Meeting the demands of climate change: Australian consumer acceptance and sensory profiling of red wines produced from non-traditional red grape varieties

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Abstract

To endure the challenge of climate change, the Australian wine industry could adopt new wine grape varieties more tolerant of these pending conditions. The aims of this study were to (i) generate sensory profiles and (ii) gain knowledge about Australian wine consumers' liking of Australian and international wines made from selected drought-resistant, red wine grape varieties not traditionally grown in Australia but better suited for a changing Australian climate. A Rate-All-That-Apply (RATA) sensory panel (n = 43) profiled 24 commercial red wines made from 9 purportedly drought-tolerant red grape varieties, plus a single example of an Australian Cabernet-Sauvignon, Grenache and Shiraz wine. A subset of 10 wines was subjected to preference trials with Australian red wine consumers (n = 113) and underwent basic chemical composition measures. Consumers liked all 10 wines, scoring them greater than 5.7 on a 9-point Likert scale. The Fine Wine Instrument (FWI) identified 3 consumer segments (Wine Enthusiasts (WE); Aspirants (ASP) and No Frills (NF)). WE liked the 2 Touriga Nacional and Nero d'Avola wines significantly more than the NF consumers and the Graciano significantly more than the ASP. Correlation tests determined that the WE segment

liked wines with aromas of vanilla, sweet taste, jammy, confectionary, vanilla and woody flavours and a non-fruit after taste, and the attributes responsible for the ASP segment's liking of the wines were red colour, jammy and toasty/smoky aromas, jammy and savoury flavours and alcohol mouthfeel and non-fruity aftertaste. NF consumers liked wines with aromas of vanilla, confectionary, jammy and red fruit flavours; smooth mouthfeel and a fruity aftertaste, but disliked wines displaying aromas of cooked vegetables and savoury, bitter taste, flavours of cooked vegetables, forest floor, green pepper and herbaceous, and rough mouthfeel. WE liked wines reminiscent of Cabernet-Sauvignon, Grenache and Shiraz while the ASP and NF consumers had preferences leaning towards wines similar in style to a Shiraz and Grenache, respectively. These findings indicate to wine producers the potential of these new wines in the current Australian market and the possibility that increasing future cultivation of these varieties as a response to climate change might lead to a more sustainable wine industry in the future.

Keywords: Rate-all-That-Apply, drought-tolerant, Barbera, Durif, Graciano, Montepulciano, Nero d'Avola, Touriga Nacional

Introduction

Climate change constitutes a major challenge, threatening the sustainability and the cultivation of grapes for wines. Australia is already experiencing an increase in mean temperatures and extreme weather events such as heatwaves and floods, and a decrease in cold days as well as water availability (Webb *et al*., 2007). An increase in the annual average temperature of 0.3 °C to 1.7 °C is predicted by 2030 in all viticultural regions, and between a 0.4 °C and 2.6 °C increase is predicted by 2050 (Webb *et al*., 2007). These climatic events affect agriculture and viticulture worldwide, by shifting viable growing areas, and decreasing yields and crop quality (Morales-Castilla *et al*., 2020, van Leeuwen and Darriet, 2016, Fleming *et al*., 2015). Temperature has the greatest influence on viticulture, affecting many aspects including grapevine phenology, reproduction, photosynthesis, respiration, carbon transport and assimilation, and the biochemistry of flavour molecules (Anderson *et al*., 2008). Under the current global warming outlook, water availability, a major issue in Australian viticulture and the evolution of pests and diseases will become other sources of concern for the wine industry (Ollat *et al*., 2017). Mosedale *et al*. (2016) mention that a change in climatic patterns will have an impact on quality, as the physical and chemical composition of the grapes interrelates with the winemaking process to determine quality. An increase in

average temperatures, during the growing season and ripening, stimulates higher quantities of grape sugars and the breakdown of organic acids and lowers concentrations of anthocyanin, flavonoids and reduces aromatics (Mosedale *et al*., 2016, van Leeuwen and Darriet, 2016, Santos *et al*., 2020). Additional climate contributors such as solar radiation and lack of precipitation are also believed to impact yield and quality (Mosedale *et al*., 2016, van Leeuwen and Darriet, 2016).

To attenuate the deleterious effects of climate change on cultivating grapevines in Australia, it is necessary to adapt to these new scenarios. Recent studies suggest that changes are already occurring in the wine industry to manage the current/future impact of climate change. In terms of mitigation, vineyards and wineries are working on emission reductions by cutting down the amount of fuel and electricity utilised (Longbottom, 2014). Concerning adaptation, the Australian wine industry is incorporating different management techniques to adapt to the warming environment.

1. Alternative varieties: a possible climate change adaptation solution

To adapt to the climatic conditions described above, grape producers are provided with information and tools to battle the rapidly changing scenario (Longbottom, 2014) and one of the strategies is switching from the commonly planted traditional grape varieties to non-traditional, drought-tolerant varieties more suited to the Australian environment. Although this is a plausible adaption strategy, Australian wine consumers habitually consume wines made from varieties with which they are familiar (Ristic *et al*., 2016). This may present a hurdle to the adoption of this strategy unless consumers like wines produced from these alternative varieties. To date, there have been no wine consumer preference studies of wines made from emerging red wine varieties in the Australian wine market and therefore this needs to be researched.

In Australia, an alternative variety is defined as any variety other than Cabernet-Sauvignon, Chardonnay, Chenin Blanc, Colombard, Gordo Blanco, Grenache, Merlot, Pinot Gris/Grigio, Pinot Noir, Sauvignon Blanc, Semillon, Shiraz, Riesling and Verdelho. This definition, provided by The Australian Alternative Varieties Wine Show (AAVWS), is the definition most commonly found in the literature. Dry *et al*. (2017) state the definition is “narrow”, as they argue cultivars such as Petit Verdot, Muscat Blanc and Ruby Cabernet are considered “alternative” even though more tonnes of them are grown than some of the “traditional” varieties. This all indicates the need to consider “alternative” from a consumer viewpoint.

Drought-tolerance, in relation to grape varieties, is non-scientifically defined as any variety that requires 50–60 % less irrigation than the “traditional” grapes listed above. This definition is sourced purely from anecdotal evidence and personal interviews with grape growers and viticulture experts (Ashley Ratcliff, personal communication, 15 August 2020; Dr Peter Dry, personal communication, 25 August 2020), as there is no current definition in the literature of what constitutes a drought-tolerant variety.

Due to the lack of a suitable definition of drought-tolerance in grapes, the varieties selected for the current study were those thought to have the potential to withstand hot and dry growing environments. Furthermore, these varieties originate from hot Mediterranean countries, such as Spain, Portugal and Italy, which, at least in some areas, have similar climatic conditions to Australia (Gladstones, 2016). While there have been studies on the sensory and chemical aspects of some of these drought-resistant varieties in continental Europe (Falqué *et al*., 2004, Cravero *et al*., 2012, Vilanova and Soto, 2006, Casassa *et al*., 2016, Tofalo *et al*., 2016), no detailed sensory profiling studies describing wines made of these varieties when grown in Australia exist in the relevant literature.

This study aimed to (i) generate sensory profiles of Australian and international wines made from selected potentially drought-resistant, red wine grape varieties not traditionally grown in Australia and (ii) gain knowledge about Australian wine consumers’ acceptance and opinions of wine styles crafted from these emerging grape varietals that are likely better suited for the hot and dry Australian climate.

The findings of this study will advance our understanding of whether Australian consumers embrace wines produced from alternative wine grape varieties, and identify their flavour preferences. This will provide winemakers/industry insights about the potential performance of these new wines in the Australian domestic wine market, enabling them to offer alternative wine styles which meet the flavour specifications of this competitive market, whilst promoting a more sustainable future, for the grape and wine industry.

Materials and methods

1. Wines, Sensory Profiling with Rate-All-That-Apply and Preliminary Hedonic Scaling

A total of 9 purportedly drought-tolerant, red grape varieties emerging in Australia were targeted for this study. A selection of wines (both Australian and International, readily available as a single varietal) made from these varieties were utilised for sensory profiling,

chemical analysis and consumer preference trials. Twenty-four commercial red wines of the following varieties were included (see details in Table 1): Aglianico (AGL1, AGL2), Barbera (BAR1, BAR2), Durif (DUR), Graciano (GRA), Mencia (MEN1, MEN2, MEN3), Montepulciano (MON1, MON2, MON3) Negroamaro (NEG), Nero d'Avola (NER1, NER2, NER3, NER4) and Touriga Nacional (TOU1, TOU2, TOU3) and 3 traditional varieties, an Australian Shiraz (SHI), Cabernet-Sauvignon (CAB) and Grenache (GRE). These last three wines were selected by 5 experienced wine academics, wine retailers and wine judges as broad representatives of Australian wines styles made from these varieties. Their inclusion as reference wines was based on the facts that they represent the most planted red varieties and most consumed red wines in Australia and are highly researched in the viticulture and wine academic literature so behaved as comparators. Only red wine varieties were included in this initial study due to time constraints, and wines no older than 2016 were utilised to avoid aged red wine characters confounding results.

All wines underwent Rate-All-That-Apply (RATA) analysis for sensory profiling (Oppermann *et al*., 2017, Ares *et al*., 2014, Danner *et al*., 2018) and preliminary liking evaluation. The results of these sensory analyses informed the choice of 10 wines to progress to a consumer acceptance trial. All wines underwent chemical composition analyses (Supplementary Table 1). More details of the wines including vintage, region and preliminary liking data from the RATA panel are provided in Table 1.

Table 1. Australian and international commercial red wines from traditional and emerging, potentially drought-tolerant grape varieties used in RATA sensory profiling, preliminary hedonic responses, consumer acceptance testing and chemical analyses.

Code	Varietal	Region	Hedonic response
AGL1	2016 Aglianico	Basilicata, Italy	5.29defg
AGL2 *	2018 Aglianico	McLaren Vale, Australia	6.07ab
BAR1	2018 Barbera	Adelaide Hills, Australia	5.54abcde
BAR2 *	2019 Barbera	Adelaide Hills, Australia	4.78gh
CAB	2018 Cabernet-Sauvignon	Coonawarra, Australia	6.07ab
DUR *	2017 Durif	Rutherglen, Australia	4.83fgh
GRA *	2019 Graciano	McLaren Vale, Australia	5.46abcdef
GRE	2018 Grenache	McLaren Vale, Australia	5.56abcde
MEN1 *	2017 Mencia	Adelaide Hills, Australia	4.20h
MEN2	2016 Mencia	Valdeorras, Spain	5.34cdefg

MEN3	2017 Mencia	El Bierzo, Spain	5.78abcde
MON1 *	2017 Montepulciano	Abruzzo, Italy	5.73abcde
MON2	2017 Montepulciano	Abruzzo, Italy	5.42bcdefg
MON3	2017 Montepulciano	McLaren Vale, Australia	5.15efg
NEG	2016 Negroamaro	Puglia, Italy	5.78abcde
NER1 *	2019 Nero d'Avola	McLaren Vale, Australia	5.59abcde
NER2	2019 Nero d'Avola	Riverland, Australia	6.07ab
NER3	2018 Nero d'Avola	McLaren Vale, Australia	5.29defg
NER4	2019 Nero d'Avola	Yarra Valley, Australia	5.56abcde
SHI *	2018 Shiraz	Barossa Valley, Australia	6.00abc
TOU1	2018 Touriga Nacional	Langhorne Creek, Australia	5.88abcd
TOU2	2018 Touriga Nacional	McLaren Vale, Australia	5.61abcde
TOU3 *	2017 Touriga Nacional	Riverland, Australia	5.56abcde
TOU4 *	2017 Touriga Nacional	Duoro Valley, Portugal	6.12a

*Wines denoted with an * were selected for the consumer trial. Wines sharing a letter in the hedonic response column are not significantly different (Fisher's LSD $p < 0.05$).*

RATA is a rapid, cost-effective, sensory profiling technique used now more frequently now to describe the sensory characteristics of a wine using untrained panellists (Danner *et al.*, 2018). A total of 43 RATA participants, all experienced red wine tasters and RATA panellists, were recruited from the School of Agriculture, Food and Wine at The University of Adelaide (staff members and higher-degree research students) and undertook two (2 hour) RATA sessions one week apart in which they evaluated 12 wines per session for a total of 24 wines. Each wine was evaluated once by the panellists. Sensory evaluations were held in a purpose-built sensory laboratory in individual, computerised booths at 21 °C, under fluorescent lighting.

During each session, the wines were presented monadically with an enforced break of one minute between each wine and a 5 minute enforced break after wine number 6. Wine presentation orders were designed in Red Jade® using a Williams Squares design and randomly assigned to each RATA participant as they entered the sensory laboratory. Thirty mL wine samples were served at 21 °C in coded (4-digit codes), clear International Standards Organisation (ISO) approved 215 mL tasting glasses covered with small plastic Petri dishes.

The sensory attributes assessed were extracted from a generic red wine attribute list described in previous studies (Danner *et al*., 2018, Crump *et al*., 2015). It consisted of 3 attributes referring to wine colour, 22 to the aroma, 3 to taste, 22 to flavour (retronasal smell), 6 to mouthfeel and 2 to aftertaste (Supplementary Table 2). A 7-point rating scale was utilised to rate the intensity of attributes (where applicable). Each panellist was required to only rate the intensity of attributes they perceived in the wine (i.e. only those that apply). To further inform the decision about which wines would be evaluated by the consumers, the RATA panellists were first asked to rate their hedonic response to each of the 24 wines on a 9-point Likert scale, where 1 = disliked extremely; 5 = neither liked nor disliked, and 9 = liked extremely before rating the sensory attributes by RATA and proceeding to the next wine. A one-way ANOVA was performed on the liking data and the results are shown in Table 1.

2. Basic wine chemical composition

Basic chemical analyses were performed according to the methods described in Iland *et al*. (2004). These included: pH, Titratable Acidity (TA) by titration to pH 8.2, Volatile Acidity (VA), residual sugars, free and total SO_2 and total phenolics (by Somers). The wine colour was determined by CIELab tristimulus method (Cintra 4040, GBC Scientific Equipment, Braeside, VIC, Australia). The ethanol content level (% v/v) was obtained by Anton Paar Alcolyzer Wine ME and DMA 4500M (North Ryde, NSW, Australia). All measurements were conducted in duplicate (Supplementary Table 1).

3. Consumer acceptance trials

Based on the results obtained during RATA, 10 wines (including one reference Shiraz wine) (Table 1) were selected and subjected to a consumer trial of 113 participants, recruited from the University of Adelaide wine consumer database via email and social media. The trial explored the respondents' opinions and knowledge about emerging wine grape varieties and wine taste preferences. The consumers were seated individually in a sensory booth and completed an online questionnaire consisting of demographic questions, before tasting the first bracket of 5 wines. The consumers were asked to rate their liking/disliking of each wine on a 9-point Likert scale, where 1 = disliked extremely; 5 = neither liked nor disliked, and 9 = liked extremely with an enforced break of 60 seconds between each wine sample. 20 mL of each wine was presented in a coded ISO approved 215 mL tasting glass covered with a small plastic Petri dish and the wines were served monadically and in a random order balanced for carry-over effects (MacFie *et al*., 1989). After the first bracket, the consumers completed the Fine Wine Instrument (FWI) (Johnson and Bastian, 2015) and the Wine Neophobe Scale

(WNS) (Ristic *et al*., 2016), before tasting the second bracket of 5 wines, which were presented in the manner described above. Following the last bracket of wines, the consumers were informed that the wines they had tasted were made from purportedly drought-tolerant grape varieties. They were asked to indicate what red varieties they had tasted in the past 12 months from a list of 16 that included "traditional" and emerging varieties. All data were collected by Red Jade® sensory software.

This study was approved by the Human Research Ethics Committee of The University of Adelaide, No. H-2017-204. Participants were required to be of legal drinking age (above 18 years old) and had consumed red wine in the past 2 weeks. All tasting sessions were conducted at the Sensory laboratory of the University of Adelaide, Waite Campus, Wine Innovation Central (WIC).

4. Statistical analyses

The RATA data were analysed using a mixed model two-way ANOVA with assessors as random and samples as fixed factor effects, with Fisher's LSD post-hoc test where $p < 0.05$ was considered significant using SENPAQ version 6.3 (Qi Statistics, UK). The mean sensory attribute intensity panel data generated by SENPAQ for both the 24 wines and the 10 wines for the consumer trial then underwent Principal Component Analysis (PCA) using XLSTAT Version 2019.1.1 (Addinsoft SARL, France). PLSR, k-means cluster analysis, one-way ANOVA of the hedonic data, the calculation of Pearson correlation coefficients and Friedman analysis were also performed using XLSTAT. Demographic data and Chi-Square analysis of consumer data were performed using SPSS Statistics 26 (IBM Corporation©).

Results

1. RATA Sensory Profiling and Preliminary Hedonic Liking

Twenty four commercial Australian and international red wines were presented to a RATA analysis panel (n = 43) during the first stage of this study. Of a total of 58 attributes selected to describe the red wines, 54 were identified as statistically significant ($p < 0.05$) by the RATA panel (Supplementary Table 2).

Principal Component Analysis (PCA) was performed on the statistically significant attributes that differentiated the wines, resulting in 58.81 % of the variation in the data being explained in the first 2 dimensions. A bi-plot of the wine samples shows the scores and loadings from the PCA of the sensory data (Figure 1). The wines presented a diverse range of sensory attributes and styles.

The first principal component PC1 (37.67 %), clearly distinguished wine samples on the right-hand side of the bi-plot which were perceived as earthy/dusty, herbal, savoury and having an astringent, rough mouthfeel, from those perceived as floral/perfumed, confectionary and with red fruit aroma and flavour plus a smooth mouthfeel on the left-hand side.

The second principal component PC2 (21.14 %), distinguished wine samples in the top half of the bi-plot perceived as possessing aromas and flavours of dark fruits, chocolate, coconut, vanilla and jammy and fuller-bodied from those perceived as cooked vegetables and acidic in the bottom half.

In the left upper quadrant, the Graciano (GRA), Grenache (GRE), Nero d'Avola (NER1) and Touriga (TOU1) wines were perceived as floral/perfumed and confectionary with a sweet taste and vanilla aroma. A Montepulciano (MON1) and the Shiraz (SHI) were perceived as dark fruits, jammy, sweet, vanilla, coconut, chocolate and smooth with a fruity aftertaste

In the right upper quadrant, 2 Tourigas (TOU2 and TOU4) were perceived as dark fruit, eucalypt/mint, spicy, woody, toasty/smoky and with a viscous and high alcohol mouthfeel. NEG, MON3, TOU3 and CAB, displayed attributes of dried fruits, leather, herbaceous, green pepper/capsicum, woody, toasty/smoky, astringent with a rough mouthfeel and a bitter taste. In the lower-left quadrant, an Aglianico (AGL2), 3 Nero d'Avola (NER2, NER3 and NER4) and 2 Barbera (BAR1 and BAR2) wines were perceived as having aromas and flavours of red fruits. Lastly, in the lower right quadrant, 3 Mencias (MEN1, MEN2 and MEN3) an Aglianico (AGL1), the Durif (DUR) and a Montepulciano (MON2) were found where the most predominant attributes which described these wines were: red and brown colour, aromas and flavours of mushroom/forest floor and cooked vegetables and a sour taste.

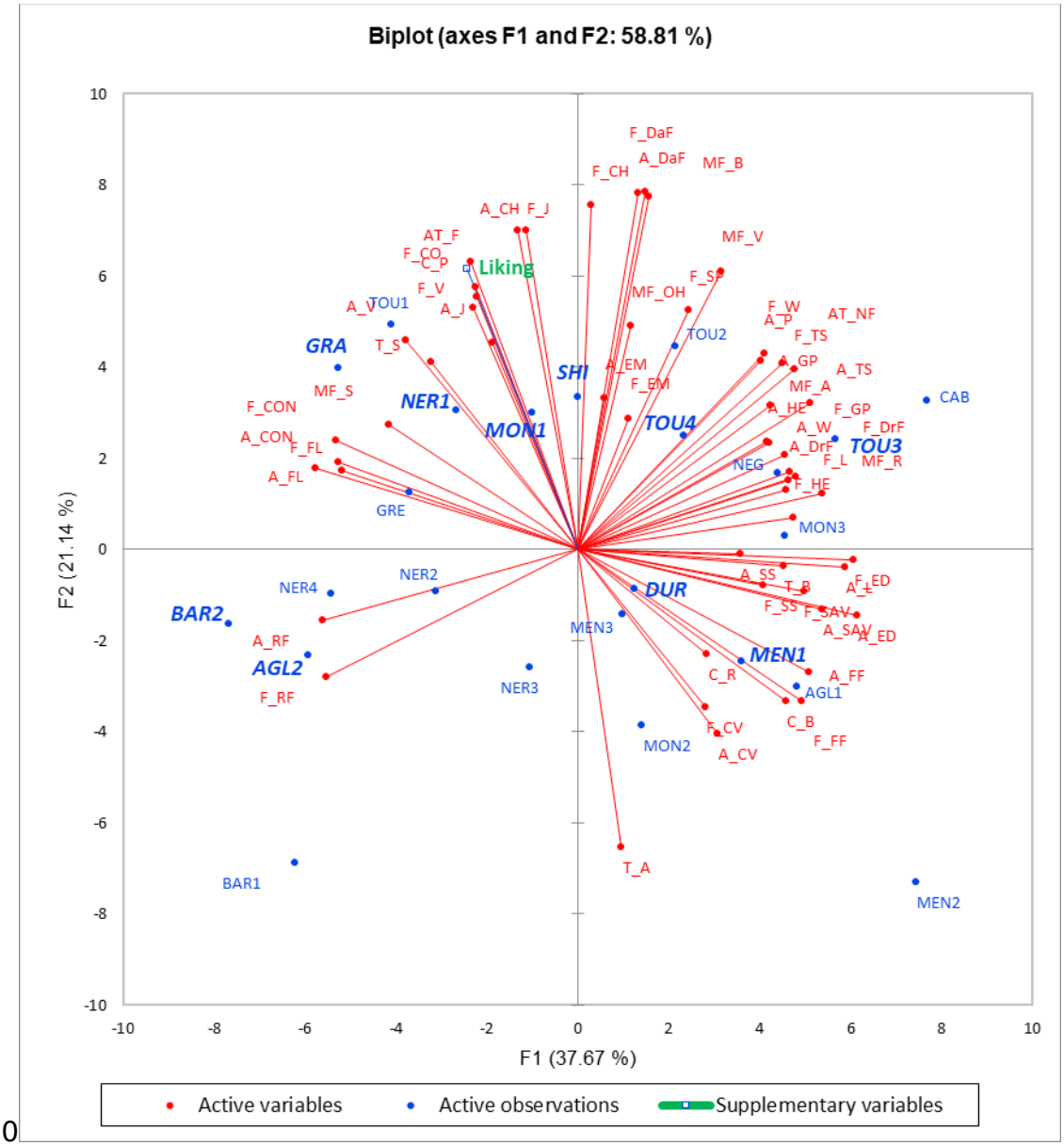

Biplot (axes F1 and F2: 58.81 %)
F1 (37.67 %)
F2 (21.14 %)
Active variables
Active observations
Supplementary variables
F_DaF
A_DaF
F_CH
MF_B
A_CH
F_J
AT_F
F_CO
C_P
Liking
MF_V
F_V
MF_OH
F_SA
A_V
TOU1
A_J
F_W
A_P
AT_NF
TOU2
F_TS
GRA
T_S
SHI
A_EM
A_GP
A_TS
MF_S
F_EM
MF_A
CAB
NER1
F_CON
A_HE
F_GP
MON1
TOU4
A_W
F_DrF
A_CON
F_FL
A_DrF
TOU3
NEG
F_L
MF_R
A_FL
F_HE
GRE
MON3
NER2
A_SS
A_L
F_ED
NER4
T_B
DUR
BAR2
F_SS
F_SAV
A_SAV
MEN3
A_ED
A_RF
MEN1
C_R
A_FF
AGL2
NER3
AGL1
F_RF
C_B
F_CV
F_FF
MON2
A_CV
T_A
BAR1
MEN2

Figure 1. PCA of the significant sensory attributes that differentiated the 24 wines assessed by the RATA panellists (N = 43) overlaid by preliminary panel mean wine liking.

Bold italic fonts indicate the 10 wines used for the consumer trial.

A = Aroma, T = Taste, F = Flavour, MF = Mouthfeel, AT = After Taste, C = Colour. Red Fruit (F_RF), Red Fruit (A_RF), Floral (A_FL), Floral (F_FL), Confectionary (A_CON), Confectionary (F_CON), Smooth (M_S), Sweet (T_S), Vanilla (A_V), Vanilla (F_V), Jammy (A_J), Jammy (F_J), Purple (C_P), Coconut (F_CO), Length of Fruit (AT_F), Chocolate (A_CH), Chocolate (F_CH), Dark Fruit (A_DaF), Dark Fruit (F_DaF), Eucalypt/Mint (A_EM), Eucalypt/Mint (F_EM), Alcohol (MF_OH), Spice (F_SP), Viscous (MF_V), Woody (A_W), Woody (F_W), Pepper (A_P), Length of Non-Fruit (AT_NF), Toasty/Smoky (A_TS), Toasty/Smoky (F_TS), Green Pepper/Capsicum (A_GP), Green Pepper/Capsicum (F_GP), Astringent (MF_A), Herbaceous (A_HE), Herbaceous (F_HE), Dried Fruit (A_DrF), Dried Fruit (F_DrF), Leather (A_L), Leather (F_L), Rough (MF_R), Stemmy/Stalky (A_SS), Stemmy/Stalky (F_SS), Bitter (T_B), Savoury (A_SS), Savoury (F_SS), Earthy/Dusty (A_ED), Earthy/Dusty (F_ED), Forest Floor (A_FF), Forest Floor (F_FF), Cooked Vegetables (A_CV), Cooked Vegetables (F_CV), Red (C_R), Brown (C_B), Bitter (T_B), Sour (T_A).

In addition to performing a RATA on the 24 wines, the panellists were also asked to provide a hedonic response to each of the wines. A one-way ANOVA revealed that the most liked wine was TOU4 ($\bar{x}$ = 6.12) and that wine was liked significantly more than 8 other wines (Table 1). All wines scored greater than 5 on the 9-point Likert scale, except for the wines DUR, BAR2 and MEN1 ($\bar{x}$ = 4.83, 4.78 and 4.2, respectively). This hedonic data was also used to inform the selection of the 10 wines to be used in the consumer trial. At least one wine from each quadrant of the PCA plot and different varieties, each with quite distinct sensory attributes, was selected (red fruit, confectionary, smooth fruit-driven wines; herbal/ minty, green pepper/capsicum, astringent style wines; dark fruits, jammy chocolate, smoky, fuller-bodied/palate, oaky styles and savoury, earthy/dusty wines). The chosen wines included the 2 most liked wines and the 3 least liked wines. A reference Shiraz was also included as it is Australia's most planted red grape variety and was more moderate in the evaluated sensory attributes compared to the Cabernet-Sauvignon and Grenache wines.

2. Consumer Demographics

A total of 113 regular red wine consumers who had consumed red wine in the past fortnight attended a central location (Sensory Laboratory, University of Adelaide) consumer trial. The demographic data of the sample are described in Supplementary Table 3. The gender was equally split between females and males. Fifty percent of the sample were over the age of 55

years and 70.2 % of the respondents had tertiary qualifications. Just over 50 % reported household incomes of more than AUD100K.

3. Consumer hedonic responses

Based on the results obtained from the sensory profiling stage (RATA) and the preliminary hedonic responses, 10 wines were selected for the consumer evaluation trial.

Table 2 details the consumer hedonic responses for the 9 red wines made from emerging varieties under study and one Shiraz wine. Of note, in contrast to the preliminary RATA panel responses, all wines scored greater than 5 on the 9-point Likert scale, indicating that all the wines were liked by the consumers. The most liked wine was an Italian Montepulciano (MON1 $\bar{x}$ = 6.71) that was significantly more liked than 3 other wines, an Australian Riverland (TOU3 $\bar{x}$ = 5.74) and Portuguese (TOU4 $\bar{x}$ = 5.74) Touriga Nacional and an Australian, Adelaide Hills Mencia (MEN1 $\bar{x}$ = 5.7).

Table 2. Australian red wine consumer (*n* = 113) mean liking score of 9 emerging red variety wines and a Shiraz wine comparator.

Wine	Mean Hedonic Score
MON 1	6.71a
DUR	6.6ab
SHI	6.58ab
NER1	6.57ab
GRA	6.54ab
BAR2	6.34ab
AGL2	6.32ab
TOU3	6.24b
TOU4	5.74c
MEN1	5.7c

Wines sharing a letter are not significantly different (Fisher's LSD p < 0.05).

4. Segmentation of the Consumer Sample

All consumers completed the Fine Wine Instrument (Johnson and Bastian, 2015) as part of their questionnaires. That instrument, which consists of three dimensions labelled Connoisseur, Provenance and Knowledge, was then used as the basis to identify consumer segments in the sample. The consumers' data for each of the 3 dimensions underwent a k-means cluster analysis with "Trace W" as the clustering criterion. Supplementary Table 4

displays the results for each of the identified segments against the 3 dimensions of the FWI. The segments were labelled Wine Enthusiasts (WE), Aspirants (ASP) and No Frills (NF), respectively. Each segment differed significantly in the mean score for each dimension. The Wine Enthusiasts scored significantly higher than both the Aspirant and No Frills segments and in turn, the No Frills segment scored significantly less than the other two segments.

The demographic data of each of these segments are shown in Supplementary Table 5. The only category where any significant differences in segment proportions were found, was where the Wine Enthusiasts had more respondents with a post-graduate degree than was statistically expected from the Chi-Square analysis.

Table 3 details the hedonic responses to the wines of each of the segments. There were significant main effects but no interactions between the wines and the FWS ($p = 0.523$) indicating that the 3 segments evaluated the wines in a similar manner (data not shown). The WEs had the highest score for each of the wines except for SHI and DUR. The WEs had a significantly higher score than the NFs for wines TOU3 and 4 and NER1 and a significantly higher score than the ASPs for wine GRA. The ASP and NF segment did not significantly differ in their wine liking.

Table 3. Mean hedonic score for 9 emerging red variety wines and a Shiraz wine comparator of the 3 FWS segments.

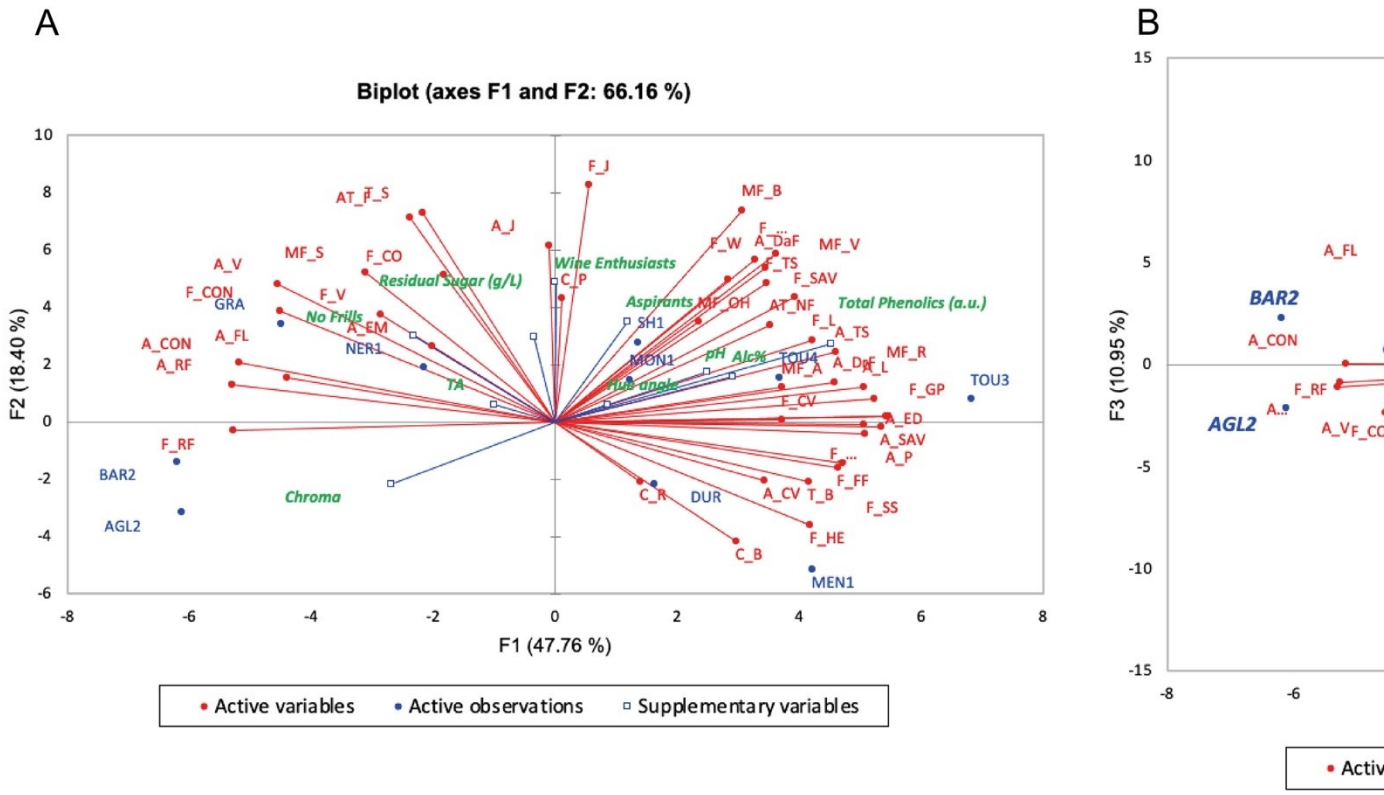
Wine	Wine Enthusiasts	Aspirants	No Frills
TOU4	**6.35a**	**5.81ab**	**5.19b**
SHI	6.42	6.62	6.64
GRA	**7.23a**	**6.19b**	**6.56ab**
TOU3	**7.15a**	**6.37ab**	**5.47b**
DUR	6.50	6.58	6.69
MEN1	6.04	5.67	5.50
NER1	**7.15a**	**6.48ab**	**6.28b**
AGL2	6.85	6.33	5.92
BAR2	5.81	5.19	6.14
MON 1	7.08	6.56	6.67

Wine liking between segments sharing a letter are not significantly different (Fisher's LSD $p < 0.05$). Significant differences between segments are indicated in bold.

5. The drivers of consumer liking

To assess which wine sensory attributes were driving the consumer liking of the wines, the significant attributes that differentiated the 10 wines were subjected to PCA. The first three dimensions of the PCA results along with both consumer hedonic responses of each of the identified segments and wine basic chemistry measures added as supplementary data are shown in the bi-plots (Figure 2A and 2B).

Figure 2. PCA bi-plots of the significant wine sensory attributes with the liking of the 3 identified FWS and selected basic wine chemistry overlaid as supplementary data; A (First and Second dimension) and B (First and Third dimension).



A = Aroma, T = Taste, F = Flavour, MF = Mouthfeel, AT = After Taste, C = Colour. Red Fruit (F_RF), Red Fruit (A_RF), Floral (A_FL), Floral (F_FL), Confectionary (A_CON), Confectionary (F_CON), Smooth (M_S), Sweet (T_S), Vanilla (A_V), Vanilla (F_V), Jammy (A_J), Jammy (F_J), Purple (C_P), Coconut (F_CO), Length of Fruit (AT_F), Chocolate (A_CH), Chocolate (F_CH), Dark Fruit (A_DaF), Dark Fruit (F_DaF), Eucalypt/Mint (A_EM), Eucalypt/Mint (F_EM), Alcohol (MF_OH), Spice (F_SP), Viscous (MF_V), Woody (A_W), Woody (F_W), Pepper (A_P), Length of Non-Fruit (AT_NF), Toasty/Smoky (A_TS), Toasty/Smoky (F_TS), Green Pepper/Capsicum (A_GP), Green Pepper/Capsicum (F_GP), Astringent (MF_A), Herbaceous (A_HE), Herbaceous (F_HE), Dried Fruit (A_DrF), Dried Fruit (F_DrF), Leather (A_L), Leather (F_L), Rough (MF_R), Stemmy/Stalky (A_SS), Stemmy/Stalky (F_SS), Bitter (T_B), Savoury (A_SS), Savoury (F_SS), Earthy/Dusty (A_ED), Earthy/Dusty (F_ED), Forest Floor (A_FF), Forest Floor (F_FF), Cooked Vegetables (A_CV), Cooked Vegetables (F_CV), Red (C_R), Brown (C_B), Bitter (T_B), Sour (T_A).

66.2 % of the variation in the data was explained in the first 2 principal components (Figure 2A). PC1 (47.8 %) saw wines with a savoury, earthy dusty character and a rougher mouthfeel separated from wines perceived as having red fruit and confectionery characters. The basic chemistry measures supported the rougher mouthfeel sensations perceived in these wines as total phenolics, which are known to correlate with more astringent mouthfeel (Waterhouse *et al*., 2016), are higher in wines on the right-hand side of the plot. PC2, which accounted for 18.4 % of the variation in the data, separated wines with a jammy fruit character and a long fruit aftertaste, with wines that were perceived as brown in colour and with a herbal flavour. PC3 further explained 10.95 % of the variation of the data in the sensory space, separating wines in the top quadrants perceived as having purple colour from wines in the lower quadrants with red colour (Figure 2B).

The consumer hedonic scores for the 10 wines ranged by only 1 point on a 9 point scale and there was no interaction between the fine wine segments and the wine liking which indicated that all 3 segments were evaluating the wines in a similar manner. On this basis, the ability to model the consumer hedonic scores on the sensory attributes was considered problematic. However, a Partial Least Squares Regression (PLSR) was performed on one consumer segment (WE; data not shown) and once a stable model was identified, the 7 attributes that drove their responses were the same 7 attributes that had a correlation coefficient > 0.4 with the overall hedonic response of that segment. Thus, we decided to use those correlation coefficients that had absolute values greater than 0.4 for each identified segment as a *de facto* indicator of attributes explaining consumer liking (or disliking). Figure 3 displays the results of that analysis.

It was determined that for the ASP segment, red colour, jammy and toasty/smoky aromas, jammy and savoury flavours and alcohol mouthfeel and non-fruity aftertaste, were the attributes responsible for their liking of the wines. No negative attributes were identified for this segment. WEs liked wines that had aromas of vanilla, sweet taste, jammy, confectionary, vanilla and woody flavours with a non-fruit after taste. No negative attributes were recorded for this segment either. The NFs liked wines with aromas of vanilla; confectionary, jammy and red fruit flavours; smooth mouthfeel and a fruity aftertaste. They disliked wines that displayed aromas of cooked vegetables and savoury, bitter taste, flavours of cooked vegetables, forest floor, green pepper and herbaceous, as well as a rough mouthfeel. Finally, at an aggregate level, the consumers liked wines with aromas and flavours of vanilla, confectionery and jammy, a smooth mouthfeel and a fruity aftertaste. They disliked wines that displayed aromas of cooked vegetables, aromas and flavours of savoury and flavours of forest floor, stalky and stemmy. These drivers are similar to those of the NFs, which is consistent with their correlation coefficient of 0.91 (data not shown).

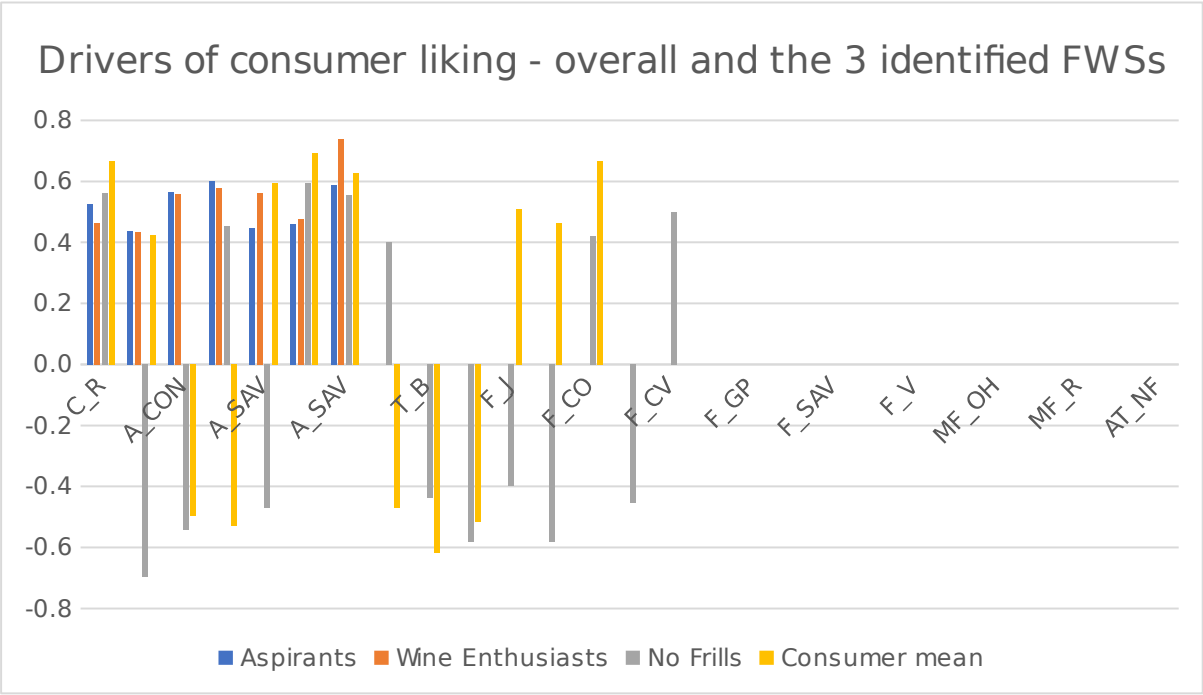


Figure 3. Sensory attributes with absolute correlation coefficients > 0.4 for each identified FWS and the overall consumer mean.

A = Aroma, T = Taste, F = Flavour, MF = Mouthfeel, AT = After Taste, C = Colour. Red (C_R), Jammy (A_J), Confectionary (A_CON), Cooked Vegetables (A_CV), Savoury (A_SAV), Toasty/Smoky (A_TS), Vanilla (A_V), Bitter (T_B), Sweet (T_S), Jammy (F_J), Confectionary (F_CON), Coconut (F_CO), Red Fruits (F_RF), Cooked Vegetables (F_CV), Forest Floor (F_FF), Green Pepper, Herbaceous (F_HE), Savoury (F_SAV), Forest Floor (F_FF), Vanilla (F_V), Woody (F_W), Alcohol (MF_OH), Smooth (MF_S), Rough (MF_R), Length of Non-Fruit (AT_NF), Length of Fruit (AT_F).

6. Alternative varieties tasted by consumers

At the end of the tasting, consumers were asked to indicate the grape varieties they had consumed in the past 12 months. The list included the 9 emerging varieties explored in this study, plus traditional varieties Australian consumers are more exposed to, such as Cabernet-Sauvignon, Grenache, Mataro/Mouvedre, Merlot, Pinot Noir, Shiraz and Tempranillo. A Friedman analysis was performed and the results (Table 4) showed that wines made of Negroamaro, Mencia and Aglianico grapes were tasted significantly fewer times than wines made of Durif, Barbera, Nero d'Avola, Montepulciano, Mataro, Merlot, Tempranillo, Cabernet-Sauvignon, Grenache, Pinot Noir and Shiraz. Conversely, traditional varieties were tasted significantly more times than wines made of Nero d'Avola, Barbera, Durif, Graciano, Touriga Nacional, Aglianico, Mencia and Negroamaro cultivars.

Table 4. Friedman analysis of red varieties tasted in the last 12 months.

Variety	Mean of ranks
Negroamaro	4.47a
Mencia	4.68a
Aglianico	5.17a
Touriga Nacional	5.88ab
Graciano	6.31abc
Durif	7.65bcd
Barbera	8.08cd
Nero d'Avola	8.08cd
Montepulciano	8.78de
Mataro/Mouvedre	9.56def
Merlot	10.91ef
Tempranillo	11.05f
Cabernet-Sauvignon	11.19f

Grenache	11.26f
Pinot Noir	11.33f
Shiraz	11.62f

Wines sharing a letter are not significantly different ($p < 0.05$).

For Durif and Mataro/Mouvedre, WEs and ASPs had tasted these non-traditional varieties in a greater proportion than the NFs. For the other alternative varieties except for Barbera, on the whole, the WE segment contained a greater proportion of respondents who had tasted these. When examining the tasting of the traditional varieties, not surprisingly, a greater proportion of consumers in all segments had tasted these relative to the alternative varieties and no differences were detected between the segments (Table 5).

Table 5. The number of respondents in each FWS who had tasted these red wine varieties in the past 12 months.

	FWS		
Variety	WE (n = 26)	ASP (n = 51)	NF (n = 36)
Aglianico	**8b**	**3a**	**5ab**
Barbera	**15ab**	**30a**	**12b**
Cabernet-Sauvignon	25	47	29
Durif	**17b**	**22b**	**12a**
Graciano	**12b**	**11a**	**9ab**
Grenache	25	47	30
Mataro/Mouvedre	**21a**	**38a**	**19b**
Mencia	3	2	4
Merlot	23	46	28
Montepulciano	19	30	18
Negroamaro	3	2	1
Nero d'Avola	**18b**	**24ab**	**15a**
Pinot Noir	25	46	32
Shiraz	25	49	33
Tempranillo	24	45	30
Touriga Nacional	**11b**	**9a**	**6a**

FWI segments not sharing a letter denotes a segment whose column proportions do differ significantly from each other using a Chi-square test at the $p < 0.05$ level.

7. Wine Neophobic tendencies

Following the protocol outlined in Ristic *et al*. (2015), the respondents were segmented according to their wine neophobic tendencies and three segments were identified: wine neophiles, wine neophobes and neither one nor the other (NONTO). A one-way ANOVA on

their hedonic responses revealed that the neophiles liked 3 alternative varieties (TOU3, NER1 and AGL2) significantly more than the wine neophobes, indicating that they might like to consume other wines produced from those varieties (Table 6). The remaining 6 non-traditional varieties were liked similarly by the three segments. Lastly, the Shiraz wine was liked significantly more by the neophiles and NONTOs than the neophobes.

Table 6. Mean hedonic scores for the 10 red wines of the 3 WNS segments.

	Neophile (n = 29)	NONTO (n = 54)	Neophobe (n = 30)
TOU4	5.86	5.95	5.23
SHI	**6.55a**	**7.02a**	**5.80b**
GRA	7.00	6.47	6.23
TOU3	**6.93a**	**6.51a**	**5.17b**
DUR	7.00	6.42	6.53
MEN1	6.21	5.64	5.33
NER1	**7.38a**	**6.35b**	**6.20b**
AGL2	**6.79a**	**6.4ab**	**5.7b**
BAR2	6.03	6.69	6.00
MON 1	6.93	6.65	6.60

Neophobe segments not sharing a letter denotes a segment whose liking does differ significantly from the other using Fisher's LSD at the $p < 0.05$ level.

In relation to the composition of wine neophobe status in the FWSs, significantly more neophiles were found in the WE segment relative to both the ASP and NF segments. There were no significant differences in the number of neophiles, NONTOs or neophobes in the ASP segment, but significantly fewer neophiles in the NF segment (Supplementary Table 6).

Discussion

1. Sensory profiling

This study was conducted to obtain a preliminary sensory characterisation of wines made from 9 emerging drought-resistant red grape varieties, not traditionally grown in Australia. There are no detailed sensory profiling studies of these varieties (when grown in Australia) in the relevant literature to date, nor have consumer acceptance trials been performed on these varieties in the Australian wine market.

54 statistically significant attributes ($p < 0.05$) were identified during RATA to successfully profile each of the 9 varieties. Wines made of Aglianico grapes (AGL1) were described as

having brown colour, aromas and flavours of forest floor, savoury and earthy/dusty. AGL2 (an Australian wine) on the other hand, was described as having a high intensity of red fruit aroma and flavour, which correlates with what Gambuti *et al*. (2007) reported. This study highlighted that when wines are made from unripe grapes of Aglianico, the obtained wines display attributes such as red fruits and herbal characters. The Australian wine (AGL2) was significantly lower in alcohol, which may explain the presence of unripe/less ripe fruit but it did not exhibit any herbal notes. This could be due to the region of origin, different canopy management techniques or higher levels of irrigation being utilised. Barbera, similarly, was described as having aromas and flavours of red fruits (BAR2) which corresponds with the common descriptors of these wines ("bright cherry flavours" Robinson *et al*. 2012, Dry, 2017a). Durif, also known as Petite Syrah, is a cross between Syrah and Peloursin. Usually described as full-bodied, dark and tannic (Dry, 2017b), the Durif wine (DUR) in the current study was identified as being intense in red colour, with aromas and flavours of forest floor, cooked vegetables and being savoury. This could be due to its relationship with Shiraz, as these descriptors can sometimes be found to describe Shiraz wines from cool climates (Kustos *et al*., 2020).

Graciano (GRA) was perceived as floral, confectionary with vanilla and sweet taste, with a smooth mouthfeel. This varietal, as described in Robinson *et al*. (2012) is a fragrant, perfumed (Gransden, 2019) and fresh, occasionally spicy varietal commonly used in the Rioja blend. Mencia, a very diverse varietal, is considered capable of producing different styles of wines (Dry, 2018), from light and fresh fruity styles to medium to heavy-bodied styles with oaky characters, herbal, savoury and gamey flavours. All the Mencia wines (MEN1, MEN2 and MEN3) were found in the lower right quadrant of the PCA plot, where attributes such as colour red and brown, aroma and flavours of cooked vegetables and forest floor and bitter taste described the wines. These results are inconsistent with the findings of Vilanova and Soto (2006), who characterised the sensory attributes of young Mencia wines from Galicia, north-western Spain. They analysed wines from five 5 different subregions. Wines from AOC Ribeira Sacra were described as "ripe fruit", "floral", "lactic", "balsamic" and "phenolic", while wines which originated in Chantada and Ribeira do Mino were identified as being higher in "metallic" and "bread" aromas, concluding that wines from at least the 2004 vintage, a limitation of the study, had distinctive sensory attributes according to their geographic origin. While this study found that wines made with grapes grown in

different regions display different attributes, our study found that the 3 Mencias (all from different regions) clustered together around very similar attributes.

According to the literature, Montepulciano can produce a big range of wine styles (Dry *et al*., 2017), from soft rosés to full-bodied reds. Its usual descriptors are syrupy, dark fruits, cherries and earthiness with deep colours and robust tannins (Robinson *et al*., 2012). Our results were consistent with these statements, as the 3 Montepulciano profiles ranged from jammy, dark fruit, chocolate with a fruit aftertaste to dried fruits, leather, earthy/dusty with intense red/brown colours. Similarly, Negroamaro was profiled with attributes that match the current literature, such as dark fruits (from dark plum to blackberries), prunes, with a "distinctive peppery note" and a slightly bitter taste (Capone *et al*., 2013, Dry *et al*., 2017). A similar pattern can be observed when looking at the results obtained for the profiling of the Nero d'Avola wines. The attributes identified during this study match the common descriptors described in the scientific literature such as cherry, raspberry and fresh herbs (Cravero *et al*., 2012, Dry, 2012). Lastly, the same can be said for the Touriga Nacional, a variety commonly used for Port, is usually described as rich in dark fruit, plum brandy, mulberry and dry raisin (Falqué *et al*., 2004), deeply coloured and concentrated (Robinson *et al*., 2012), as it was perceived in this study.

Overall, the sensory results obtained for this set of red wines by RATA are consistent with the information available in the relevant literature, which indicates the efficacy of this method to successfully profile diverse and complex sensorial products such as wine (Danner *et al*., 2018). Further studies with greater numbers of wines made from each of the varieties are required to identify more robust varietal sensory signatures (Johnson *et al*., 2013).

Shiraz is Australia's most planted red varietal (Bastian and Iland, 2020), hence one of the most popular red wines consumed in the local market (Wine Australia, 2020). Australian Shiraz has been extensively reported (from both the chemical and sensory perspectives) as having the following attributes: dark fruit, dried fruit, chocolate, jammy, smoky, savoury, spicy, earthy, astringent, with palate fullness and hotness (Kustos *et al*., 2020, Copper *et al*., 2019, Hranilovic *et al*., 2018, Lattey *et al*., 2010). Based on this sensory description, one could consider wines like Durif, Touriga Nacional and Montepulciano as alternative wine offerings to Shiraz in the near future, as all these wines displayed very similar sensorial characteristics for aroma, flavour, taste and mouthfeel in the current study. Wine volatile and phenolic chemistry should be analysed to further our understanding of the molecular drivers

of the sensory attributes of these non-traditional red varieties when grown and made in Australia.

Cabernet-Sauvignon, another traditional variety highly popular in Australia, has been well documented in the scientific literature (Chapman *et al*., 2005, Lattey *et al*., 2010, Robinson *et al*., 2011, Chira *et al*., 2011, Souza Gonzaga *et al*., 2020). Described as having aromas/flavours of bell pepper/capsicum, dark berries, dried fruits, canned vegetables, earthy, eucalyptus/mint, leather, vanilla, smoky, obvious alcohol mouthfeel, astringency and sour and bitter taste, among others (Robinson *et al*., 2011), the Cabernet-Sauvignon reference wine profiled very similarly to the wines made from Touriga Nacional grapes. These varieties not only showed similar sensory aroma, flavour and taste attributes, Touriga Nacional wines also recorded high levels of total phenolics (compounds related to astringency and bitterness) and alcohol content. Cabernet-Sauvignon has been reported as having high levels of phenolics as well as "green" characters, usually attributed to Methoxypyrazines and Six-carbon (C6) alcohols (Waterhouse *et al*., 2016). A recent study (Sáenz-Navajas *et al*., 2018) linked the interaction between isoamyl alcohol and the anthocyanin-derivative fraction and/or tannin as the possible contributor to the green characters in red wines. For a better understanding of Touriga Nacional as an alternative to Cabernet-Sauvignon, the phenolic composition, as well as the compounds mentioned above, should be further investigated in this variety.

On the other hand, wines like Graciano or Nero d'Avola could become a possible alternative to consumers, like the NF segment in the current study, who prefer wines like Grenache (easily available in the Australian wine market) with more floral, red fruit and confectionary characters (Alegre *et al*., 2020).

From the results obtained during this study, it can be said that the varieties selected in this investigation displayed a vast range of sensory attributes, from red fruit, confectionary, smooth fruit-driven wines, to herbal/ minty, green pepper/capsicum, astringent; and dark fruits, jammy chocolate, smoky, fuller-bodied/palate, oaky styles, which could potentially fulfil the already diverse taste of the Australian red wine consumers.

2. Australian consumers' response to emerging red wine varieties

Another purpose of this study was to advance our understanding of the Australian wine consumers' acceptance of wines made from non-mainstream, emerging, potentially drought-resistant red grape varieties. Ultimately, knowing their acceptance of these wines may assure grape growers and wine producers considering planting or changing current vineyards over to

these varieties in a strategy to face climate change challenges. This part of the study aimed to not only investigate Australian consumers' responses to these alternative varieties but to determine the positive and negative drivers of each segments' liking as well.

In terms of our consumer sample's demographic, even though there were more individuals with post-graduate degrees than expected, overall the figures showed that our sample would be considered representative of the Australian red wine consumer population. Australian wine drinkers are a highly educated population and similar figures have been consistently reported in the literature over the years (Johnson and Bruwer, 2003, Johnson and Bastian, 2007, Cox, 2009, Lattey *et al*., 2010, Kustos *et al*., 2019).

Upon examination of the liking scores obtained for each wine, all wines scored 5 or more (on a 9-point scale) which indicated that all wines were liked by the consumers. This is an important finding, as there is no current knowledge about Australian wine consumers' preferences and opinions of wines made of non-traditional grape varieties, in the scientific literature. These initial promising results may provide winemakers vital information about consumers' opinions of new wine styles and provide the basis for a potential competitive advantage.

Based on the sensory attributes identified during the RATA stage of the study, correlation coefficient analysis (Figure 3) identified which of these attributes were driving the liking/disliking of the 10 wines subjected to consumer trials. Our results are consistent with what was reported in previous studies (Lattey *et al*., 2010, Bastian *et al*., 2010, Copper *et al*., 2019, Kustos *et al*., 2019, Nguyen *et al*., 2020) that explored the sensory attributes driving the liking of red wine consumers. The NF cohort seems to prefer simple, smooth and fruity wines with red fruit and confectionary characters, whereas the other 2 segments, ASP and WE, liked more complex, oaked and savoury wines. For the NF segment, a varietal like Graciano or Nero d'Avola could become an acceptable alternative for this group's preferences, as both wines were perceived very similarly to a Grenache, which is usually described with the attributes liked by this cohort (Alegre *et al*., 2020). On the other hand, wines made from Montepulciano and Touriga Nacional cultivars could become alternative varietals for both WE and ASP segments, as these wines exhibited attributes such as jammy, vanilla, woody, high alcohol and viscous, which correspond to the characteristics liked by these 2 segments.

On average, the WE segment rated all wines higher than the other 2 segments, a pattern that has been observed previously (Danner *et al*., 2020) (Table 3). WEs liked TOU3, TOU4 and NER1 significantly more than the NFs and they liked the GRA significantly more than the ASP consumers. Overall, the ASP segment rated the wines slightly higher than the NF but this was not significant.

When inspecting the frequency of tasting different grape varieties of each segment, the results obtained matched our expectations. Wine grape plantings in Australia are dominated by traditional varieties like Shiraz, Cabernet-Sauvignon, Merlot and Pinot Noir, followed by Tempranillo, Grenache and Mataro (Bastian and Iland, 2020). These wines are readily available and consumed in the Australian wine market as found in the current study, unlike their non-mainstream wine counterparts. As expected, the WE and ASP segments that displayed more fine wine behaviours than the NFs had tasted a greater proportion of alternative varieties than NFs. This might be explained by the fact that WE and ASP segments are more knowledgeable and more interested in the variety and provenance aspects of wines, and they are considered greater risk-takers (WE more than the ASP) when it comes to trying new wine products (Johnson and Bastian, 2015). In contrast, the NF consumers are observed as being less knowledgeable, showing lesser interest in the provenance of the wines (compared to the other 2 segments) and are more risk-averse, which aligns with their lack of tasting the emerging varieties.

Wine neophobes are less willing to try unfamiliar wines or wines made from varieties they have not heard of (Ristic *et al*., 2016). To further confirm this trend, wine neophobic tendencies were analysed for each FWS and the results revealed that, as we expected, more WE and ASP consumers were found in the neophile segment, and more NF consumers were identified as neophobes. These findings are consistent with their fine wine behaviour tendencies mentioned above, as WE and ASP segments are considered to be greater risk-takers and therefore, they are more willing to try new varieties, unlike the NF segment, which showed more neophobic tendencies (by sticking to familiar wine products) when trying and rating new wine varietals (Ristic *et al*., 2016).

3. Study limitations and future research

Even though this study has demonstrated a potential for success in the Australian wine market for wines made from these emerging grape varieties, it is not without limitations. Firstly, to gain a full sensory profile of these varieties, a greater amount of wine samples of each variety would need to be assessed (Kustos *et al*., 2020, Johnson *et al*., 2013). Secondly, a complete

varietal expression examination should be considered, by standardised winemaking to remove confounding factors (such as oak maturation) and to let the grape varieties speak for themselves (Kustos *et al*., 2020, Johnson *et al*., 2013). Thirdly, a truly representative consumer sample of the population, instead of a convenience sample would provide more accurate findings of the wine consumer population. Lastly, wine volatile and phenolic chemistry should be analysed to assist in determining the chemical composition of these varieties when grown in Australia and the molecular drivers of the sensory attributes and consumer liking.

The scale of this study only allowed the exploration of red wine varietals. Further research will be necessary to investigate the sensory properties and consumers' opinions of non-traditional, potentially drought-tolerant white wine grape varieties.

To accurately label these varieties as “drought-tolerant”, all viticultural parameters regarding water usage should be measured and field performance of the varieties be assessed when grown under Australian climatic conditions. Finally, a consensual definition of what constitutes an alternative/non-traditional grape variety in Australia should be created with input from consumers.

Conclusion

This study has revealed that the 21 wines made from potentially, drought-resistant red grape varieties, not traditionally grown in Australia, possessed a vast range of sensory attributes to suit all tastes (from fruit-driven, smooth, red fruit predominant wines to more complex, savoury and oak predominant wines). The preliminary hedonic results obtained during the RATA stage suggested that all wines were going to be well received by the consumers. The consumer trial corroborated this assumption, which demonstrated that all 10 wines in the subset were liked. A segmentation analysis based on Johnson and Bastian’s 2015 FWI, revealed 3 segments that were labelled WE, ASP and NF. All 10 wines were liked by each segment but with some significant differences in liking between the segments identified. Further analysis identified the specific positive and negative sensory attributes that drove the liking of the wines for each of these segments. Furthermore, the alternative wine liking and behaviour demonstrated by the different fine wine segments might be driven partly by the neophobe status of these segments’ members.

The knowledge obtained from this preliminary study of the sensory properties and consumers' opinions of emerging red grape varietal wines has provided wine producers with in-depth and positive information about the potential performance of these new wines in the current Australian market. As Australia faces a hotter, drier future, adaptation by the wine grape industry by cultivating more drought-resistant grape varieties may offer a solution to this challenge. This study may assist producers who might be contemplating a switch from more traditional grape varieties to alternative wine styles by providing the confidence to do so, thereby meeting the taste specifications of this competitive market whilst promoting a more sustainable future for the grape and wine industry.

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