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Intertwined: What makes food and wine pairings appropriate?

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ABSTRACT

This study sought to identify sensory attributes of appropriate food and wine pairings and relate them to 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, flavour intensities increased and wine taste attributes changed in relation to individual components. Appropriate pairings positively correlated with liking, sensory complexity, and expected price to pay, and negatively with balance as a slight wine dominance was preferred. 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. 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 better 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.

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 consuming either in isolation (Lahne, 2018). The culinary literature has many theories on pairing food and wine, and the most explained ideas investigate interactions between the key elements of food and wine (Harrington, 2007). Paulsen, Rognså, and Hersleth (2015) reviewed 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 based on 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, Payne, Perrenoud, Joscelyne, & Johnson, 2009; King & Cliff, 2005), but they are generally not good predictors of good or bad pairings. 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 disobey the fundamentals of sensory evaluation and consumer research (Lawless & Heymann, 2010), therefore, it is difficult to rely on these results. It has been suggested that consumers might perform similarly to trained panellists if a suitable method is used (Varela & Ares, 2012), however, considering the complexity of evaluating 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, Collins, & Johnson, 2010; Madrigal-Galan & Heymann, 2006), which stemmed from an empirical discovery by Nygren, Gustafsson, and Johansson (2003) that showed 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

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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 result in attribute suppression or enhancement, but the question is whether the suppression or enhancement is pleasant for consumers. For instance, it is unlikely that the increased bitterness or harsh acidity of a wine can 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 a systematic approach in sample selection, namely on what basis certain foods and wines were chosen for investigation in pairings. Studies attempted to disprove anecdotal rules of food and wine pairings (Harrington & Seo, 2015; Harrington, McCarthy, & Gozzi, 2010) yet they chose supposedly "good" and "bad" pairings without evidence. A more viable approach is to select pairings based on experts' recommendations (Bastian et al., 2009; Harrington & Hammond, 2006b; Harrington et al., 2010), however, those expert suggestions may not overlap with consumers' choices (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. Usually, 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, these neglected the cultural associations of the selected wines and foods. Furthermore, evaluating one wine per grape variety/appellation without a pre-selection process assumes that all wines within a variety or region share the same sensory characteristics. 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). Therefore, generating pairings for research purposes based on a detailed understanding of the actual sensory properties of pairing components is a more effective approach.

Limitations of the analytical studies have been the use of scales which assume that in an ideal match, 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 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 some studies contradict that belief (Bastian et al., 2010; Donadini, Fumi, & Lambri, 2012). However, if we accept synergy between food and wine as driving ideal matches, the pairing would be more liked than 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 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 literature on food and wine pairing tends to base the success of a pairing on consumer liking. However, studies disagree whether the liking of the pairing is influenced by the liking of individual food or wine items (Bastian et al., 2010; Donadini et al., 2012; Harrington & Seo, 2015) or not (Eindhoven & Peryam, 1959). 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 could be segmented by either demographic, geographic, behavioural or psychographic measures e.g., gender, location, purchasing behaviour, hedonic scores, neophobia, and levels of consumer knowledge, attitudes, opinion, involvement and interest, thus consumers with similar traits are grouped together (Kotler, Keller, Brady, Goodman, & Hansen, 2009; Johnson, Danner, & Bastian, 2017).

Besides the sensory characteristics of products, other subjective and complex dimensions might also influence consumer decisions (Masson, Delarue, Bouillot, Sieffermann, & Blumenthal, 2016). Among such factors, perceived complexity; comprising sensory, cognitive, and emotional dimensions, seems important, 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 using 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 or a synergistic relationship between food and wine. We hypothesised that appropriate food and wine pairings would 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 would be greater than liking of the food or wine element alone. The secondary aim was to determine sensory attribute changes in food and wine with pairing and if they drive perceived appropriateness and liking of pairing.

2. Material and methods

The experimental design comprised a series of DAs followed by a consumer test (Fig. 1). 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 trained during three 120 min training sessions. In these sessions, 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 nine aroma, 15 taste and mouthfeel and ten 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. Foods were assessed in duplicate with seven foods presented individually in each session in 4-digit coded, clear plastic containers with a 5 min break after four foods and 60 s between samples.

2.1.2. Wine DA panel

The training and evaluation procedure was identical to that of the food panel. The panel agreed on 25 sensory attributes, comprising nine aroma, seven taste and mouthfeel and nine flavour attributes (Table A.2). Wines were assessed in duplicate with eight wines presented individually in a randomised order during each session, with a 60 s 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 et al., 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

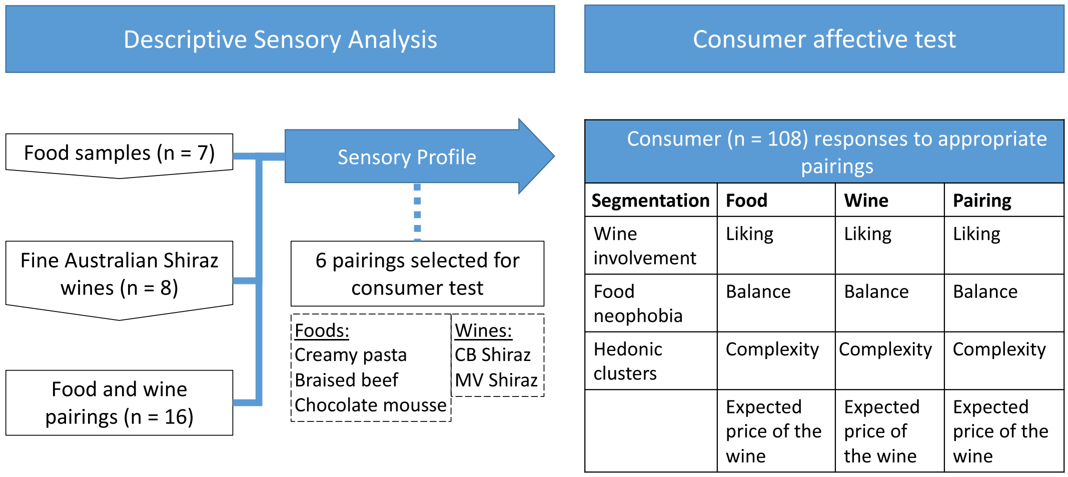

Fig. 1. The summary of the experimental design.

(8 mL) of wine. The panel agreed on 21 sensory attributes, comprising 11 taste and mouthfeel and ten 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 the University of Adelaide, Waite campus using RedJade Sensory Software (RedJade Software Solutions, LLC). The study was approved by the University of Adelaide Human Research Ethics Committee (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 was based on an online consumer survey specific to fine Australian Shiraz wines (Kustos, Goodman, Jeffery, & Bastian, 2019). Pre-selected meal and food samples underwent a preliminary benchtop test with experts (Parr, White, & Heatherbell, 2004) and seven samples were chosen for the DA (Table A.4). Principal component analysis (PCA) of the DA data provided an effective tool for selecting four samples with very different sensory attributes: 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 (Fig. 2). As the spicy hot salami dominated all pairings in the DA, it was excluded, and consumers evaluated three foods in pairings to cover items of a regular meal: starter/entrée, main, and dessert. See the Food sample selection process in supplementary information for further details.

2.2.2. Wine samples and selection

From a larger group of eight fine Shiraz wines (Kustos, Goodman, Jeffery, & Bastian, 2019), which underwent DA (Table A.6, (Lawless & Heymann, 2010)), four wines with very different sensory attributes were chosen to be evaluated in the food and wine pairing DA (Fig. 3). 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). See the Wine sample selection process in supplementary information for further details

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 consent prior to the first tasting session and received an US$10 gift voucher to an online store upon completion. The study was

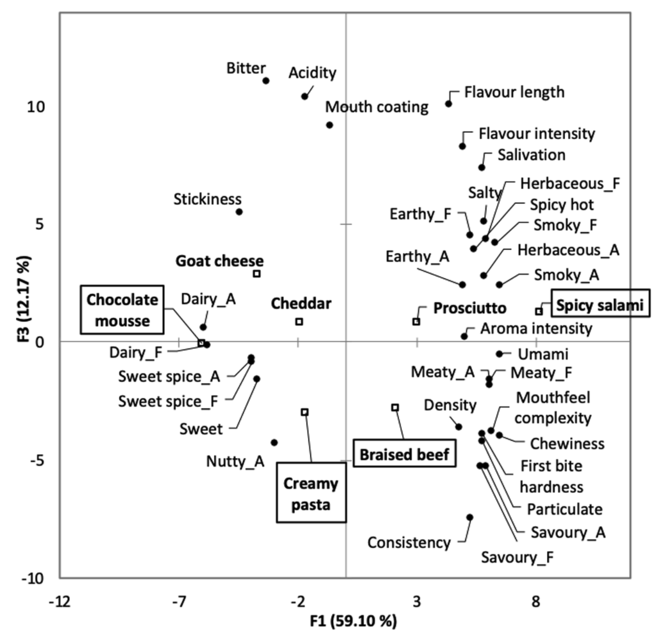

Fig. 2. Scores of the food samples (n = 7) with loadings of sensory properties on the first two principal components explaining the variability in sensory data. Boxed products marks the selected samples for food and wine pairings.

approved by the Institutional Review Board of University of California, Davis (1228622-1).

First, consumers received food samples in sequential monadic order, presented in uncoded, clear plastic containers. The presentation order 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. All wine samples (15 mL) were presented in clear 215 mL ISO glasses coded with 3-digit codes 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

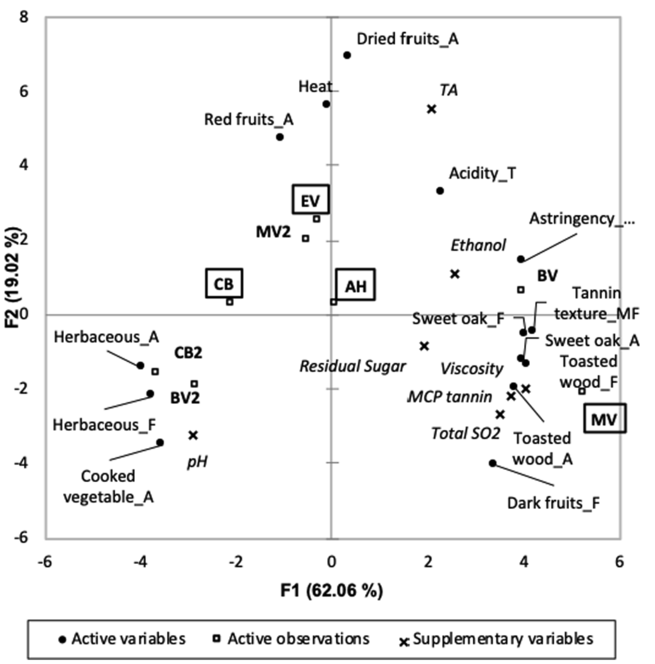

Fig. 3. Scores of the Shiraz wines (n = 8) with loadings of sensory properties and chemical composition as supplementary variables on the first two principal components explaining the variability in sensory data. Boxed wines mark the selected samples for food and wine pairings.

presented one at a time. Consumers received both verbal and written instruction about the mixed-tasting method (Nygren et al., 2003).

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. 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).

2.4. Statistical analysis and calculations

The DA data were analysed by univariate three-way analyses of variance with all two-way interaction (ANOVA) using a mixed model with product and replicate as fixed factors and judge as random factor. 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. 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, etc. As the DA panel did not assess aromas for pairings, only in mouth attributes (flavours, taste and mouthfeel) were used for this method. Consumers were segmented by agglomerative hierarchical clustering (AHC). 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. Variable importance for the projection values (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.

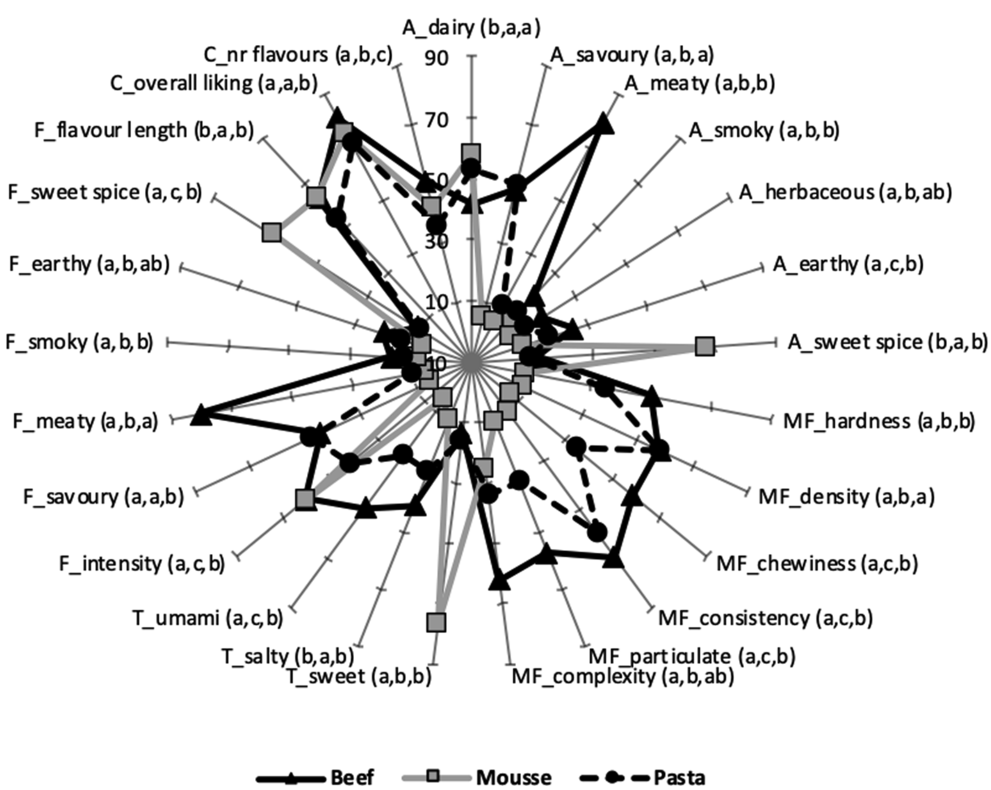

Fig. 4. Descriptive analysis intensity rating scores of sensory attributes and consumer sensory and hedonic scores for food samples. Note: The "A" prefix denotes aroma, "MF" mouthfeel, "T" taste, "F" flavour, and "C" consumer rated attributes. C_nr flavours denotes the number of flavours perceived by consumers. The letters following the attributes show the result of Fisher's pair-wise comparison for a given attribute p < 0.05. Consumer attributes were measured on 9 point scales (converted to 100 point scales for visualisation) and sensory attributes on a 100 point scale.

3. Results and discussion

3.1. Sensory profile and consumer ratings of food samples

Fig. 4 shows the results of the DA for the three selected foods. Twenty-three of 34 attributes significantly differed across sensory modalities by product. As expected, the mousse was the sweetest and the pasta (starter) and beef (main) were more salty and umami (Fig. 4). 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 (Fig. 4). 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 ($r = -0.722$).

3.2. Sensory profile and consumer ratings of wine samples

Nine of 25 sensory attributes differed significantly across the two Shiraz wines (Fig. 5). In most cases MV was more intense than CB, except for red fruits aroma and savoury flavour, 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 (Fig. 5). Such sensory differences were expected, since 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 (Lattey, Bramley, & Francis, 2010; Kustos et al., 2020). CB possessed red fruit aromas and savoury flavour,

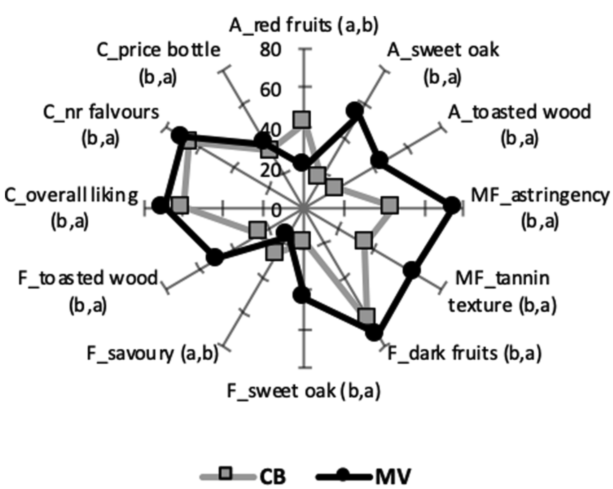

Fig. 5. Descriptive analysis intensity rating scores of sensory attributes for Shiraz wines evaluated in the consumer test. Note: The "A" prefix denotes aroma, "MF" mouthfeel, "T" taste, "F" flavour, and "C" consumer rated attributes. C_nr flavours denotes the number of flavours perceived by consumers. The letters following the attributes show the result of Fisher's pair-wise comparison for a given attribute $p < 0.05$. Consumer attributes were measured on 9 point scales except "C_price bottle" (7 point) and converted to a 100 point scale for visualisation purposes. The sensory attributes were measured on 100 point scales.

which are common descriptors for cool climate Shiraz wines (Iland, 2009). The two Shiraz wines represented the diversity that exists within wines made with this grape variety.

3.3. Sensory profile and consumer ratings of food and wine pairings

3.3.1. Sensory profile of food and wine pairings

From the 21 sensory attributes (Table A.6), 15 differed significantly across the pairings (Table 1). 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 1), 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, implying 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, Fig. 5). Although wine sensory characteristics was expected to be supressed by the food (Nygren, Gustafsson, & Johansson, 2002), the savoury flavour similarity with beef (mean = 44.9 (Fig. 4)) 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 scored low on most attributes. The sensory differences between pairings (Table 1) resembled the results of the food DA (Fig. 4), and the pair-wise comparison suggested a significant food effect on most sensory descriptors as per Nygren's findings (2001). 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 1). 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 bitter and unbalanced (Fielden & Robinson, 2009). Among the major sensory attributes of wines distinguishing BeefCB and BeefMV, the more astringent, oaky and smoky MV increased bitterness in pairing with the high umami and moderately salty beef (Table 1). This result seems to support expert opinions (Fielden & Robinson, 2009), however, Brannan, Setser, and Kemp (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).

The astringency difference between wines remained significant in pasta and mousse pairings, however it was suppressed with beef and potato puree pairings (Table 1). The latter pairing supports the theory that astringent wines pair with foods that are high in fat and protein (Des Gachons et al., 2012; Madrigal-Galan & Heymann, 2006), however only partially as BeefMV was not significantly less astringent than

Table 1
Rating scores of sensory attributes and consumer attributes evaluated for food and Shiraz wine pairings that were included in the consumer test.

	BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
OSD	-2.7 c	6.8 bc	13.9 b	13.7 b	17.1 ab	28.5 a
F_sweet spice	10.6 cd	13.3 c	65.4 a	65.6 a	5.3 d	19.8 b
F_savoury	65.6 a	54.9 b	4.4 d	5.8 d	44.9 c	40.9 c
F_smoky	12.9 b	37.3 a	6.3 b	39.4 a	12.4 b	32.1 a
F_meaty	74.4 a	73.1 a	5.1 b	5.0 b	5.6 b	5.4 b
T_acidity	52.2 b	56.6 b	68.6 a	69.9 a	68.6 a	70.4 a
T_sweet	20.4 b	20.2 b	48.4 a	49.9 a	18.5 b	22 b
T_salty	43.7 a	45.8 a	8.1 c	9.3 c	25.2 b	25.1 b
T_bitter	10.2 c	23.9 ab	19.9 abc	28.1 a	13.2 c	17.4 bc
T_umami	54.9 a	56.6 a	5.6 c	5.6 c	14.1 b	13.8 b
MF_complexity	66.5 a	70.5 a	36.9 c	38.3 c	44.8 bc	48.6 b
MF_chewiness	75.8 a	76.0 a	6.6 c	5.8 c	56.6 b	57.4 b
MF_body	53.4 ab	60.8 a	48.4 bc	54.3 ab	41.9 c	52.6 ab
MF_astringency	33.1 c	44.8 bc	45.2 bc	60.6 a	39.9 c	56.4 ab
MF_heat	62.6 b	62.5 b	63.1 ab	71.4 a	53.6 c	64.9 ab
C_overall liking	6.6 a	6.6 a	6 bc	6.3 ab	5.6 c	5.6 c
C_pairing	6.4 a	6.4 a	5.9 ab	6.3 a	5.5 b	5.4 b
C_balance	0.0 c	0.5 b	0.6 b	0.6 b	1.0 a	1.0 a
C_nr flavours	5.2 a	5.1 ab	4.6 cd	4.8 bc	4.5 d	4.7 cd
C_price bottle	2.8 a	2.9 a	2.4 b	2.7 a	2.4 b	2.6 ab

OSD: Overall Sensation Dominance. 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 row 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 no dominance/balance towards food (negative) or wine (positive).

PastaMV, possibly due to the buttery cheese sauce in the pasta pairing (Bastian et al., 2010) (Table A.2). It appears that astringency and fattiness can oppose each other resulting in a perceptual palate cleansing effect (Des Gachons et al., 2012).

3.3.2. Consumer hedonic ratings of food and wine pairings

BeefCB and BeefMV rated the highest in liking; however, they were not significantly different from MousseMV (Table 1). MousseCB, PastaCB and PastaMV were 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 2), 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, Gustafsson, Haglund, Johansson, & Noble, 2001) and thus either pair inducing improvement or deterioration of the wine is 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

Table 2
Pairing induced changes in liking and perceived sensory complexity of food and wine.

		BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
Liking	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	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 letters following the scores show the result of Fisher's pair-wise comparison within the column for a given attribute $p < 0.05$.

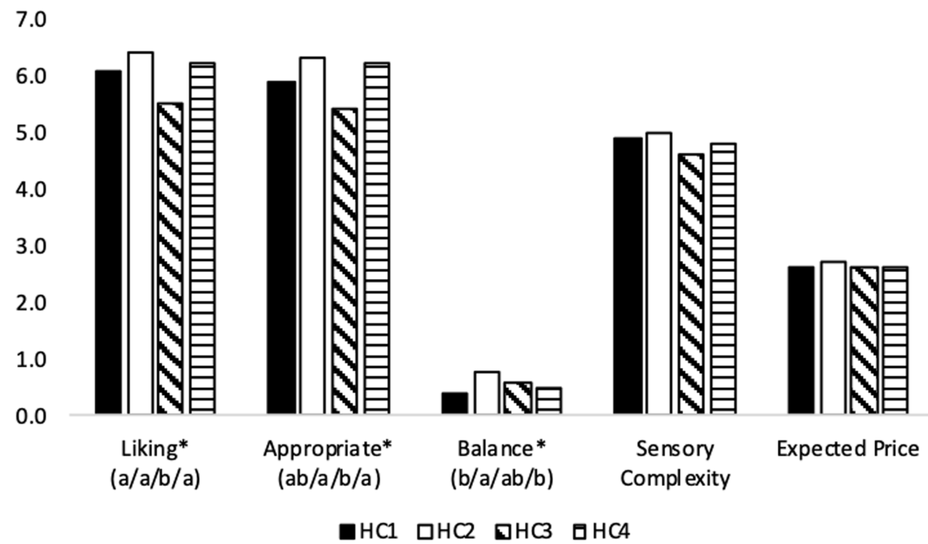

Fig. 6. Hedonic cluster (HC) effect on consumer perceptions in relation to food and wine pairings. Asterisk indicates significant ($p < 0.05$) HC effect and the letters following show the result of Fisher pair-wise comparison across clusters.

difference in consumer liking might be due to a heterogeneous consumer cluster effect, which might further explain food and wine pairing.

3.3.3. The role of balance in food and wine pairings

Consumer perceived balance (Table 1) was 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.

3.3.4. 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 1). However, 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 2). In the wine dominated pairings (PastaCB, PastaMV, MousseCB, MousseMV (Table 1)), 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 aroma 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.

3.3.5. 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 1). 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 since savoury wines, such as CB, may be less favoured on their own (Johnson et al., 2013; Lattey et al., 2010) (Fig. 5), they can comprise appropriate food pairings that consumers enjoy (Table 1). 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 2). 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.

3.3.6. Expected price to pay for wine in appropriate pairings

The expected price of the wine (Table 1) had strong positive relationships with 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 1). 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 shows the importance of offering appropriate pairings to enhance the consumer experience and improve profitability.

3.3.7. Consumer clusters

To account for the individual variation of consumers we used psychographic scales developed for food and wine. 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 ($F = 3.018$, $p = 0.408$;

Table 3
Consumer ratings for food and Shiraz wine pairings by hedonic cluster (HC).

Attributes	Cluster	BeefCB	BeefMV	MousseCB	MousseMV	PastaCB	PastaMV
Liking	HC1	7.3 a	5.9 abcde	4.3 efg	7.1 ab	5.1 cdefg	6.7 abc
	HC2	7.4 a	5.8 abcdef	6.8 abc	6.9 abc	7.1 ab	4.4 defg
	HC3	6.6 abc	7.2 ab	4.0 fg	3.6 g	5.5 bcdefg	6.2 abcd
	HC4	5.2 cdefg	7.3 a	7.5 a	7.1 ab	4.2 efg	5.9 abcde
Pairing	HC1	6.8 abc	5.7 abcd	4.2 de	7.1 ab	5.0 cde	6.7 abc
	HC2	7.2 a	5.7 abcd	6.7 abc	6.9 abc	6.8 abc	4.2 de
	HC3	6.7 abc	7.1 a	4.0 de	3.6 e	5.1 bcde	5.6 abcd
	HC4	5.1 cde	7.2 a	7.3 a	7.1 a	4.4 de	5.8 abcd
Number of flavours	HC1	5.7 a	4.8 abcde	4.1 de	4.9 abcde	4.7 abcde	5.1 abcde
	HC2	5.4 abcd	4.9 abcde	5.0 abcde	5.0 abcde	4.8 abcde	4.8 abcde
	HC3	5.5 ab	5.5 abc	3.9 e	4.2 cde	4.3 bcde	4.5 abcde
	HC4	4.8 abcde	5.3 abcd	5.1 abcde	4.9 abcde	4.1 de	4.5 abcde
Price	HC1	2.9 ab	2.5 ab	2.0 ab	2.9 ab	2.3 ab	2.9 ab
	HC2	3.1 a	2.7 ab	2.6 ab	2.9 ab	2.9 ab	2.3 ab
	HC3	3.0 ab	3.2 a	1.9 b	2.1 ab	2.4 ab	2.9 ab
	HC4	2.2 ab	3.2 a	2.7 ab	2.9 ab	2 b	2.7 ab
Balance	HC1	2.8 abc	1.7 abcdef	0.2 efg	3.1 a	1.0 defg	2.7 abcd
	HC2	3.2 a	1.7 abcdef	2.7 abcd	2.9 ab	2.8 abc	0.2 efg
	HC3	2.7 abcd	3.1 a	0.0 fg	-0.4 g	1.1 bcdefg	1.6 abcdef
	HC4	1.1 cdefg	3.2 a	3.3 a	3.1 a	0.4 efg	1.8 abcde

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

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. Food and wine pairings can be defined as basic context effects, in which consumer perceptions of wines and foods change because of the context of dining (Lahne, 2019). Therefore, food and wine pairing-related consumer behaviour might be different from food or wine-related behaviour.

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 (Fig. 6), 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).

All clusters were female dominant except HC4 (male = 62.5% and female = 37.5%) (Table A.7). In terms of household income, 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 3). 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, the male dominated cluster (Table A.7), preferred 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 3). 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 3). This reinforces the notion that equal intensities of food and wine flavour alone is a poor indication of the 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).

3.3.8. *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 (Fig. 7). 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 (Fig. 7a) described pairings appropriate when

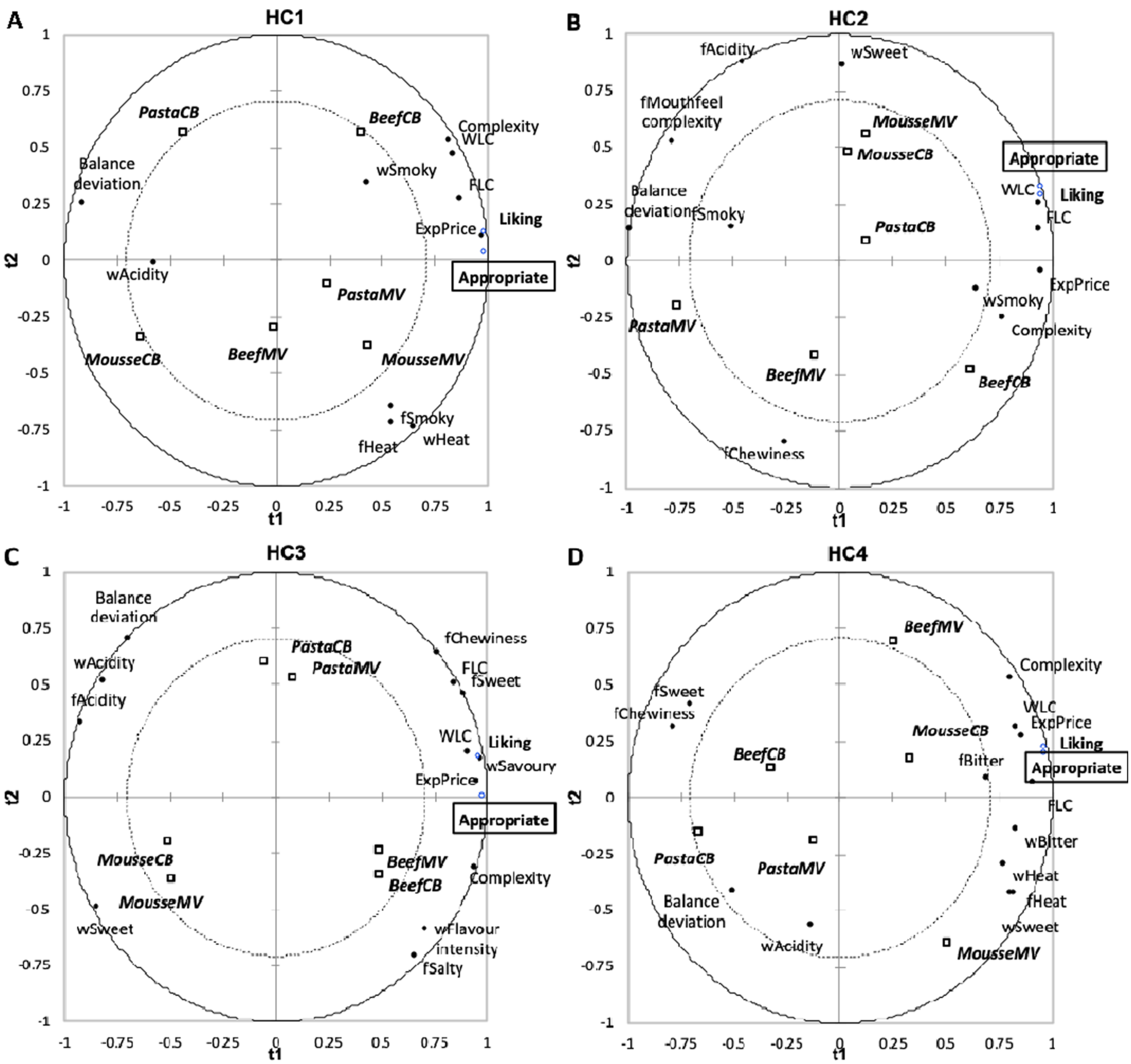

Fig. 7. PLS2 of pairing attribute profiles (PastaCB, PastaMV, BeefCB, BeefMV, MousseCB, MousseMV) by consumer liking clusters (HC). The 'w' prefix indicates pairing induced changes on the wine, and the 'f' prefix indicates pairing induced changes on the food attributes. Open circles signify consumer responses. FLC is the pairing induced change of food liking, WLC is the pairing induced change of wine liking.

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 (Fig. 7b) 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 (Fig. 7c) 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 (Fig. 7d), 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 to HC3, who favoured beef with both red wines. Other clusters seemed to freely express their ideas, even deeming red wine with chocolate mousse to be a suitable pairing in the case of HC4 (in contrast to HC1 and HC3).

Pairing 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 ($r = -0.494$). 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 (Fig. 5) but was moderately to highly liked when paired with beef for all clusters except HC4, who preferred it with mousse (Table 3). 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.

3.4. 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 a food and wine pairing context. As there are individual differences in bitterness perception, it might be worth screening consumers based on 6-n-propylthiouracil (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 it 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.

4. Conclusions

This study explored consumer ratings and sensory drivers for appropriate food and Shiraz wine pairings. On average, liking and appropriateness of pairings were driven by food, confirming that food suppresses wine attributes in a pairing situation; this is significant to hospitality and winery cellar door operators, suggesting that the consumer experience is likely to be optimal if the wine is tasted before the food. Another implication might be to design recipes and create courses that complement the wines, not *vice versa*.

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 was preferred. 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. The balance theory may still be an important predictor for successful food and wine pairings; however, it 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. 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.

In terms of consumer segmentation methods, neither wine involvement nor food neophobia had significant effects on consumers' food and wine pairing related behaviour. Segmentation by liking of the pairing accounted for the individual variability of consumers, and revealed greater differences between pairings. Importantly, consumers across clusters seem to agree on the sensory drivers of appropriate pairings, but the pairings clusters' deemed appropriate varied. So although universal methods to measure food pairing may be desirable, appropriate consumer segmentation could better account for the variability of results.

CRediT authorship contribution statement

Marcell Kustos: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration, Funding acquisition. **Hildegarde Heymann:** Conceptualization, Methodology, Writing - review & editing, Visualization, Supervision, Funding acquisition. **David W. Jeffery:** Conceptualization, Methodology, Writing - review & editing, Supervision. **Steven Goodman:** Conceptualization, Methodology, Writing - review & editing, Supervision. **Susan E.P. Bastian:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

See Table A.1–A.7.

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 200C oven for 7 min
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 200C oven for 7 min
*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	

(*continued on next page*)

Table A.3 (*continued*)

Attribute	Definition	Reference
*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.

Ingredients	Preparation
Pasta	
500 g Penne (Barilla S.p.A., Italy)	1. In a pot, bring water to boil.
30 g unsalted butter (Foodland Australia PTY Ltd)	2. Add the pasta and cook for 8 min (*al dente*).
30 g wheat flour (Foodland Australia PTY Ltd)	3. Remove the pasta from the boil, cool under cold running water, and reserve until required.
30 g Parmigiano Reggiano, grated (Zanetti S.p.A., Italy)	4. In a heated medium size pot, melt the butter, add the minced garlic, and cook until slightly golden in colour.
1 clove garlic, minced	5. Whisk in the flour and add the milk and chicken stock while continuously whisking the mixture.
260 mL chicken stock (Massel Australia PTY Ltd)	6. When the mixture starts thickening, add the salt and Parmigiano Reggiano.
260 mL whole milk, (Foodland Australia PTY Ltd)	7. Reheat the pasta and serve it with sauce on top.
4 g salt (Foodland Australia PTY Ltd)	
Braised beef	
800 g beef gravy meat, diced into 2.5 cm	1. In a soup pot, cover the potatoes with water, bring to boil and cook until soft (about 20 min), strain water and reserve.
200 g onion, quartered	2. In a hot pressure cooker, add 2 Tbsp vegetable oil and gently sweat the onion until tender.
2 Tbsp vegetable oil (Foodland Australia PTY Ltd)	3. Gently add the beef, stock and salt.
10 g salt (Foodland Australia PTY Ltd)	4. Secure lid and bring cooker to high pressure.
500 mL beef stock (Massel Australia PTY Ltd)	5. Reduce heat to stabilise pressure and cook for 35 min.
1 tsp corn starch (Foodland Australia PTY Ltd)	6. Release pressure according to manufacturer's instructions and remove lid.
600 g red potato, peeled, coarsely diced	7. Set aside the beef and blend the cooking liquid and onion with corn starch until smooth.
120 g unsalted butter (Foodland Australia PTY Ltd)	8. Bring the mixture to boil until the gravy thickens.
180 g whole milk (Foodland Australia PTY Ltd)	9. Add the beef back to the gravy and allow to cool.
4 g salt (Foodland Australia PTY Ltd)	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	4.0	60.0
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	0.2	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	1.0	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	28.0

*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

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2020.109463.

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