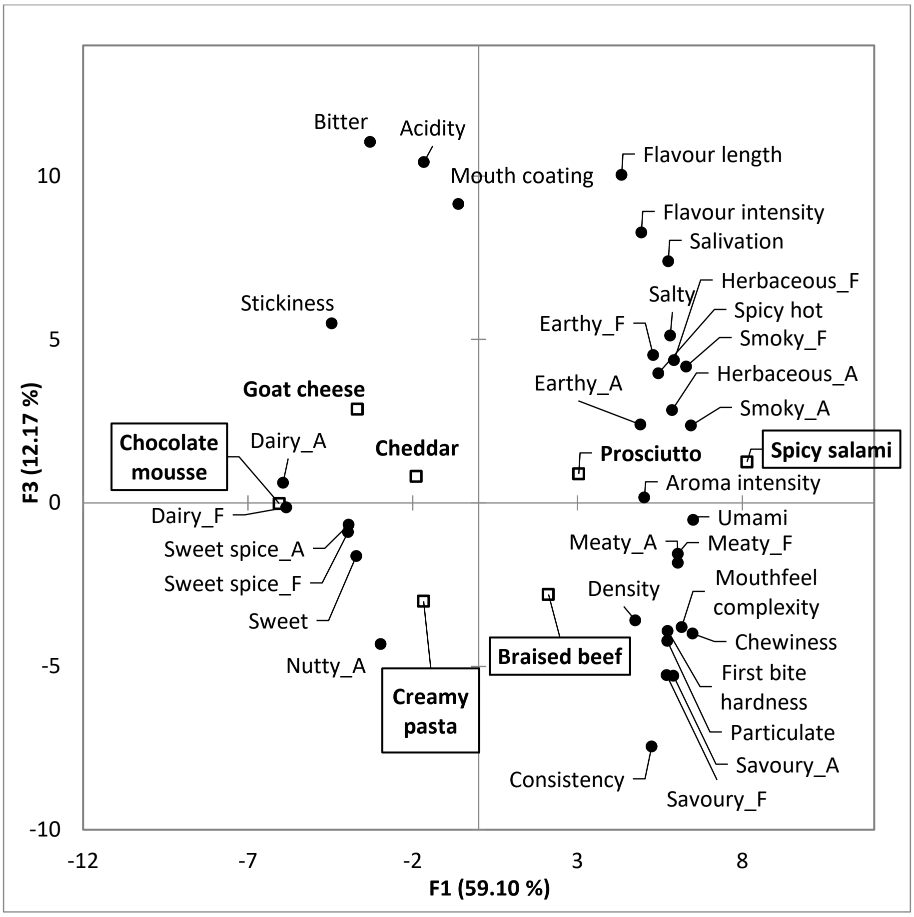

Figure A 1. Scores of the food samples (n=7) with loadings of sensory properties on the first two principal components explaining the variability in sensory data. Boxed products marks the selected samples for food and wine pairings.

S-8

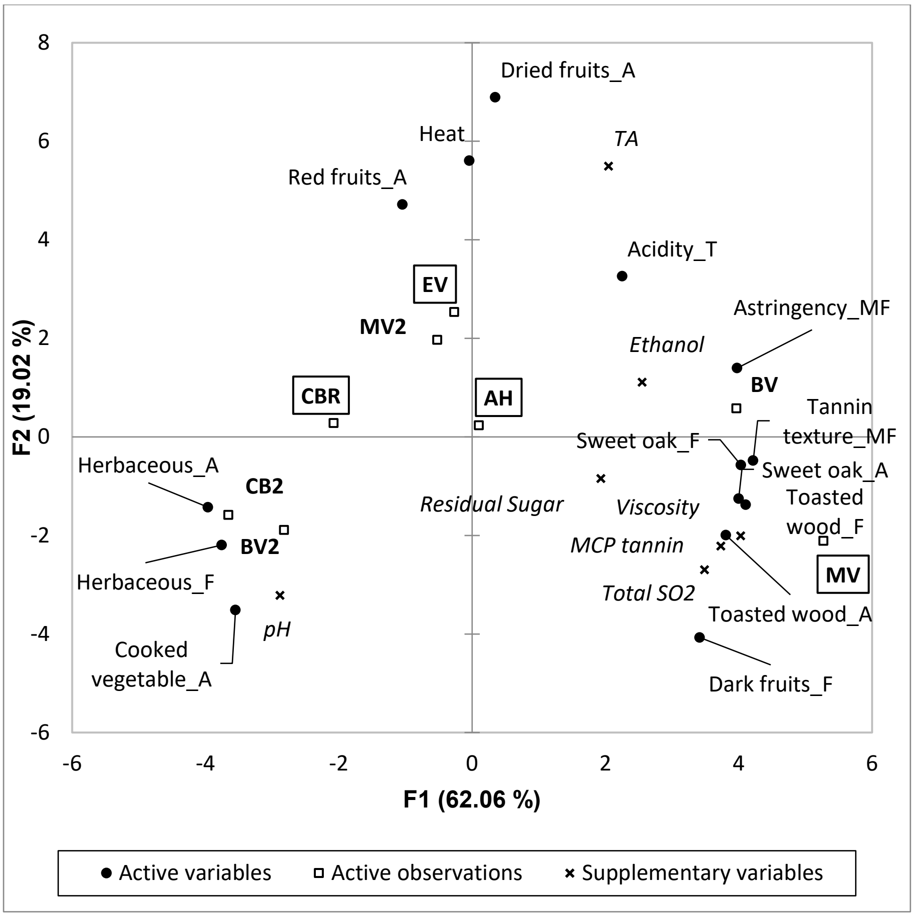

Figure A 2. Scores of the Shiraz wines (n=8) with loadings of sensory properties and chemical composition as supplementary variables on the first two principal components explaining the variability in sensory data. Boxed wines indicate the selected samples for food and wine pairings.

Chapter 6

Concluding remarks and future directions

6.1 Conclusions

Fine wines have been associated with superior quality and provenance since the establishment of the appellation systems in Europe. Old World wine regions became brands in their own right, and were associated with distinct sensory characters and quality, which in turn has led consumers to rely on those regions and a preparedness to pay high prices for them. In the New World, wine regions emerged that have proven capable of producing fine wines, but without the benefit of the appellation system driven 'provenance' brand seen in the Old World. The Australian wine industry has long been at the forefront of applying science and technology in production, resulting in the emergence of varieties and wine styles associated with Australia as a wine producer. Notable examples include Barossa Valley Shiraz, Hunter Valley Semillon, Margaret River Chardonnay, and Coonawarra Cabernet Sauvignon, among others. At the Australian industry's outset, grape varieties and wine styles were experimental, but it laid the foundation for finding the most suitable grapes per site and producing the most reflective wine style for a region. As a result, Chardonnay and Shiraz grapes are grown in virtually every Geographic Indication (GI) in Australia and more recently, new directions for the Australian wine industry have set the scene for defining regional typicality and understanding provenance related consumer behaviour;

Australian consumers tend to associate wine quality with winery brands and price points rather than wine regions and make quality assumptions based on previous experiences. Nonetheless, region-based marketing has proven to be effective at promoting fine wines in other New World regions like the USA, but this strategy's success relies on developing a specific language to communicate with consumers. Correct business to consumer communication is important, because wine consumers tend to describe wines differently to experts. Furthermore, if sensory and chemical profiles of wines from a region are identified, any distinctive characteristics may be used to promote regional typicality.

Understanding specific consumer needs is increasingly important to the wine and hospitality industries as they seek to offer unique and tailored experiences and generate increased margin; especially when working with New World products. When buying non-utilitarian goods, such as fine wine, consumers do not buy products/services for mere satisfaction, they look for experiences through the senses, experiences to create memories, memories and experiences they pass on to other consumers. Engaging the multi-sensory components of the wine tasting experience allows sensory marketing to enhance the emotional connection with flavour perception and tailor it into a memorable consumer experience. In particular, food and wine pairings or food recommendations are often used to increase consumer satisfaction and the price paid for wine at restaurants; thus it is a valuable strategy for operators. Food and wine pairing is valued by consumers and is gaining increasing importance in winery tasting rooms as well. It is a logical step to extend food and wine pairing into the sensory marketing of fine Australian wines (FAW) of provenance; essentially to use it to establish provenance and create positive consumer memories. However, research on food and wine pairing is scarce and the concept is built on anecdotal rules stemming from European region-based pairings that do not necessarily work with New World wines or food culture. In order to take full benefit of food and wine pairing with FAW, it is essential to research Australian wines and foods that consumers are likely to consume. Furthermore, consumers' taste preferences and behaviours are heterogeneous, meaning the population generally cannot be treated as a single group.

The consumer experience does not end at the core consumption of food and wine. Investigating post-experience is essential to understand repeat purchase intention and positive word of mouth effects. Therefore, this study set out to investigate consumer understanding of FAW and the potential of food and wine pairing as a tool to promote FAW of provenance in consumers' pre-consumption, core consumption, and post-consumption experience underpinned by sensory and chemical data of both food and wine.

6.1.1 Using consumer opinion to define New World fine wine: Insights for hospitality

In order to investigate pre-consumption experience in relation to fine Australian wines, the first part of the research explored consumers' fine wine related behaviour through an online questionnaire. Despite the long history of the notion of fine wine, the definition of what fine wine constitutes in consumers' minds was superficial at best.

Focus groups offered a tool for designing a consumer survey from which consumers provide their vocabulary surrounding fine wine, confirmed that Australia's most important white and red varieties, Chardonnay and Shiraz, are associated with a fine wine image, and identified FAW associated wine regions and food pairings. The subsequent survey data led us to propose a consumer definition of Australian fine wine:

"Australian fine wines are of high quality, good value for money, easy to drink and consistently show balance, plus diverse, fruity and regional characteristics"

Defining fine wine intended to provide a tool for the wine and hospitality industries to tailor their products/services to consumers' expectations and thus assist in positioning fine Australian wine in their offerings. Consumers' heterogeneous behaviour and preferences were confirmed as their fine wine behaviour significantly varied across fine wine involvement (FWI) segments. For instance, wine enthusiasts (ENT) appeared to utilise the most information, implying that the fine wine definition can be tailored to the preferences of each FWI segment as required, and allowing marketers to develop relevant communication strategies. In terms of label information, grape variety, brand, region, and vintage broadly arose as the most important label elements, however ENT also highly valued technical information.

Irrespective of FWI segment, consumers believed that the Barossa Valley region produces the finest Chardonnay and Shiraz wines. Although Barossa Valley established its reputation with Shiraz, regional branding increased consumer confidence in the quality of other wine styles from that region, suggesting consumers actually associate provenance to FAW, much as they do for Old World wines. ENT appeared to utilise the most information, reflecting their extended wine knowledge and interest in provenance. Further, consumers associated specific regions with fine Chardonnay and Shiraz wines, which informed the region and sample selection in the second stage of the research, as discussed in Chapter 3. ENT also tended to use a greater vocabulary of sensory descriptors for Chardonnay and Shiraz, and this participant segment favoured complex, oak-derived attributes over aspirant (ASP) and no frills (NF) consumers. Overall, fine Australian Chardonnay wines were seen as fresh, fruity, elegant, and delicate, whereas Shiraz was deemed to be full bodied, rich, dark fruited and complex. These are important signals for the hospitality and wine sectors to tailor communication with different consumer segments.

As for food and wine pairings, consumers indicated they expected to drink Chardonnay with fish and chicken meals, and Shiraz with meals dominated by red meat. The general association that cheese and wine go hand in hand was reaffirmed, as consumers equally expected Chardonnay or Shiraz to pair with various cheese styles. On the other hand, desserts were not considered appropriate matches with either of the varietal wines that consumers were asked to consider. Consumer food pairing associations informed the selection of food and wine pairings for the later stages of the research, as discussed in Chapter 4 and Chapter 5. In addition to exploring consumer perceptions of fine wine, this research reinforced the use of the FWI as an effective tool for segmenting wine consumers.

6.1.2 A matter of place: Sensory and chemical characterisation of fine Australian Chardonnay and Shiraz wines of provenance

Establishing a fine wine image according to regional typicality has been of interest for New World wine countries like Australia to extend beyond single variety and brand associations. Besides pre-consumption experience, such as information and associations, consumer's core consumption experience was influenced even more by the composition and sensory attributes of wines. Therefore, a blend of sensory and chemical analyses was applied to explore the regional and sub-regional typicality of commercially available fine Australian wines. The regions for Chardonnay and Shiraz were selected based on consumer associations for fine wines for these varieties, as discussed above in Chapter 2, with further sub-regional selection based on expert consultations.

Fine Chardonnay wines could be grouped by region to some extent as the principal component analysis (PCA) separated the samples on the basis of the cooler climate Yarra Valley (YV) possessing more prominent stock and vegetal sensory attributes, in contrast to the fruit and oak-driven Margaret River (MR) wines. The sensory analysis by sub-region partially discriminated YV Gladysdale (YVG) and MR Wallcliffe (MRA) wines on the basis of citrus, vanilla and oak descriptors. Differentiation could be made between YVG, YV Dixons Creek (YVD), and YV Regional (YVR) wines but not completely between MRA, MR Wilyabrup (MRW), and MR Regional (MRR) wines. Even if regional wines (i.e., blends from within the GI) MRR and YVR possessed significantly different sensory and volatile profiles, the Chardonnay wines from MR and YV in this study generally seemed to be categorised by wine styles such as "oaky", and "fruity/crisp" rather than by region.

Shiraz wines showed some similar properties across regions as the PCA tended to separate the samples on the basis of Barossa Valley (BV) possessing more savoury, cooked vegetable sensory attributes in contrast to the fruit and oak dominated McLaren Vale (MV) wines. Discriminant analysis revealed subtle differences by sub-region, and contrasted BV Northern Grounds (BVN) from BV Southern Grounds (BVS) in partial agreement with the Barossa Grounds study, and MV Blewitt Springs (MVB) from MV Willunga (MVW) as per the Scarce Earth study. In our hypothesis, sub-regions within regions were expected to produce wines that are more similar; however, Shiraz wines had similarities across regions as well, which might derive from similarities in climate and winemaking tradition of the two South Australian wine regions. In particular, oak-derived sensory attributes and tannin concentrations varied across samples but not necessarily across regions and sub-regions.

Less winemaking intervention or wines produced under research conditions (i.e., not matured, oaked or blended like commercial wines) could perhaps better unveil regional typicality, however, consumers believe oak-derived aromas and flavours are part of fine Australian Chardonnay and Shiraz. Producing wines without as much oak influence would therefore be a potential risk for wineries seeking to create a fine wine image. In addition, because bottle maturation tempers oak-derived aromas and astringency in wine, research could be extended to assess 5-10 year old commercially produced fine wines to examine the impact on regional typicality.

6.1.3 Inter(t)wined: what makes food and wine pairings appropriate?

Food and wine pairings have been gaining global interest recently, however, the historical anecdotes of colour and/or weight matching do not necessarily take into account the preferences of today's consumers. Provenance-based pairing recommendations stemmed from cuisines and wines traditionally paired in Old World wine regions, but those are not necessarily applicable in New World wine producing countries such as Australia. Furthermore, previous studies left a methodological question unanswered in relation to how food and wine pairings should be measured. Should an appropriate pairing be a balance of intensities between food and wine, or should it have a measurable increase in liking from the individual food and wine components? In the Australian wine industry there is a drive to promote its fine wines coupled with gastronomic experience in the domestic and export markets. Therefore food and wine pairing recommendations may be a valuable tool, and research is needed to investigate fine Australian wine and food pairings in meal situations.

Besides selecting wines (n = 4) with distinct sensory profiles based on Chapter 3, four wines were added from cool climate wine regions (Adelaide Hills, Canberra District, and Eden Valley) to represent some of the climatic and stylistic diversity of Australian Shiraz. The selected foods nominally comprised dishes from a three course meal, representing a real life scenario of pairing wine with food. Descriptive sensory evaluation of foods, wines, and consecutive pairings generated data to identify the sensory drivers for food and Shiraz wine pairings that consumers deemed appropriate. The consumer test was carried out with American consumers in California, one of the most important export markets for FAW.

On average, the liking and appropriateness of pairings were driven by food items, confirming that food suppresses wine attributes in a pairing situation such as that typically found in hospitality settings. This is significant to restaurants and winery tasting rooms, suggesting that consumers' wine experience is likely to be better if the wine is tasted before the food. In the most appropriate pairings, the intensities of food and wine flavours increased, wine taste attributes changed, there was a positive relationship with liking, sensory complexity, and expected price to pay for the wine but a negative relationship with balance, as consumers preferred pairings where the wine slightly dominated. Most importantly, the pairings had an increase in liking and sensory complexity over the individual wine, but not the food component. It may be that food impacts pairings more so than wine, which might have led to hedonic contrast due to the within-subject experimental design. Nevertheless, the pairing-induced increase of wine liking and sensory complexity indicates that appropriate food and wine pairing is a synergistic interaction, rather than a balance of intensities. Even so, food and wine pairing is a complex phenomenon and there is no guarantee that two subjects assess the same construct. Therefore, instead of direct single scale measurements, a combination of direct (dominance/balance, appropriateness of pairing) and indirect methods (sensory complexity, liking) might be more effective.

To account for the heterogeneity of the consumer cohort, consumers were segmented by liking of the pairings, which revealed greater differences between pairings. Importantly, even though consumers across hedonic clusters seemed to agree that appropriate pairings were slightly dominated by the wine, had higher sensory complexity and expected price to pay, the configuration of matched pairings varied. Universal methods to measure food pairing may be desirable, however the perception of appropriate pairings remains largely subjective and driven by personal preferences. Therefore, appropriate consumer segmentation could better account for the variability of results. In terms of segmentation methods, neither wine involvement nor food neophobia had significant effects on consumers' food and wine pairing related behaviour, which warrants the development of a specific food and wine pairing scale.

6.1.4 Food and wine pairing: A tool for memorable gastronomic experience

Food and wine pairing has been a valuable tool for the hospitality and wine industries to increase consumer satisfaction; however, to address contemporary experience-driven consumer preferences, this study set out to bring together Chapter 2, Chapter 3 and Chapter 4 by investigating the interactions between pre-consumption, core consumption and post-consumption experience of food and wine pairings.

The pre-consumption experience effect was tested under two information levels (blind and informed (wine provenance)) and it influenced consumers' ratings during the core consumption and post consumption. Information about the wine region had a negative effect on sensory complexity due to the complicated nature of the evaluation task whereby tasting with provided information might have exceeded consumers' complexity optimum. In addition to suppression of wine sensory attributes by foods outlined in Chapter 4, this finding suggests that restaurants may increase the core consumption experience by presenting the wine on its own before the food is served. Wine provenance information further increased remembered liking of appropriate pairings, which is particularly important for hospitality operators and wineries who rely on a word-of-mouth effect.

The sensory profile of food and wine pairings significantly impacted the core consumption experience. Pairings described by high levels of savoury, meaty, salty, umami, mouthfeel complexity, chewiness, and body, and low sweet spice, acidity, sweetness, and astringency attributes, were considered more appropriate, liked, had higher sensory complexity and consumers expected to pay up to 23% more for them irrespective of information level. The concept of food and wine pairing is indeed valued by consumers, and provision of more appropriate pairings by hospitality operators may increase consumer satisfaction and further financial gain. Appropriate pairings evoked more positive and less negative emotions than inappropriate pairings, thereby demonstrating consumers' engagement on the emotional level, which is a key factor for memorable experiences. Consequently, consumers retained more vivid memories and reported higher remembered liking, memorability and repeat consumption intention of appropriate pairings. Therefore, positive core consumption experience and evoked emotions had a positive effect on post-consumption experience.

Overall, this study reinforced the experiential nature of food and wine and revealed relationships between sensory qualities of food and wine pairings and pre-, core-, and post-consumption components of the gastronomic experience, which provides valuable information for hospitality and wine tasting room operators who seek to offer provenance-based fine wine experiences.

6.2 Future directions

There is now a need for future research to investigate the hedonic relationships between FAW and FWI segments with consumer preference taste tests. Consumer perceptions of FAW should be explored in Australia's export markets in order to develop tailored marketing strategies appropriate to different market places, cuisines and cultures. As wine involvement affects the recalled vocabulary, expanding research to immersive consumer surveys including wine tastings would be valuable. The sensory experience of tasting fine wine might give a better understanding of regions associated with fine wine and food pairings.

Oak influence has been and perhaps will be part of fine wine character for fine Australian Chardonnay and Shiraz wines, thus investigating FAW with little to no oak maturation might be less representative of commercially available wines. On the other hand, oak aged wines in which oak-derived sensory and volatile markers are less prominent would be worth further investigation for regional typicality.

Wine samples mentioned in Chapters 3, 4 and 5 were selected following previous research recommendations, such as expert ratings and price points, and from regions that experts and consumers considered capable of producing fine Chardonnay and Shiraz wines in Chapter 2. On the other hand, consumers were not asked to rate wine quality during consumer tastings in Chapter 4 and 5, and future research could thus explore how food pairings affect perceived wine quality.

The tasting in a laboratory setting might have been perceived as unrealistic by some consumers, and thus future research could confirm results in a real life meal context in a restaurant setting and different types of dining settings (e.g., fine dining, casual dining, at home) as well. On the other hand, Danner et al. (2016), showed no difference in consumers' liking between laboratory, home and restaurant but there was an emotional difference that might be worth exploring in food and wine pairing context. As there are individual differences in bitterness perception, it might be worth screening consumers based on PROP sensitivity as well as other phenotypic traits as a basis for further segmenting and understanding consumer liking. As a consequence of sensory heterogeneity between consumers, their concept of appropriate food and wine pairing may differ too, thus would be worth exploring what construct they use to assess pairings. Future research could also be extended to more elaborate information levels provided to the consumer (as education dimension) during pre-consumption experience, or other grape varieties, wine styles, and cuisines, to offer more insights for the wine industry, hospitality and tourism sectors. Furthermore, better understanding of the motivational factors behind consumer preferences requires future research that segments consumers based on their interest in food and wine pairings.

List of abbreviations

ABV	alcohol by volume
DA	descriptive analysis
GI	geographic indication
AOC	appellation d'origine controlee
AOP	appellation d'origine protégée
PDO	protected designation of origin
PGI	protected geographic indication
FAW	fine Australian wine
FWI	fine wine instrument
MTE	memorable tourism experiences
NF	No Frills
ASP	Aspirants
ENT	Enthusiasts
CATA	check-all-that-apply
ANOVA	analysis of variance
CA	correspondence analysis
MR	Margaret River
YV	Yarra Valley
BV	Barossa Valley
MV	McLaren Vale
GC-MS	gas chromatography-mass spectrometry
MRW	Margaret River Wilyabrup
MRA	Margaret River Wallcliffe
MRR	Margaret River Regional
YVD	Yarra Valley Dixons Creek
YVG	Yarra Valley Gladysdale
YVR	Yarra Valley Regional
BVN	Barossa Valley Northern Grounds
BVS	Barossa Valley Southern Grounds
MVB	McLaren Vale Blewitt Springs
MVW	McLaren Vale Willunga
TA	titratable acidity
PCA	principal component analysis
DMS	dimethyl sulfide
AH	Adelaide Hills
CB	Canberra District
EV	Eden Valley
CBR	Canberra District
FN	food neophobia
LSD	least significant difference
PLS2	partial-least-square-regression
HC	hedonic cluster
AHC	agglomerative hierarchical clustering
FLC	pairing induced change of food liking
WLC	pairing induced change of wine liking
SD	standard deviations

Appendices

Appendix 1

Food for wine styles-Sydney international wine competition

Kustos M.

Wine & Viticulture Journal. **2017**, 32(2), 63-64

Appendix 2

The wine tasting 'experience'

Goodman, S., Kustos, M., Bastian, S. E. P.

Grapegrower and Winemaker. **2019**, 661, 75-76

Appendix 3

Dynamic viscosity levels of dry red and white wines and determination of perceived viscosity difference thresholds

Danner, L., Niimi, J., Wang, Y., Kustos, M., Muhlack, R. A., Bastian, S. E. P.

American Journal of Enology and Viticulture. **2019**, 70(2), 205-211

Finalist wines in the Sydney International Wine Competition are sorted into food-friendly style categories then judged beside food dishes of similar palate weight.

Food for wine styles – Sydney International Wine Competition

By Marcell Kustos

The Sydney International Wine Competition, sponsored by the publisher of the Wine & Viticulture Journal Winetitles Media, is the only Australian wine show to judge finalist wines in combination with appropriate food. With a Bachelor in Food Engineering and a Masters in Gastronomy, Marcell Kustos, a PhD candidate in food and wine pairing and sensory marketing at The University of Adelaide, was invited to design food and wine pairings alongside renowned chef Michael Manners for the 2017 SIWC. We asked Marcell to give us some insight into how they went about the process.

Food and wine have generally been consumed together since ancient times - enjoying them together can increase the satisfaction of both. However, when it comes to pairing food and wine, multi-sensory interactions are involved between taste, texture, aromas and emotions. I am currently investigating these interactions as part of my PhD research at the University of Adelaide and last year, I was invited to design food and wine pairings at the 37th Sydney International Wine Competition (SIWC) alongside guest celebrity chef Michael Manners.

The SIWC is unique among wine shows in Australia in that the final wines are judged with food. In October 2016 the competition took place in the Blue Mountains with 1911 wines from eight countries. The final 400 wines were retasted and judged alongside appropriately matched food.

Another difference with the SIWC is that apart from the specialist categories (sparkling, fortified, Pinot Noir, etc) the bulk of the finalists are pre-tasted prior to the final phase of judging and separated into categories based on their palate weight (lighter, medium and fuller-bodied dry wines). Palate weight is one of the most critical elements when finding balance with food, as you will often find lighter, medium and fuller bodied styles of the same grape varietals.

If pairing food with a single bottle does not sound challenging enough, imagine pairing food for 15 wine style categories, each consisting of more than 10 wines. For instance, the medium-bodied red was a group of more than 40 wines. Since the wines were categorised based on palate weight, they might have differed in other sensory aspects such as aroma profile, acidity, alcohol, astringency, flavour intensity, etc, so it is important that this is understood when considering how to match the wines with food.

As a researcher who has a great passion for gastronomy, I was delighted to combine Michael's knowledge with part of my research. So how did we match 20 wines with a single plate? Most importantly, we kept it simple. Although we brought a more scientific approach to the process, deconstructing food and wine down to the molecular level, we remained true to the legacy of the SIWC. The food needs to be simple, does not overpower the wine and is consumer friendly to prepare.

For consistency during the judging process, each mouthful has to have identical flavours and textures which are consistent irrespective of temperature as a panel tasting could take up to 30 minutes. We took into consideration seasonal local produce, the number of wines and the dominating wines from each category in previous years. Portion size and ease of edibility are also important for the international judging panel in day-long tastings.

All too often books talk about aroma compounds shared by both food and wine and get lost in the nuances of pairing. However, in reality, if you randomly take 10 wines they are more likely to share similarities in taste (sour, sweet, bitter, salty) and mouthfeel sensations (grainy, drying, viscous, alcohol heat, etc.).

Take the medium-bodied dry white wines category, for example. In the previous five years of the SIWC, mainly Chardonnay wines made it to the final alongside a few Pinot Gris and Semillon Sauvignon Blancs. Chardonnay can be described as moderately fruity with medium alcohol, medium weight, and medium to high acidity. To match that, we designed a refreshing, summery dish, a twist on the classic pairing of Chardonnay and chicken: chicken fillet with tomato mandarin gazpacho, white sauce, and crunchy fennel salad. The mouthfeel of a tender breast fillet rather resembles a fruity, crisp Chardonnay whereas rich, roasted thighs would better suit full-bodied, oaked, lees-stirred Chardonnays. To complement the racy acidity and fresh fruits of the wines, traditional gazpacho (roast garlic, basil leaves, chicken stock) was spiced up with mandarin while the addition of a creamy white sauce lifted the dish up to medium palate weight.

Michael Manners (right), guest celebrity chef for the 2016 Sydney International Wine Competition, with Marcell Kustos, who assisted Michael in designing the food and wine pairings for the competition.

Besides the crust on the fillet we wanted to put more texture into the dish. Thinly sliced fennel bulb was marinated in lemon and mandarin juice with fresh coriander leaves. Although our initial focus was on taste and mouthfeel, the final dish defined a flavour style: cooling freshness that is often associated with modern Chardonnay wines.

The suggested food and wine combinations arguably make the SIWC the most relevant wine competition for consumers. After all, the awarded wines are expected to perform at the dining table.

The winning wines and the paired dishes can be found at www.top100wines.com

Panel judge Megan Brodtmann retastes some finalist wines with food at the 2016 Sydney International Wine Competition. Following her first experience as a panel judge for the event in 2012 Brodtmann said she was fascinated to see certain wines outperform when tasted with the food.

The wine tasting 'experience'

Is sensory marketing the next step in the evolution of the Australian cellar door experience, asks the University of Adelaide's Associate Professor in Marketing **Steve Goodman**, PhD student **Marcell Kustos** and Associate Professor in Oenology and Sensory and Consumer Science **Sue Bastian**?

The Australian wine industry has a reputation for innovation and embracing science and technology in wine production, yet we don't see this in marketing operations such as the consumer experience in cellar doors.

Since wineries opened cellar doors in the 1970s they have been used as a marketing tool for building direct relationships between wineries and consumers, as well as offering wine as an Australian product to domestic and international tourists. Over 70 percent of Australian wineries operate a cellar door, presenting their wines to consumers and attempting to boost sales of the wines involved – but as we approach the year 2020 does the wine tasting experience, nearly unchanged for 50 years, need a makeover, or even a reinvention?

Regional wine tourism has advanced with: improved infrastructure, the architecture of wineries has seen significant upgrades, and wineries now incorporate art, food, music and events. But, what are the wine tasting experiences at cellar doors like today? Well, consumers taste anywhere between five and 20 wines across a wine producer's quality range, guided by buzzwords like 'single vineyard' and 'reserve'. Staff attempt to regale with stories of the wines or winemaker and gauge the tastes, experiences and spending habits of visiting consumers in an attempt to personalise the interaction. Training, where it is done, typically focusses on the technical aspects of the wine. There are taste descriptions and some information about the winery as well on display in laminated tasting notes on the tasting bench. Alternative grape varieties pop up here and there, but despite increasingly fashionable tasting fees, the wine tasting experience remains uncannily similar to the '70s.

The Australian wine industry has a reputation of innovation and embracing science and technology in wine production, yet we don't see this in marketing operations such as the consumer experience in cellar doors. It is somewhat surprising, because the present state of knowledge in sensory and consumer science disciplines shows wine tasting goes beyond aroma and flavour described in tasting notes. Wine tasting is a multi-sensory experience, engaging our unconscious thoughts and emotions intertwined with memories. Even the 'simple' elements such as flavour have a far great experiential impact than most consider.

Flavour perception begins with a wine's appearance – yes, how it looks in the glass, but research also shows that ambient music, lighting, décor and aromas in the surrounding vicinity affects what we see and taste in a wine. The appearance of the bottle it has come from and who has poured it impacts our opinion. Colour, intensity and clarity all create expectations around a wine's flavour before we even reach towards the glass. The aromas might generate further expectations, like associations of citrus aromas with vibrant acidity or dried fruits and spicy oak aromas with a warm, rounded palate. Or how about something savoury to enhance the drying sensation of tannins? ▸

What do those tannins feel like? Smooth like velvet or as rough as sandpaper? Can you relate that tactile sensation to the bench surface you are resting your hands on or to the loud, distorted rock music playing in the background?

Different wine flavours evoke different emotions: for example, chocolate and rose, happy, well-being, pleasantly surprised and romantic; lemon, energised and invigorated emotions. These are areas for staff to utilise in the crafting of the sensory experience. If it was sparkling wine, the popping sound of cork and fizzing bubbles would have set the scene for citrusy refreshment even before smelling the wine – as well as a heightened sense of 'celebration', something not experienced by those tasting but not present at the opening.

Flavour perception does not end with the interactions between our sensory modalities of sight, hearing, smell, taste, and touch. Based on our past experiences, we tend to couple memories with certain aromas and flavours. It is also known as the Proustian moment – a brief, vivid, sensory invoked memory of a nostalgic childhood moment. During tasting, memories evoke emotions and vice versa, which will impact the perceived flavour and thus the tasting experience. Arousing a consumer's involuntary memory through suggestion from staff communication during the experience of wine tasting might prove to be a defining moment with the consumer adopting and generating positive word-of-mouth for the wine brand.

Sensory marketing is a type of marketing that engages consumers' senses on an emotional level, and affects their perception, judgement and behaviour in relation to the brand/product/service. Emotional bonding using sensory marketing has been widely used in the luxury goods industry to create long-term brand loyalty that has moved far beyond simply 'wanting'. This is because, other than utilitarian products, consumers do not buy products or services only, but they buy experiences, and experiences are created using the senses.

Engaging the multi-sensory component of the wine tasting experience allows sensory marketing to enhance the emotional part of flavour perception and tailor it into a memorable winery experience. To achieve that today, a tasting room with a fancy vineyard view may no longer be enough. An increasing number of wineries offer wine tasting with food or canapés. This approach to some extent creates consumer engagement, but still remains rather product focussed by presenting a sequence of wines instead of an experience. This is the approach used in promotional wine dinners as well, with each course paired with a wine in order to showcase the wine. This does not involve sensory marketing, nor creates a memory through an experience. Variations of steak and veggies might pair well with bold Shiraz and Cabernet wines, but how does it set apart the showcased wine from others?

> **...a tasting room with a fancy vineyard view may no longer be enough**

Wine provenance is important to high-end consumers as are vintage conditions, but are you able to tell the story of winemaking and vintage through the paired aromas, flavours and textural elements of the wine – and of the physical environment in which it is taking place? Food and wine pairing is desired by consumers and with a scientific approach it may lead to significant consumer satisfaction and financial gain.

In short, a memorable consumer experience is immersive, innovative enough to engage and entertain the guest, while the environment - and in this case the food pairing - is appropriate with the wine and memories intended to be created. As the wine industry evolves, the tasting experience and food pairings should go in hand with it too. It is time to explore sensory marketing as a field – combined with communication techniques – and engage science in a bid to deliver experiences that create memories and win customers.

Though not exhaustive, here is a list of questions to consider when planning your wine tasting:

- Do you quality check opened bottles or decant new ones? How are they tagged/stored? Oxidised wine or flat sparkling is disappointing!
- What is on display in the tasting area, e.g. texture of the tasting bench, colour of walls and surrounds? For example, blue light makes wine taste bitter.
- What music/sound do you use? Pitch style and genre changes how we perceive wine aroma taste and flavour.
- Do you limit yourself to crackers and bread as palate cleansers? Do you include local or seasonal produce?
- Have you trained staff communication to avoid purely technical language? Are they able to invoke memories or arouse 'Proustian moments'?
- Do you ensure engagement throughout the tasting?

The present state of sensory marketing permits us to understand multi-sensory interactions and reconstruct memorable sensory experiences, but we can also use that knowledge to create new ones.

In many ways, cellar door experience is like a theatre piece, or a sensorial roller coaster. So, put time aside to plan your tasting experience starting with what you want to achieve. Then talk with (and listen to) your visitors. After all, it is the perfect opportunity to solicit feedback from consumers – but then ensure there is a system or process for capturing this and passing it along.

About the authors

Steve Goodman is an Associate Professor in Marketing at the University of Adelaide's Business School with a focus on researching wine marketing, particularly understanding and influencing consumer choice, cellar door servicescape and supply chain marketing.

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Research Note

Dynamic Viscosity Levels of Dry Red and White Wines and Determination of Perceived Viscosity Difference Thresholds

Lukas Danner,[1] Jun Niimi,[1] Yuxing Wang,[1] Marcell Kustos,[1]
Richard A. Muhlack,[1] and Susan E. P. Bastian[1]*

Abstract: Wine mouthfeel significantly contributes to the overall sensory perception and quality of wines. However, the influence of dynamic viscosity on the mouthfeel of dry table wines is still not fully understood. The three objectives of this study were to 1) determine the perceived viscosity difference threshold in wine using wine/xanthan gum solutions, 2) measure dynamic viscosity levels of Australian commercial dry Shiraz and Chardonnay table wines, and 3) investigate in wine samples the relationship between dynamic viscosity and chemical parameters, specifically, residual sugar, ethanol, and pH. A wine viscosity difference threshold value of 0.138 mPa·sec at 20°C was determined by ascending two-alternative forced-choice difference threshold tests with a sensory panel (n = 45). The dynamic viscosity for 34 commercial Chardonnay wines at 20°C ranged from 1.448 mPa·sec to 1.529 mPa·sec, and from 1.488 mPa·sec to 1.695 mPa·sec for 29 Shiraz wines. These results indicate that on the basis of the determined threshold values, tasters could likely differentiate wines in terms of viscosity within the viscosity range of this sample set of Shiraz, but not Chardonnay, wines. Furthermore, significant correlations between dynamic viscosity and ethanol concentration, but not for pH and residual sugar, were found for both varieties, indicating that ethanol may have been the main compositional factor that increased dynamic viscosity in commercial dry wines.

Key words: viscosity difference threshold, viscosity range, wine body, wine mouthfeel

Frequently, winemakers categorize wine into different levels of “body,” with the purpose of informing their consumers about the intrinsic sensory properties of their products. In the literature, body is often defined with words such as “fullness,” “thickness,” and “weight” (Langstaff and Lewis 1993, Gawel et al. 2000, Szczesniak 2002), and as such, it has been thought to closely relate to perceived viscosity. Unfortunately, there is no consensus on any concrete definition of wine body (Yanniotis et al. 2007). Consumers at least regard body as being related to the holistic perception of flavor and less related to mouthfeel (Niimi et al. 2017). This may explain why there is a poor understanding of its meaning and how it relates to various compositional aspects of wine. Viscosity, on the other hand, is a more precise term that is easily recognizable as a textural perception, and, unlike wine body at present, is physically measurable.

Viscosity is considered one of the most notable and recognizable mouthfeel characters of beverages (Szczesniak 1979) and can be measured mechanically or perceptually in all fluid/semifluid food products (Bourne 2002). Dynamic viscosity is defined as the ratio of the viscous shear stress to the rate of strain for a given fluid (Atkins and Escudier 2013). Wines at 5°C appear to exhibit non-Newtonian fluid character (Trávníček et al. 2016), but those at temperatures of 10°C and above have characteristics of a Newtonian fluid (having a linear relationship between shear stress and strain) (Košmerl et al. 2000, Zuritz et al. 2005, Yanniotis et al. 2007, Neto et al. 2015). Perceived viscosity in the context of wine, is “the degree to which wine resists flow when moved from side to side in the mouth” (Pickering et al. 1998). Perceived viscosity in wine tends to increase with increased sugar (Burns and Noble 1985, Nurgel and Pickering 2005), polysaccharides (Vidal et al. 2004, Jones et al. 2008, Gawel et al. 2016), amino acids (Skogerson et al. 2009), and pH (Gawel et al. 2014, 2016); however, studies investigating how pH influences wine viscosity in general are still lacking. Other wine components do not appear to influence perceived viscosity despite a clear increase in dynamic viscosity as a function of the concentration of, for example, ethanol and glycerol (Noble and Bursick 1984, Pickering et al. 1998, Nurgel and Pickering 2005, Runnebaum et al. 2011). Other authors suggest that astringency can influence saliva viscosity and that perceived astringency

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in wine may be influenced by viscosity (Smith et al. 1996, Bajec and Pickering 2008, Pickering and DeMiglio 2008, McRae and Kennedy 2011). However, the role of tannin concentration in dynamic viscosity remains unexplored.

A limited number of studies have determined the dynamic viscosities of dry table wines. Viscosities of 40 Slovenian white and red wines were studied, and of those, only 14 were dry (<4 g/L residual sugar), ranging in viscosity from 0.089 mPa·sec measured at 30°C to 0.138 mPa·sec measured at 20°C (Košmerl et al. 2000). Runnebaum et al. (2011) reported a similar dynamic viscosity range of 0.081 mPa·sec at 30°C across 17 dry white wines from six different varieties. From these two limited studies, it appears that differences in dynamic viscosity in dry commercial wines are rather small, which begs the question, are such differences perceivable?

Several attempts have been made to determine the difference thresholds for perceived viscosity in commercial dry wines, but these attempts had variable outcomes. Through discrimination testing of white wine with xanthan gum additions, Noble and Bursick (1984) estimated the difference threshold of perceived viscosity as 0.141 mPa·sec. A much lower difference threshold of 0.027 mPa·sec has been extrapolated from descriptive analysis data (Runnebaum et al. 2011). Both studies performed sensory evaluation of the wines at room temperature (20 to 22°C) (Noble and Bursick 1984) and at "air-conditioned room temperature" (Runnebaum et al. 2011), but dynamic viscosity was measured at 20°C by Noble and Bursick (1984), and at 30°C by Runnebaum et al. (2011). As temperature can influence viscosity, direct comparisons of the difference thresholds determined from these two studies are difficult. To enable better comparisons across studies, using a standard temperature for viscosity measurements in wine, preferably close to tasting/consumption temperature, is recommended for future research. However, according to observations by Košmerl et al. (2000), the temperature at which the dynamic viscosity was measured can only partly explain the difference in the reported difference thresholds between the two studies.

A literature review revealed substantial discrepancies in reported perceived viscosity difference thresholds in wine and a lack of studies investigating dynamic viscosity in dry table wines produced from the same grape variety. On the basis of the commercial importance of Shiraz and Chardonnay in Australia (they are the most planted red and white grape varieties in Australia, respectively), and in many other wine-producing countries, these two varieties were chosen to investigate the dynamic viscosity ranges within dry red and white wines produced from the same grape variety.

Furthermore, how compositional parameters contribute to dynamic viscosity of dry wines has not been fully established. Therefore, the objectives of this study were to 1) determine the perceived viscosity difference threshold in wine with wine/xanthan gum solutions, 2) determine dynamic viscosity levels of 63 dry (<4 g/L residual sugar) commercially available Australian Shiraz and Chardonnay wines, and 3) investigate the relationships between dynamic viscosity and several basic chemical parameters, including residual sugar, ethanol, pH, and tannin concentration within the two examined wine varieties.

Materials and Methods

Wine samples. A commercial Semillon (Hunter Valley, 2015) which had neutral flavor characters and a relatively low dynamic viscosity (1.367 mPa·sec at 20°C), was used as base wine for the viscosity difference threshold tasting.

To investigate the viscosity ranges of Australia's most planted red (Shiraz) and white (Chardonnay) winegrape varieties, commercially available dry (<4 g/L residual sugar) Australian Chardonnay (n = 34) and Shiraz (n = 29) wines were sourced from South Australian stores or donated by the wineries (Table 1). All wines were stored in a 15°C cool room until analysis.

Difference threshold sensory testing. Wine viscosity difference thresholds were determined with an ascending two-alternative forced-choice test, in which the reference was the base wine (Semillon, Hunter Valley, 2015) without xanthan gum addition. To alter the wine viscosity, xanthan gum (The Melbourne Food Ingredient Depot) was added in 0.02 g/L steps within the range of 0.02 g to 0.12 g to simulate the viscosity range of commercial dry wines. Xanthan gum was chosen because it is soluble and stable under wine conditions, as well as tasteless and odorless at the concentrations used. The xanthan gum wine solutions were prepared the evening before the tasting, with continuous stirring at room temperature (20°C) overnight to ensure complete dissolution of the gum, under a nitrogen atmosphere to prevent oxidation. The same treatment was applied to the base wine without xanthan gum addition.

Assessors (n = 45) were recruited from the University of Adelaide Waite Campus and comprised enology students and staff experienced in wine tasting and formal sensory testing (20 men and 25 women, average age 27 years). Each assessor tasted two warm-up samples that were specifically presented as low (base wine without xanthan gum) and high (base wine with 0.12 g/L xanthan gum) viscosity standards before performing the test. Assessors were then presented with six pairs of samples in black INAO glasses, in a random order, and labeled with four-digit codes. Each pair consisted of a sample of base wine without xanthan gum and a sample with one of six xanthan gum concentrations. Upon tasting, the assessors were forced to choose from each pair one sample that was perceived to be higher in viscosity. All samples including the warm-up samples were served at 20°C. For each test, deionized water and crackers were provided as palate cleansers, and a break of 30 sec between sample pairs was enforced. Test administration and data acquisition was performed using the RedJade software system (RedJade). Sensory testing was conducted in individual sensory booths and approved by the Human Research Ethics Committee of the University of Adelaide (project number: H-2013–048).

Wine chemical and physical measures. The density and alcohol content of all wine samples were measured in duplicate with the Alcolyser Wine ME (Anton Paar, MEP Instruments Pty Ltd.). Residual sugar of wines was measured

Table 1 List of wines/varieties, vintages, and origins.

Chardonnay	Vintage	Region
C1	2014	Adelaide Hills, SA
C2	2013	Barossa Valley, SA
C3	2015	Margaret River, WA
C4	2015	Margaret River, WA
C5	2015	Margaret River, WA
C6	2015	Margaret River, WA
C7	2015	Margaret River, WA
C8	2015	Margaret River, WA
C9	2015	Margaret River, WA
C10	2015	Margaret River, WA
C11	2015	Margaret River, WA
C12	2015	Margaret River, WA
C13	2015	Margaret River, WA
C14	2015	Margaret River, WA
C15	2015	Margaret River, WA
C16	2015	Margaret River, WA
C17	2015	Margaret River, WA
C18	2012	Mornington Peninsula, VIC
C19	2013	Yarra Valley, VIC
C20	2015	Yarra Valley, VIC
C21	2015	Yarra Valley, VIC
C22	2015	Yarra Valley, VIC
C23	2015	Yarra Valley, VIC
C24	2015	Yarra Valley, VIC
C25	2015	Yarra Valley, VIC
C26	2015	Yarra Valley, VIC
C27	2015	Yarra Valley, VIC
C28	2015	Yarra Valley, VIC
C29	2015	Yarra Valley, VIC
C30	2015	Yarra Valley, VIC
C31	2015	Yarra Valley, VIC
C32	2015	Yarra Valley, VIC
C33	2015	Yarra Valley, VIC
C34	2015	Yarra Valley, VIC
Shiraz	**Vintage**	**Region**
S1	2014	Barossa Valley, SA
S2	2014	Barossa Valley, SA
S3	2014	Barossa Valley, SA
S4	2014	Barossa Valley, SA
S5	2014	Barossa Valley, SA
S6	2014	Barossa Valley, SA
S7	2014	Barossa Valley, SA
S8	2014	Barossa Valley, SA
S9	2014	Barossa Valley, SA
S10	2014	Barossa Valley, SA
S11	2014	Barossa Valley, SA
S12	2014	Barossa Valley, SA
S13	2014	Barossa Valley, SA
S14	2014	Barossa Valley, SA
S15	2014	McLaren Vale, SA
S16	2014	McLaren Vale, SA
S17	2014	McLaren Vale, SA
S18	2014	McLaren Vale, SA
S19	2014	McLaren Vale, SA
S20	2014	McLaren Vale, SA
S21	2014	McLaren Vale, SA
S22	2014	McLaren Vale, SA
S23	2014	McLaren Vale, SA
S24	2014	McLaren Vale, SA
S25	2014	McLaren Vale, SA
S26	2014	McLaren Vale, SA
S27	2014	McLaren Vale, SA
S28	2014	McLaren Vale, SA
S29	2014	McLaren Vale, SA

enzymatically as total glucose and fructose (Boehringer-Mannheim/R-BioPharm) with an automated sampler (Corbett 3800) and a spectrophotometric plate reader (Tecan M200 Infinite). pH and titratable acidity measures of the wines were determined with a Mettler Toledo T50 Autotitrator, titrating to an endpoint of pH 8.2 with 0.33 M NaOH solution. The chemical and physical measures of each wine sample were assessed in duplicate from individual bottles. The tannin concentration of red wines was determined by the methyl cellulose precipitable-tannin assay and expressed as epicatechin equivalents (Mercurio et al. 2007).

Dynamic viscosity of wines was measured with a falling-ball viscometer (Fungilab Viscoball) in which the ball consists of borosilicate glass (with a density of 2.230 g/cm^3 and a diameter of 15.80 mm) and is used to measure Newtonian fluids. The viscometer was held at a constant temperature of 20°C with water circulation. All wine samples (40 mL) were equilibrated in a water bath at 20°C for at least 15 min prior to measurements. The exact falling time of the ball in each wine sample was recorded with two cameras (model KYT-U130–01MBWCS, Kayeton Technology Co. Ltd.) at a rate of 30 frames/sec. The dry wine samples were assumed to have Newtonian fluid characteristics, according to previous studies (Košmerl et al. 2000, Neto et al. 2015), and the dynamic viscosity of wines was calculated with the following equation based on Stokes' Law:

$$\eta = t(\rho_1 - \rho_2)K \qquad \text{Eq. 1}$$

where η is the viscosity (mPa·sec), t is the ball-falling time (sec), ρ_1 is the density of the borosilicate glass ball (2.230 g/cm^3), ρ_2 is the density of the wine samples (using the determined values from the alcolyzer), and K is a constant corresponding to the ball used (0.02532 m^2/sec^2). Viscosity ball-falling times of each wine were determined in triplicate. Wine samples with or without xanthan gum additions used for sensory discrimination testing were also measured for dynamic viscosity to extrapolate the minimum dynamic viscosity change required for a perceived difference threshold.

Data analysis. Difference thresholds were determined from a one-tailed binomial distribution table, which corresponded to 64.4% correct responses with n = 45 panelists (Roessler et al. 1978). Descriptive statistics were used to analyze the viscosity range, mean, median, and interquartile ranges of commercial wines. The Kolmogorov-Smirnov test was used to test for the assumption of normal distribution. To investigate dynamic viscosity differences across growing regions within variety, one-way analyses of variance (ANOVAs) were conducted. In the case of the Chardonnay wines, only wines from the regions Yarra Valley and Margret River were included in this analysis, as the number of samples/region was too small for the other regions.

One-way ANOVA was used to analyze chemical parameters across samples. To define the relationship between viscosity and basic chemical parameters, Pearson correlation and linear regression were used. All statistical analyses were performed in SPSS 25 (2016, IBM Corporation) at a 5% level of significance.

Results and Discussion

The difference threshold of perceived viscosity. The perceived viscosity difference threshold, determined by using xanthan gum additions to a Semillon wine as a base wine, of 0.138 mPa·sec ($p < 0.05$) (Figure 1) confirmed the finding of 0.141 mPa·sec reported in a previous study (Noble and Bursick 1984). Given that discrimination testing is commonly regarded as a more sensitive method to detect subtle changes in sensory perception than descriptive analysis, the results of the current study suggest that the difference threshold of 0.027 mPa·sec reported previously (Runnebaum et al. 2011) may have been an underestimation.

Dynamic viscosities of commercial Chardonnay and Shiraz wines. The Kolmogorov-Smirnov test indicated that the dynamic viscosity data for the Shiraz ($p = 0.502$) and Chardonnay ($p = 0.642$) wines followed a normal distribution.

Dynamic viscosities of the wines were measured and analyzed with descriptive statistics (Figure 2). Overall, the dynamic viscosity range was lower and smaller across Chardonnay than across the Shiraz wines, with means of 1.475 and 1.611 mPa·sec, respectively. The viscosity range of Chardonnay was 1.448 to 1.529 mPa·sec (difference of 0.081 mPa·sec), and, accordingly, the interquartile ranges were also narrow (0.02 mPa·sec). The dynamic viscosities of the four Chardonnays from older vintages (1.48, 1.48, 1.50, and 1.52 mPa·sec) were well within the values of the 2015 Chardonnays. Dynamic viscosities of Shiraz ranged between 1.488 and 1.695 mPa·sec, more than double the range of Chardonnay (difference of 0.207 mPa·sec). The interquartile ranges were similar, at 0.03 mPa·sec, suggesting that the larger range in dynamic viscosity of Shiraz was mainly driven by one outlier. Further studies considering an even wider range of wine-compositional parameters and wines are needed to identify possible reasons for such outliers.

The viscosity range for the dry Shiraz and Chardonnay wines (1.448 to 1.695 mPa·sec at 20°C) concurs with previous findings by Košmerl et al. (2000) (1.456 to 1.594 mPa·sec at 20°C), who analyzed 14 Slovenian dry wines from several different varieties, and also with data we generated from 180 commercial Australian dry table wines, encompassing a wide range of grape varieties and styles (1.321 to 1.702 mPa·sec at 20°C) (unpublished data). The slightly lower maximum viscosity level reported by Košmerl et al. (2000) might be a result of the lower alcohol levels in the Slovenian wines (max 12.1% ethanol concentration) than in the Australian sample (max 15.7% ethanol concentration).

No significant differences between growing region were observed for Shiraz ($F(1, 27) = 2.435$, $p = 0.130$) and Chardonnay ($F(1, 29) = 1.794$, $p = 0.194$). This indicates that different growing conditions across the investigated growing regions (Barossa Valley and McLaren Vale for Shiraz, and Margret River and Yarra Valley for Chardonnay) did not have a significant influence on the measured dynamic viscosity. As different winemaking techniques might interfere with regional differences, future research should investigate wines from different regions or vintages, produced under standardized conditions.

Dynamic viscosity correlations with basic chemical measures of wine. The results of the one-way ANOVAs showed significant ($p < 0.001$) differences across samples for all compositional measures of ethanol content, pH, and residual sugar in both Shiraz and Chardonnay wines, and total tannins in Shiraz.

The ethanol concentration ranged between 13.4% and 15.7% for Shiraz samples, and from 12.2% to 14.5% for the Chardonnay samples (Figure 3A, 3B). The results indicated significant moderate to strong positive correlations between dynamic viscosity and ethanol concentration in both wine varieties ($p = 0.002$ and $r = 0.541$ for Shiraz, and $p < 0.001$

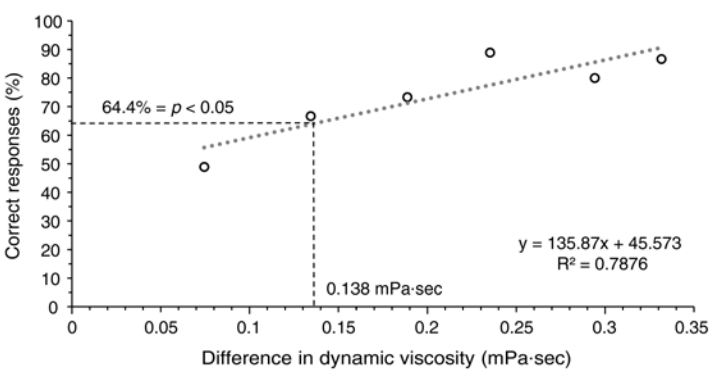


Figure 1 Correct responses in perceived viscosity differences as a function of difference in the dynamic viscosity of wines spiked with xanthan gum. Broken lines denote a significant difference ($p < 0.05$) between the reference and sample of interest, with a corresponding difference in dynamic viscosity, interpolated with the linear slope.

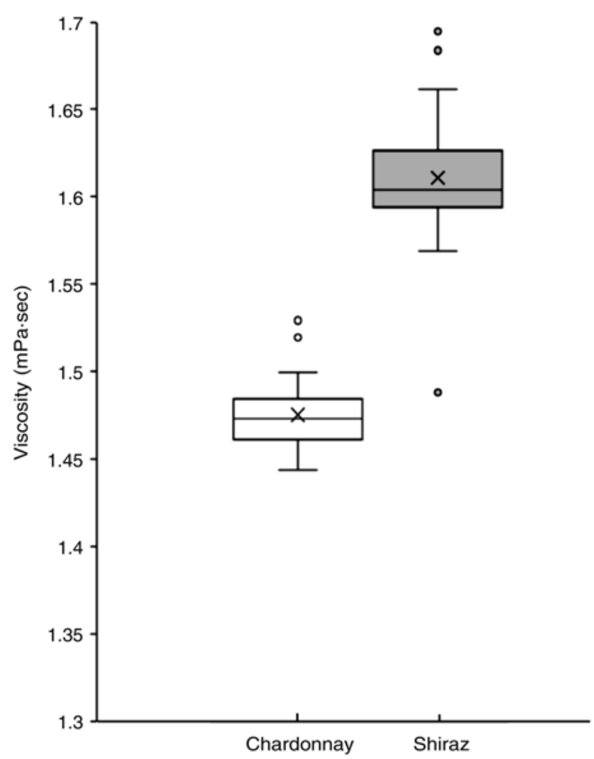
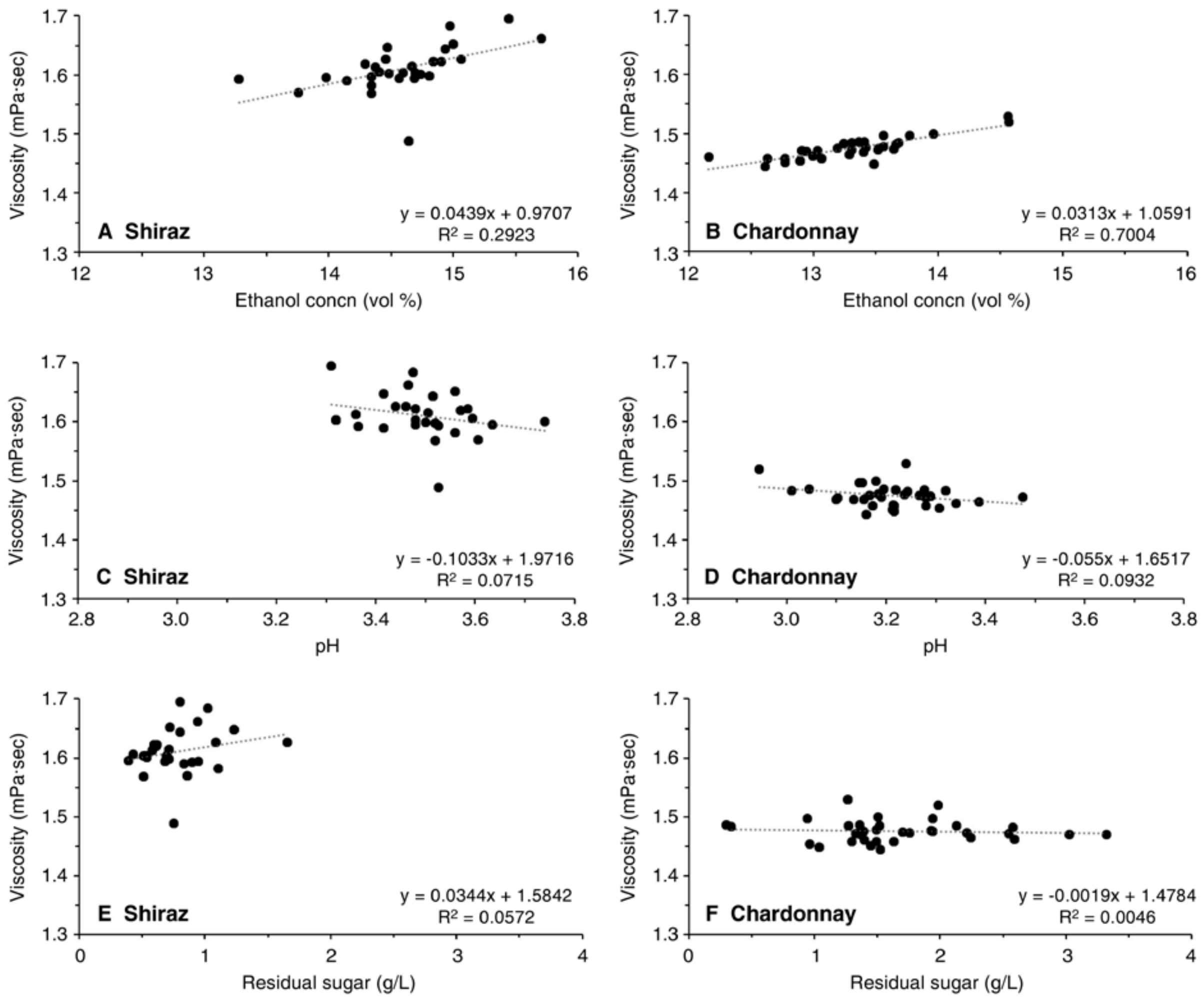


Figure 2 Box and whisker plots of dynamic viscosities for dry Australian commercial Chardonnay (n = 34) and Shiraz (n = 29) wines. Means are denoted with the × symbol in the boxes.

and r = 0.837 for Chardonnay). However, the rather moderate slopes identified for both Chardonnay and Shiraz meant that a minimum difference of 4.5% and 3.2% ethanol, respectively, is theoretically required for viscosity to be perceivably different (based on interpolating the difference threshold of 0.138 mPa·sec determined above). This confirmed previous findings by Pickering et al. (1998), who found significant positive correlations between ethanol concentration and dynamic viscosity, but not for perceived viscosity at ethanol concentrations typically present in wine.

pH values ranged between 3.31 and 3.74 in the Shiraz samples, and between 2.95 and 3.48 in the Chardonnay samples (Figure 3C, 3D). No significant correlations between pH and viscosity were observed for either of the two evaluated varieties (p = 0.161 and r = 0.267 for Shiraz, and p = 0.079 and r = 0.305 for Chardonnay). In contrast, perceived viscosity has previously been shown to positively correlate with pH (Gawel et al. 2014, 2016).

Residual sugar content has been identified as a major contributor to both dynamic and perceived viscosity in sweet and fortified wines (Burns and Noble 1985, Nurgel and Pickering 2005); however, in the present study of dry wines (having a sugar concentration below 4 g/L), no significant correlation between sugar concentration and dynamic viscosity was found (p = 0.211 and r = 0.239 for Shiraz, and p = 0.704 and r = 0.068 for Chardonnay, Figure 3E, 3F). This suggests that for dry wines, the influence of sugar content at such low levels has a negligible influence on viscosity.



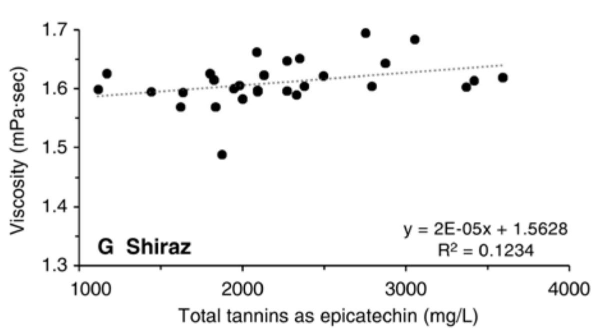


Figure 3 Relationships between dynamic viscosity and basic chemical parameters of ethanol concentration, pH, and residual sugar concentration within the two examined wine varieties, and tannin concentration as epicatechin equivalents for Shiraz wines.

Tannin concentration expressed as epicatechin equivalents ranged from 1116 to 3594 mg/L. Regression analysis indicated a non-significant relationship between epicatechin concentration and dynamic viscosity ($p = 0.062$ and $r = 0.351$, Figure 3G) in Shiraz wine. However, the direction of the trend indicated that tannin concentration could potentially contribute to the higher dynamic viscosities of Shiraz than of Chardonnay wines with the same ethanol level.

The results of the current study indicated a disparity between dynamic and perceived viscosity measures of wine, as has been reported in previous studies. Positive correlations of perceived viscosity with other chemical measures such as pH, total phenolics, hydroxycinnamates, and flavonols in wines were previously reported (Gawel et al. 2014), so there may be other mechanisms at play that result in the difference between the dynamic and perceived viscosities of wine. One possible explanation could be that wine chemical components interact with salivary components or oral epithelial surfaces, and these interactions could influence the perceived viscosity of the wine (Nordbö et al. 1984), but this remains to be investigated. Such effects could also explain why Runnebaum et al. (2011) found a lower difference threshold of perceived viscosity than the thresholds identified by Noble and Bursick (1984), and in the current study. Runnebaum et al. (2011) used a wide range of commercial wines for their study, not controlling for potentially biasing effects such as pH, whereas the current study and that by Noble and Bursick (1984) solely changed viscosity through xanthan gum addition.

Limitations. The difference threshold of viscosity in wine was determined indirectly using xanthan gum, a constituent not inherently present in wine. Therefore, the difference threshold is only an indicative value that could be applied to perceivable differences among commercial wines. This was the most suitable approach in determining difference thresholds without having potential compositional factors confound the results, as would have been the case if a range of commercial wines had been studied. The correlations determined here reveal the relationships between chemical composition and dynamic viscosity. Whether these correlations also hold true between perceived viscosity ratings and chemical measures requires further investigation. The range of wines tested here is by no means extensive, and the findings of the current study would be greatly enhanced with further research investigating a larger, more variable set of commercial wines which also includes a more comprehensive approach to differentiate among different tannin classes.

Conclusion

The perceived viscosity difference threshold of wine at 20°C was confirmed in the current study as 0.138 mPa·sec, providing a firm basis for further research on this topic. To enable a better comparison across studies in the future, we recommend using a standardized temperature for measuring viscosity in wine.

Dynamic viscosity differences among commercial dry wines made from the same grape variety were relatively small. Despite analyzing wines from different regions and a wide range of producers using different production techniques, we found that these differences were below the determined difference threshold for the 34 analyzed Chardonnay wines, and just above for the 29 Shiraz wines, indicating that winemaking techniques and harvest condition may have only limited influence on viscosity. Ethanol was the main chemical component that influenced dynamic viscosity within variety; however, even differences of up to 2.5% ethanol in Chardonnay wines did not result in changes in dynamic viscosity that would exceed the determined threshold level.

Wine consumption is a multisensory experience, and mouthfeel, including viscosity, is increasingly being recognized as an important driver of wine quality. Winemakers are greatly interested in producing wines with pleasing texture; therefore, it is imperative to better understand the physiological and psychological bases for wine mouthfeel perception and the intricate roles of wine composition for these sensations.

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