Stream 3.1: Wine and consumer needs

1. Abstract:

The objectives of this stream were to:

- establish an efficient sensory resource for a broad range of R&D and problem solving projects;
- measure responses of consumers - including consumers in China - to wine sensory and non-sensory attributes; and
- determine the relationships between sensory attributes and the chemical composition of wine.

The results of the studies showed that a) consumers respond negatively to surprisingly small levels of flavours such as 'Brett', oxidation and reduction; and b) there are sub-groups who differ in their preference for other flavours, such as 'green', sweetness, oak, pepper or mint. These sub-groups provide valuable targets for different wine styles, and optimal flavour strengths have been found for some attributes, such as astringency.

Unexpectedly, wine consumers in China showed only modest differences in liking of red wine flavours compared to those in Australia; at the same time a stronger response was observed to many attributes that were also drivers of preference for Australians, especially acidity, sweetness and oxidation.

Research into the chemical basis of off-flavours has allowed the AWRI to augment and replace sensory panel data with readily available chemical measures for 'Brett', reduction, oxidation, cork taint, smoke taint, and chemical/plastic taint, together with the understanding of levels which might trigger a negative response from consumers.

Research studies into purchase intent when wines are not tasted blind were undertaken in collaboration with The University of South Australia. The results showed that purchase behaviour could be predicted well with shelf simulation experiments using best-worst methods together with sensory rating data from a trained panel.

Overall, the outcomes achieved in this stream by combining detailed flavour chemistry data with sensory results and other feedback from consumers, have:

- greatly expanded knowledge of consumer responses;
- complemented expert and 'research-type' sensory studies; and
- identified stylistic targets for large and small producers.

The activities have also resulted in a strong increase in awareness of the benefits of the use of formal sensory and consumer methods by the wine industry.

2. Executive summary:

Measurement of consumer acceptance or liking is important to guide the Australian wine industry to make wines that consumers appreciate and to ensure that the intrinsic sensory properties of wines are appropriate. When activities in this stream commenced, research in this area was extremely limited, with little information publicly available, and little or no capability within the Australian wine sector to conduct consumer sensory testing studies.

This stream was undertaken to provide knowledge of critical attributes that drive consumer preference, in turn allowing work to improve winemaking and grapegrowing inputs to cost-effectively optimise those attributes. The AWRI was uniquely placed to conduct this research, combining its core capabilities in both the sensory evaluation of attributes that most influenced consumer preferences, with chemical analytical capability which objectively related those key attributes to the chemical

composition of the wines. Activities in the stream utilised non-technically trained sensory descriptive analysis panels to objectively quantify the sensory attributes of wines, together with untrained, regular wine consumers providing hedonic liking data.

Sensory capacity was greatly expanded in the early stages of the investment agreement, with an on-going sensory descriptive analysis panel formed, trained, and evaluated on a continuous basis. Expert technical and discrimination testing panels were also formed and provided technical support for taint and fault investigations as well as research projects. A database of consumers was also established for hedonic testing. Rapid methods were evaluated such as 'Napping' (projective mapping) and 'difference from control', and subsequently included in the suite of testing methods. Substantial extension and training activities were conducted, including practical workshops and production of material for the AWRI website and industry journal articles, which assisted the industry in applying formal sensory methods.

Consumer acceptance studies on red wines, initially assessing consumers in Sydney, and later comparing wine consumers in Australia with those in China, provided valuable information regarding key negative attributes, and their levels, that consumers find undesirable. These attributes included flavours derived from the action of *Brettanomyces* yeast ('Brett' flavour), alcohol 'heat', bitterness, oxidative flavour, reductive flavour and excessive acidity. It was found that winemakers' responses did not align to those of consumers, and that there were clear sub-groups of consumers with distinct preferences. Some sweetness in red wines was preferred by larger numbers of wine consumers in China, but there were also substantial numbers of consumers in Australia with similar responses. Only a small minority of wine consumers in China appreciated higher alcohol, richer red wines.

'Brett' flavour was confirmed to be highly disliked by consumers in follow-up investigations, providing a strong basis for producers to avoid this flavour in their wines. Closure-related sensory differences in white wines were found to affect consumer liking response, with sizeable sub-groups of consumers disliking wines with a low level of cork taint, oxidative flavour or 'reductive' aroma. For red wines, wines with lower fruit freshness and higher bruised apple flavour were not well accepted.

Assessment of a neutral wine with added Sauvignon Blanc flavour compounds showed that many consumers like 'green' flavour in combination with tropical fruit flavour, with a minority preferring the tropical fruit dominant wines. A study on commercial white wines showed that sweetness/acid balance was a major acceptance factor for many consumers.

While studies were generally conducted blind, work on the interplay between price, brand and label with sensory characteristics of wines, showed that while non-sensory attributes are important, the flavour of the wine, particularly attributes such as low level 'Brett', oxidation and fruit 'freshness', has a very strong influence on re-purchase intent. From this work, undertaken in collaboration with the University of South Australia, a valuable novel testing approach was established to predict re-purchase.

For many of the investigations completed, differences among consumers in taste preference were found to be most strongly related to years of wine drinking or degree of involvement with wine, rather than to age or other demographic factors. In a study to assess the effect of repeated exposure to wines on short-term changes in liking, it was found that consumers new to wine shifted strongly in their liking towards the wine style of the type to which they were exposed.

The stream activities have generated good knowledge of consumer responses to levels of key flavour compounds such as eucalyptol, rotundone ('pepper', 'spice' in red wine), isobutyl methoxy pyrazine ('green flavour') and salt, together with understanding of the potency and sensory significance of multiple compounds, notably those involved in taints from bushfire smoke.

Overall, the activities gave numerous insights into consumer responses to wine sensory properties providing data that otherwise would not have been available to the vast majority of wine producers. Australian wine producers were able to make informed decisions as to wine style to:

- more closely align with preferences in the growing Chinese market;
- control flavours such as 'Brett', bitterness and 'reductive';
- ensure that wines have fruit freshness; and
- limit alcohol related heat.

Producers can also take advantage of the knowledge generated that for newer wine consumers their liking of a wine strongly shifts upon exposure.

Wine companies are encouraged to make greater use of trained sensory panels and consumer testing to ensure that products meet consumer's needs, with stronger links between production and marketing through sensory testing. Numerous wine companies and personnel were involved in the activities of this stream and are gratefully acknowledged.

Affiliation	**Area of support/contribution**
University of South Australia, School of Marketing	Joint project on interaction of sensory and non-sensory factors on consumer response; Brett flavour, Shiraz wines
University of Adelaide, School of Agriculture, Food and Wine	Smoke taint, Sauvignon Blanc flavour
CSIRO Plant Industry	Salt studies
Tragon Corporation, USA	Wine consumer research in China
Sensory Insights	Exposure studies, consumer testing

3. Background:

The Australian wine industry has been successful, at least in part, by being responsive to consumer taste preferences. However, knowledge of consumer preferences has been acquired predominantly by the slow and imprecise means of analysing historic sales data of wines previously launched in a market, or by general feedback from consumers, without the involvement of any objective testing methods. One essential factor for future success is that the industry must obtain direct, specific and reliable information to better understand taste preferences, especially those of consumers in export markets.

Prior to the commencement of research in this stream:

- formal consumer affective testing, involving the gathering of both consumer liking and, separately, quantitative sensory data, was not conducted in the wine industry;
- there was no expertise or capacity in even the largest companies to conduct or interpret the results of specialised sensory tests; and
- there was very little publicly available knowledge regarding consumer preferences for specific wine attributes.

At the commencement of the investment agreement, there was strong debate about whether 'Brett' flavour might be positive for some or negative for all consumers, or indeed whether it might be responded to at all. Similarly, the effects of 'green' flavours, oak flavour or astringency on consumers were not known.

This research had the expected outcomes of:

- Increasing the ability of wine producers to tailor wines to different market segments, especially to consumers of wine and consumers in emerging markets.
- Producing knowledge of critical attributes that drive consumer preference, allowing work to improve winemaking and grapegrowing to cost-effectively optimise those attributes.

- Producing understanding of whether consumer preference can be influenced by exposure, especially for consumers new to Australian wine.
- The development of methods for research studies and industry application, with the overarching objective of extending the basis for the industry to increase sales of premium Australian wine.

4. Stream objectives:

The stream had the following objectives:

- Establish procedures for an efficient, high capacity sensory resource and apply such methods to measure responses to wine sensory attributes.
- Determine, for specific wine styles, the relationships between consumers' sensory preferences, including the existence of consumer segments, and intensity ratings of sensory attributes.
- To compare how sensory preferences vary within Australia and in key export markets, notably China.
- To assess how consumer preferences, especially those of low consumers of wine, might be influenced through exposure to wine styles new to them.
- To find how consumer preferences relate to purchase decisions when non-sensory attributes are involved.
- To establish the relationship between sensory attributes of importance to consumer preference and chemical composition for specific wine styles.

5. Methodology:

The stream involved several stages and sub-projects, with an early stage involving recruitment of a specialist external trained sensory descriptive panel to ensure maximal efficiency and throughput while removing response bias at the same time.

Trained panel, sensory descriptive analysis was conducted using consumer based non-technical language with external part-time assessors who were screened, recruited and trained and whose performance was continually monitored, according to International Organization for Standardization (ISO) standards. A consensus-based training approach was used, applying reference standards and defined attributes (Stone et al. 2012), with practice rating sessions completed before formal data collection to assess panel performance and redundancy of attributes.

Qualified consumers for sensory acceptance testing were sourced from the local Adelaide community, or as needed (such as for more diverse, larger groups of consumers meeting set criteria which were recruited from Sydney and Melbourne and cities in China). A sequential monadic ('one by one') rating of each coded wine was used, applying the standard nine-point hedonic scale (Peryam and Haynes 1957) and forced rest between samples, no expectoration and five to seven samples per session. Where required, consumer assessors completed two sessions over two days to assess sufficient wines (12-14) for preference mapping models to be generated. Applying best practice methods for 'central location' testing, samples were assessed in isolated, temperature controlled and well ventilated booths, under daylight type lighting, according to ISO standards. For white wines, samples were assessed at 15-17°C. For exposure studies, home use testing was applied, with a single wine assessed under typical consumption conditions.

For many studies, samples were assessed by both a trained descriptive analysis panel and by untrained subjects rating liking, and chemical compositional data was obtained using targeted quantitative analysis of key volatile aroma compounds and non-volatile analytes. To determine how consumer responses relate to sensory and chemical attributes, several approaches were taken:

- Correlative studies, where multivariate preference mapping techniques were applied with 10-14 selected commercial wines.

- Addition studies, with target compounds added to base wines, sensory properties profiled and consumer liking responses determined.
- By using experimentally produced wines, and using designs to answer specific treatment questions.

Technical panels were used comprising highly experienced technically trained assessors' rating of wine faults and off-flavours, and giving quality scores.

Generally, consumers assessed wines under blind conditions, without being influenced by any information about the wines. In order to understand the interplay of extrinsic and intrinsic attributes of wines, best-worst methods were applied (Finn and Louviere 1992), with acceptance testing conducted on both an informed and blind basis for separate studies. This work was undertaken in close collaboration with the University of South Australia School of Marketing.

6. Results and discussion:

Sensory capability development

Building on previous capacity at the AWRI, a dedicated wine sensory descriptive analysis panel was recruited from the local community through a multi-step screening process and, following training, was convened for three two-hour sessions per week throughout the year. The panel provided strong advantages in reliability and validity of results, increased throughput of studies, unbiased response, and use of non-technical language, over previous panels used. To the AWRI's knowledge, it is the only on-going wine sensory descriptive analysis panel of its type in Australia.

Methods and internal panels were developed for difference testing. In addition, screened and trained AWRI staff members were used for studies related to identification of off-flavours and, where needed, for more specialised descriptive analysis studies such as mouth-feel investigations.

As part of this project, a technical quality panel was formalised, comprising highly technically trained and experienced AWRI assessors with wide professional experience in wine assessment. This panel was applied to wine industry and technical support issues such as smoke taint, plastic/chemical taint, and general evaluation of wines with production issues. The panel provided off-flavour ratings, quality scores and descriptive notes, giving guidance for chemical investigations and allowing design of more rigorous tests.

A database of more than 600 regular wine consumers was also established for hedonic testing in Adelaide, and a collaborative arrangement was made with a major consumer testing firm based in Sydney to undertake field tests to the AWRI's requirements.

As part of method development, comparative tests were conducted to confirm the utility of the 'difference from control' method as a more rapid method than triangle or duo-trio difference testing, when large numbers of comparisons are required.

A projective mapping method, as a rapid alternative to descriptive analysis, was evaluated and found to give very similar groupings of wines compared to the conventional method, with somewhat lower precision in descriptive interpretation. Separate mapping tasks for aroma and palate were found to give improved sensitivity.

In conjunction with Stream 2.3, a 'Pinot Gris/Grigio style' scale was developed following rating sessions with a large winemaker panel and validation with a technical AWRI panel (Robinson et al. 2011). The method was applied to large numbers of 'Pinot G wines', described in Stream 2.3, and the chemical basis of the differences among the styles was determined. The concept has also been used for Chardonnay, working in collaboration with winemakers from major wine companies, and found to be valuable in giving insight into the chemical basis of style differences.

Working with Stream 4.1 to foster extension and industry adoption, a practical workshop on sensory methods was developed and delivered. A shorter format presentation was delivered in multiple regions, and a separate workshop developed to measure winemakers' detection thresholds for a range of important compounds. Many industry articles detailing sensory methods, including consumer testing, were published (such as Lattey et al. 2007a, 2007b; Cowey and Travis 2008; King et al. 2008a), and a new section was added to the AWRI website to give a practical industry guide to sensory testing. A sensory specialist trained by the AWRI has established a new sensory and consumer research section for new product development and research trials at one of the largest wine companies, using methods developed at the AWRI. An informal South Australian-based interest group was organised involving sensory practitioners in industry, as well as researchers, to share problems and advice, to try to increase the spread of sensory analysis in the industry. During the course of the investment agreement, the AWRI has also assisted wine producers in sensory procedures, including testing winemakers for their detection threshold for 'Brett' compounds in sparkling wine, plastic/chemical taint rating, provision of reference standards, and provided assistance in developing and analysing data from tasting scorecards for comparative tastings by industry associations.

Consumers' sensory preferences of wine sensory attributes

A major focus of the stream was conducting consumer acceptance studies to quantify the response of consumers to wine sensory attributes, particularly those characteristics that reduce liking. The aim was to find levels of attributes that were responded to by regular wine consumers, to be able to provide information for effective control of those key sensory properties.

A preference mapping study on widely available commercial Shiraz and Cabernet Sauvignon (Lattey et al. 2007a, 2007b, 2010) included a range of wines with a diversity of sensory properties, to allow the maximum ability to find the sensory properties of greatest importance for blind liking by consumers in Sydney. It was one of the first wine consumer studies of its type, and the first in Australia. A very strong consumer negative response to 'Brett' flavour, bitterness and 'hotness' due to alcohol was found. Clear sub-groups of consumers – varying in size from 15% to 45% – with distinct preferences were identified. A small proportion strongly preferred wines with a degree of green capsicum/blackcurrant flavour, and tolerant of higher acidity, while others preferred oak flavour or wines with moderate degree of astringency. Quality scores from winemakers were found to have negligible relationship with consumer liking scores, with the main common factor being a dislike for 'Brett'-affected wines. Otherwise, the low level of bitterness that consumers responded to was not a concern for winemakers, who generally preferred wines with higher fruit, alcohol, oak and astringency, and for whom hotness was a strong positive attribute, correlating strongly with the quality score. Differences among the sub-groups of consumers were found to be related to years of wine drinking experience, rather than age or other demographic differences. The study provided information about relevant sensory targets for wine companies, for attributes that explain the needs of different consumer groups, as well as styles that would meet all consumers' preferences. The work showed that winemaker judgements do not necessarily provide a suitable approximation or proxy for consumer data.

In two smaller follow-up studies, different levels and combinations of volatile compounds important to 'Brett' flavour were added to a red base wine and assessed by consumers (Mueller et al. 2009; Curtin et al. 2008a), in isolation or in the presence of other flavour compounds. There was no sub-group of consumers who liked wines with 'Brett' flavour, although there was a small group who did not react. The results confirmed that consumers respond to surprisingly small sensory differences and this knowledge assisted producers in making the decision to take steps to avoid or reduce 'Brett' flavour in red wines across Australia. Through studying combinations of 'Brett', oak, green and alcohol levels it was also observed that in a specific red wine many consumers (40%) found elevated alcohol a negative attribute.

Blind taste preferences of consumers in China were investigated, with a red wine cross-cultural study conducted comparing consumers in three cities in China (Shanghai, Beijing, and Guangzhou) with Melbourne and Sydney consumers (Osidacz and Francis 2009; Osidacz et al. 2011b; Williamson et al. 2012). In this study, wines with a wide range of sweetness were included, on the advice of the industry advisory group, up to 16 g/L, as well as wines of higher alcohol, oak flavour and aged flavour. The study showed that there were surprisingly similar responses of wine consumers in China and Australia, with some notable differences, but generally the two markets were not as dissimilar as previously believed. The effect of slight sweetness of red wines to soften in-mouth properties of wines was important to both Chinese and Australians, although there was a higher proportion of Chinese who preferred softer, fruity wines, and the Chinese had a lower tolerance for astringency, alcohol warmth or sourness. There were more consumers in Australia not driven by sweetness than in China. There were no differences between Chinese major cities, and the Australian wines were overall the most liked over international benchmark wines. Extensive information relating to wine consumption habits and attitudes of consumers in China was collected in this study.

During the course of the research program, several projects were conducted investigating consumer liking and closure-related bottle storage effects. Two sets of wines from a study of an unoaked Semillon wine were assessed after 24 months in bottle (O'Brien et al. 2009; Nygaard et al. 2010). The results showed that many consumers reject wines with very low levels of cork taint (1-2 ng/L of TCA) and also wines with low levels of oxidative flavour, while approximately 40% of the consumers tested on both occasions disliked the wines with higher 'struck flint'/'reductive' aroma. For red wines, a Shiraz wine assessed after two years' post-bottling was also found to be less accepted by consumers if bottled under closures with higher oxygen transmission properties.

To assess consumer responses to the range of flavour compounds in Sauvignon Blanc, an evaluation of controlled additions of 'tropical' thiols, isobutyl methoxypyrazine (IBMP, green capsicum/green bean) and a mixture of esters, both in isolation and in combination, was conducted (King et al. 2011b). Each was added to a neutral white wine at levels observed in typical Sauvignon Blanc wines. It was found that IBMP generally dominated any mixture, although as expected, in the presence of thiols the intensity of the fresh green flavour was greatly diminished, illustrating the mutual suppressing effect that aroma compounds display. The study showed that a degree of green flavour is attractive to a sizeable proportion of consumers; i.e. when both tropical fruit flavour and green flavour are present in balance consumers like the combined flavours. This is not very surprising in some respects, as many high selling New Zealand Sauvignon Blanc wines also generally have relatively high green flavour as well as strong tropical fruit aroma compared to many Australian wines. While it is uncommon to see greener style wines from Australia, the results give some cause to consider that the Australian wine producers' propensity to avoid green flavour might have resulted in styles disappearing from the market which some consumers highly appreciate. 'Cat pee/sweaty' flavour from the thiols was acceptable to consumers up to a point, with higher levels reducing preference. There were quite strong demographic differences among the consumer preference segments identified, with differences related to proportions of females; degree of wine experience; and proportions of consumers who purchase and report higher liking for New Zealand Sauvignon Blanc wines compared to other white wines (King et al. 2011b, 2012). This is in contrast to most consumer studies where generally demographic differences are not a strong driver of preference.

A study assessing variations in viscosity, bitterness, acidity and astringency in commercial white wines and relationships to consumer acceptance was performed (Francis et al. 2010 , 2011). The study showed that a sizeable minority of consumers (36% of the total tested) responded most strongly to palate differences, with a negative influence of acidity, bitterness and astringency on liking scores, and a positive influence of sweetness (all wines contained less than 4 g/L of glucose and fructose) and overall fruit flavour. With Riesling, oaked and unoaked Chardonnay and Pinot Gris wines included, 41% of consumers preferred Chardonnay wines and those with higher oak flavour, higher alcohol levels and higher viscosity. A smaller group most liked wines with higher citrus flavour and higher acidity, mainly Riesling wines.

Consumer acceptance: fundamental studies and influence on consumer behaviour

Working with Professor Larry Lockshin and Dr Simone Mueller-Loose from the University of South Australia, a collaborative study comparing a novel 'best-worst' sensory method and conventional hedonic rating showed that the best-worst approach was less suitable due to fatigue and alcohol ingestion effects (Mueller at al. 2009). While those effects could be overcome with fewer samples and/or longer rests between sets, the consequent high cost and poor efficiency of the 'best-worst' testing method means it is less suited for sensory consumer studies.

A new approach in modeling informed choice of Shiraz wine with non-sensory and sensory variables was developed. This work confirmed that consumers responded strongly negatively to oxidative, bottle aged, 'Brett' or reductive flavours (Mueller et al. 2010) even when informed of the wine's identity and for wines that are high priced. Re-purchase intent was well predicted by knowledge of both initial choice prior to tasting, as determined by a simulation of choice from a retail shelf using 'best-worst' scaling, together with knowledge of wine sensory properties, and these predictions also related well to actual sales data.

Repeated exposure of consumers to wines was found to have only a small effect on consumer acceptance (Osidacz et al. 2011a), although the effect was larger for newer wine consumers. Consumer preferences moved towards richer red wines with stronger flavour and away from slightly sweet, fruity styles following the exposure condition. The study confirmed that high astringency and bitterness were negatives to virtually all consumers and that consumers cannot be 'trained' to like wines that experts consider high quality if these negative attributes are present. It was also found that home use testing gave comparable results to central location tests. An education component to the study, where consumers attended a wine course, showed that while liking scores increased across the wines following the education course, preferences generally remained similar for the wines tested, especially for more established wine consumers. The size of the sub-groups with similar preferences changed somewhat: after the course a higher proportion of consumers moved even more strongly away from wines with a degree of bitterness, excessive astringency and hotness.

Research support activities

There have been many projects conducted working with other research streams, making use of the capability and efficiencies to produce multidisciplinary outcomes from projects that would previously not have had sensory or consumer acceptance data available. These are discussed elsewhere in this report, and include:

- A concerted approach to study yeast strain effect on Sauvignon Blanc flavour with Stream 1.3 showed that sensory properties were strongly affected, whether in isolation or in co-inoculation strategies. This study being arguably the first to definitively show that yeast strain has a clear effect on wine flavour, with differences retained even after three years of cellar storage (King et al. 2010a, 2011a). The influence was also sufficient to affect consumer and winemaker preference (King et al. 2008b, 2010b, 2011b; Swiegers et al. 2009). A study to assess yeast strain effect on Chardonnay flavour gave similar outcomes, including enhanced 'tropical' flavour, with consumers being divided on preference for general fruit intensity or tropical fruit flavour (Curtin et al. 2009).
- A series of sensory descriptive tests conducted on Shiraz wines made with either nitrogen added in the vineyard in the form of urea, or in the winery as diammonium phosphate (DAP), showed that too little or too much nitrogen has a deleterious effect on wine flavour (reported in Stream 1.3, Torrea et al. 2011; Ugliano et al. 2009, 2010).
- A succession of studies to characterise the impact malolactic fermentation can have on wine aroma properties (reported in Stream 2.1, Costello et al. 2012).
- Investigations of treatment options for avoiding protein haze in white wines (reported in Stream 2.2, Marangon et al. 2012)

- Several studies assessing the effect of phenolics, alcohol, glycerol and polysaccharides on white wine in-mouth sensory properties, with relatively small but nonetheless significant differences observed, notably for viscosity and warmth in whites (reported in Stream 1.2).

Chemical drivers of preference

As part of the multiple consumer testing studies completed, wide ranging chemical data was obtained from the sample sets. Data was taken from, in some cases, fairly simple measures such as basic composition, together with more detailed information pertinent to the study, such as sulfur off-flavour compound concentration or degree of browning. In other studies, detailed quantitative profiling of volatile composition was achieved. The ability to link consumer response, sensory attribute ratings and chemical data of wine composition, provided a continuum of knowledge for connecting consumer liking and chemical data. It is not generally possible to directly relate chemical composition and consumer response, as complex non-linear responses are involved, so the additional step of relating the instrumental data to the sensory characteristics of the samples and then to the consumer response is needed.

Studies have shown which compounds are of greatest importance to sensory attributes of Sauvignon Blanc that drive consumer preference. These included which of the several 'tropical' thiols give rise to 'cat pee' and which contribute more to passion-fruit or citrus flavour, and what levels of IBMP, together with the thiols, are optimal to give acceptable flavour (King et al. 2011b). For in-mouth sensory properties of white wines (Francis et al. 2010), the non-linear responses of consumers to chemical composition was correlated with residual sugar and spectral phenolics measurements. This showed either low levels of residual sugar and low phenolics being desirable, or a moderate sugar level in presence of higher concentrations of phenolics. The ability to predict sensory attributes such as viscosity, astringency and acidity by measuring simple variables such as pH, phenolics and residual sugar was found to be strong, giving wine companies the ability to set limits for different wine styles without requiring complex analyses.

In a study with high and low additions of some flavour compounds, added to a relatively low flavour intensity red wine, most consumers reacted strongly, either positively (40% of the total) or negatively (30%) to *Eucalyptus* flavour; rotundone ('pepper', 'spice') generated a relatively neutral influence; and a sizeable group disliked elevated smoky flavour (Herderich et al. 2012). The last group preferred the base wine with a low level addition of eucalyptol but did not like the higher addition level. The results provided context for studies into control of these compounds in Stream 1.1.

For red wines, the work on 'Brett' flavour showed that 4-ethylphenol (4-EP) and 4-ethylguaiacol (4-EG) were most important to the 'medicinal' and 'leather' flavour attributes and strongly reduced consumer liking, with 4-ethylcatechol being less critical. In addition, masking effects of other compounds such as oak or alcohol were found to have a strong influence.

Sensory threshold values were obtained for many compounds found to be of importance to consumer acceptance, notably volatile phenols involved in taints originating from bushfire smoke and 'Brett' flavour; halophenol taint compounds; various salts; a fermentation derived off-favour compound indole; and lactones involved in fruity flavour. The sensory detection threshold of several key sulfur compounds involved in 'reductive' flavour that consumers strongly responded to in several studies, were determined: hydrogen sulfide; methane thiol; and benzenemethanethiol. It was separately found that hydrogen sulfide and methanethiol - either in isolation or in combination - gave cooked egg/rubber/cabbage aromas while benzenemethanethiol gave a struck flint aroma. Of the 13 halophenol compounds tested, 2,6 dichlorophenol had the lowest sensory detection threshold and was the primary compound related to a plastic/chemical taint (Coulter et al. 2008).

Regarding smoke taint, the causative compounds were confirmed through sensory and chemical studies. It was established that several volatile phenols not previously recognised are involved but also

glycoside precursors of these phenols that can be broken down in-mouth, release smoky/medicinal off-flavour and contribute to lingering unpleasant aftertaste (Parker et al. 2012).

Studies have been completed investigating salty taste in wine, and showed that electrodialysis can be effective in reducing salty taste (Cowey et al. 2010). Taste threshold work, including consumer detection threshold, was conducted on sodium and potassium chloride, as well as a collaborative project undertaken with Dr Rob Walker from CSIRO Plant Industry on the effect of rootstocks on salty taste in Chardonnay and Shiraz wines.

Based on several preference mapping studies, the AWRI now has a good ability to predict sensory attributes important to consumer red wine preference from volatile and non-volatile chemical composition, including attributes such as 'red berry', 'dark fruit', 'green bean/capsicum', oak, and astringency, with a relatively small number of key compounds (Francis et al. 2010). Work conducted in conjunction with Stream 1.2 provided more detailed insight into classes of tannins and their involvement in astringency and bitterness (McRae et al. 2013).

An investigation assessed chemical changes with grape ripeness and their effect on sensory properties and consumer acceptance for Cabernet Sauvignon wines (Bindon et al. 2013), with samples also obtained from a Shiraz industry trial. Wines made from grapes at intermediate levels of total soluble solids (TSS) were well accepted by consumers; the wines with lowest levels of ripeness were less well liked, and this related to lower fruit flavour and higher 'green bean' flavour; while highest TSS values gave wines with greater astringency, bitterness, viscosity and hotness. Key chemical compounds were identified that were strongly associated with these attributes, such as total tannin (astringency, bitterness), alcohol (heat), and glycerol, polysaccharides, alcohol (viscosity). The importance of methoxypyrazine and C6 compounds (hexanol, z-3-hexenol) to 'green' flavour was also shown, while dimethyl sulfide was indicated as important to 'dark fruit' flavour.

7. Outcome and Conclusion:

The results of activities undertaken in this stream have provided insight into consumers' taste preferences and how they relate to sensory characteristics of wines. Consumers respond strongly to rather small differences in sensory properties, especially key negative flavours such as 'Brett', oxidation, reduction, bitterness, and excessive astringency, giving clear targets for wine companies in product development and wine production. Instrumental measures and in-depth knowledge of concentrations of compounds causing key flavour attributes, both positive and negative, have been developed.

It was established that changes in wines with storage can reduce acceptance due to even very low levels of oxidative or reductive flavours. The reductive compounds hydrogen sulfide and methane thiol have the greatest sensory significance, with benzenemethanethiol being important to 'struck flint' aroma, which can be more evident with use of low oxygen transfer closures. The knowledge of threshold concentrations of these compounds and that consumers respond to their presence, allows specifications to be set and winemaking and bottling procedures to be reviewed and improved. This work also assisted winemakers in selecting closures based on their oxygen transmission rate and provided performance improvement targets to a number of closure suppliers.

Even when influenced by knowledge of wine price and brand, consumers respond to lack of fruit freshness, 'Brett', reductive and oxidative flavours. A combined marketing science/sensory science approach involving choice of brand followed by sensory testing and purchase intent response has great promise as a tool for new product development.

From the results of the repeat exposure studies it is evident that avenues to expose 'new to wine' consumers to higher priced wines can be beneficial in changing preference patterns, but consumers cannot be persuaded to like wines with key negative sensory attributes, even if some experts might consider them excellent. Cellar door, trade show or wine course activities can assist new wine

consumers to move more quickly than they otherwise might towards higher priced, richer and intensely flavoured wines.

Knowledge of sensory detection thresholds for a wide range of off-flavour compounds allows the identity of the compounds causing taints to be rapidly established in industry incidents. This assisted companies to make decisions about disposing of tainted wine, and assisted in insurance claims and the settling of third party disputes, thereby generating financial benefit for the industry. Interaction of off-flavour compounds with other wine compounds can be highly significant: together, the several important 'Brett' compounds in combination have a very low threshold, while oak and other wine flavours can suppress perception of taint, information greatly assisting taint investigations and allowing specifications to be set.

Distinct sub-groups of consumers were identified in almost all studies, which all responded to common negative flavours such as bitterness, but had different preferences for other flavour characteristics, such as 'green', sweetness, oak, red fruit, mint or dark fruit (red wine); or tropical fruit, 'green', stone fruit or citrus flavour (white wines), and overall strength of flavour. These sub-groups provide valuable targets for different wine styles, and the existence of these multiple targets means that wine producers cannot expect that a particular wine style or a single wine will meet all consumers' needs. These studies on red and white wines have shed further light on the complex relationships between consumers' sensory preferences, wine sensory characteristics, and the chemical composition of the wines.

A further important outcome from this research program is an increased ability for producers to tailor wines to different preference segments, through the ability to relate (and hence influence) consumer preference to key sensory attributes to wine aroma compounds. Knowledge of consumer response to key attributes allowed concerted effort by the AWRI and wine companies to implement processing changes to manage those attributes, most notably off-flavours; with the wider wine industry now effectively controlling 'Brett' flavour and other faults, providing a market advantage over traditional producers in Old World countries.

From a taste preference point of view, there are unexpectedly only modest differences between wine consumers in Australia and China, with a stronger response by many Chinese to many attributes that are also important to Australians. This shows that new styles are not necessarily required in this market; but higher proportions of consumers with preferences for softer, less acid or astringent wines means styles commonly found in the Australian market such as red wine made from Shiraz or Grenache are suitable for many consumers in China. This study has generated knowledge of red wine styles for the Chinese market, together with a wealth of marketing-relevant information, and assisted the wine industry to make decisions for this market. Consequently, larger companies didn't need to undertake additional studies in-house, while it provided access for medium sized and small companies with detailed actionable information.

At this stage, it is not clear whether high alcohol levels *per se* lead to undesirable sensory effects for consumers, with several studies indicating a negative influence, while in others it was found to be mildly positive or neutral.

Knowledge generated that consumers have a relatively low preference for aged red wines contributed to a change in practices for releasing wines onto market.

In general, there is increased use of formal sensory methods across the Australian wine industry, in part due to research and concomitant extension efforts in this stream, helping to avoid product failure and increasing profitability.

The new insight into in-mouth release of flavour from flavourless precursors is important in smoke taint and is likely to be significant for positive flavours and aftertaste, potentially not just in wine but many other foods and beverages.

Procedures have been established for efficient sensory testing, with multiple panels to suit different testing types. The use of 'trained consumers' by the AWRI allows reliable and valid sensory profile data to be obtained that is directly relatable to the consumer. This is a very valuable resource for the wine sector, other research organisations and for the wider wine industry. Highly trained and sensitive technical panels that have been established also have a place in investigating off-flavours, especially for industry assistance. Rapid methods such as 'projective mapping' and 'difference from control' provide cost-effective sensory data with good information value. Mapping techniques require sophisticated data analysis but complement other commonly used descriptive methods and can be adopted by wine companies relatively easily. The use of a single sensory scale to characterise Pinot Grigio/Pinot Gris ('Pinot G') wine style by a trained sensory panel was shown to be repeatable and valid; related well to spectral data to produce a calibration model; and the methods applied can be used for other wine types.

Overall, the sensory and consumer-based studies conducted by this stream give a strong foundation which the industry can use to continue producing wines to consumers' needs, with chemical composition and sensory data informing decision making processes in a targeted, specific way.

8. Recommendations:

Greater industry awareness of the benefits of formal sensory analysis and blind consumer acceptance testing is still required, although there is much greater application across the sector now than at the start of the investment agreement. Related to this, there is a continued confusion regarding the difference between market research and sensory-based consumer affective testing, among both the marketing community and wine producers (Francis et al. 2013). Use of a trained panel and consumer acceptance data in combination, whether generated in-house or through third party providers, is still extremely limited, even in the largest companies. Greater interaction of marketing and production specialists in wine companies with sensory knowledge through a sensory specialist as the link is recommended, along with collaborative research by consortia or groups of companies with common interests, such as regional groups, to help smaller companies gain access to such data.

In addition it would be highly desirable to improve understanding of wine composition links with consumer taste preference. This information can be used to guide wine style development and winemaking practices for customer orientated products, (outlined in Project 2.1.1 of the AWRI's 2013-2018 R,D&E plan). While consumer acceptance studies can be expensive, a model of consortia of wine companies or regional associations could have a place in this important research area.

Understanding the genetic drivers of difference in consumer preferences in the general population would enable wineries to effectively design wine styles for specific market groups and gain insight to size of specific market segments, (to be addressed in Project 2.1.2 in the AWRI's 2013-2018 R,D&E plan).

Control of negative attributes in wines by producers will have the greatest effect on consumer acceptance of wines and re-purchase. Apart from major attributes that can be labeled faults, such as 'Brett' or smoke taint, more subtle characteristics play a major role in consumer preference and should be targeted more by wine producers in their sensory assessments and production process (such subtle characteristics include low level, barely perceptible bitterness – which individuals, including winemakers, vary in sensitivity to – or slight reductive or oxidative flavour, or high acidity or astringency). For example, addition of some commercial tannin products can increase astringency to improve wine 'body' or balance, but might add some bitterness, which in the past was either not recognised or considered of no consequence, (to be addressed in Projects 3.1.4 and 3.5.1 in the AWRI's 2013-2018 R,D&E plan).

Regular marketing and sensory acceptance studies would be highly valuable to gain knowledge about the interaction of sensory and non-sensory influences on wine choices and how they evolve with time.

The routine assessment of chemical variables and outcomes of production changes in relation to consumer acceptance should be a feature of as many research projects as possible; ideally with wines that are suitable for consumer hedonic testing being produced from pilot and proof-of-concept trials undertaken before and after the research.

9. Budget reconciliation:

Financial Year	Receipts / Income ❶	Outgoings / Expenditure ❷
Year 1: 2006/2007	$471,685	$471,685
Year 2: 2007/2008	$806,209	$806,209
Year 3: 2008/2009	$801,435	$801,435
Year 4: 2009/2010	$968,435	$968,435
Year 5: 2010/2011	$990,242	$990,242
Year 6: 2011/2012	$855,915	$855,915
Year 7: 2012/2013	$849,398	$849,398
TOTAL	$5,743,319	$5,743,319

❶ Note that the GWRDC – AWRI Investment Agreement budget was established and approved at an aggregate level, with variances to budget (i.e. annual overspends and underspends) reported and considered at that same aggregate (i.e. whole of agreement) level. The receipts / income relating to a Stream for any year therefore equate to the outgoings / expenditure within that Stream for that year, as any variances between total Investment Agreement funding received and total funds expended were considered at the whole of Agreement rather than individual Stream level.

❷ Includes a pro-rated share of Theme 5 *Executive management and administration*.

I hereby certify that this statement is true and accurate.

Signature of duly authorised representative.....

Chris Day	Group Manager – Corporate Services	29/11/2013
Name:	*Title:*	*Date:*

10. References:

The AWRI's new R,D&E plan 2013-2018; http://www.awri.com.au/about_the_awri/rde-plan/

Bindon, K., Varela, C., Kennedy, J., Holt, H., Herderich, M. (2013) Relationships between harvest time and wine composition in *Vitis vinifera* L. cv. Cabernet Sauvignon 1. Grape and wine chemistry Food Chemistry 138: 1696-1705.

Costello, P.J., Francis, I.L., Bartowsky, E.J. (2012) Variations in the effect of malolactic fermentation on the chemical and sensory properties of Cabernet Sauvignon wine: Interactive influences of *Oenococcus oeni* strain and wine matrix composition. Australian Journal of Grape and Wine Research 18 (3): 287-301.

Coulter, A.D., Capone, D.L., Bladock, G.A., Cowey, G.D., Francis, I.L., Yayasaka, Y., Holdstock, M.G., Sefton, M.A., Simos, C.A., Travis, B. (2008) Taints and off-flavours in wine - case studies of recent industry problems. Blair, R.J., Williams, P.J., Pretorius, I.S. (eds) Proceedings of the Thirteenth Australian Wine Industry Technical Conference, Adelaide, South Australia. The Australian Wine Industry Technical Conference Inc., Adelaide, South Australia 73-80.

Cowey, G., Travis, B. (2008) Practical sensory evaluation in the winery The Australian & New Zealand Grapegrower & Winemaker 535: 57-62.

Cowey, G., Travis, B., Simos, C., Francis, L. (2010) Salt removal from wine using electrodialysis. Australian & New Zealand Grapegrower & Winemaker 556: 60-64.

Curtin, C., Bramley, B., Cowey, G., Holdstock, M., Kennedy, E., Lattey, K., Coulter, A., Henschke, P., Francis, L., Godden, P. (2008a) Sensory perception of 'Brett' and relationship to consumer preference. Blair, R.J., Williams, P.J., Pretorius, I.S. (eds) Proceedings of the Thirteenth Australian Wine Industry Technical Conference, Adelaide, South Australia. The Australian Wine Industry Technical Conference Inc., Adelaide, South Australia 207-211.

Curtin, C., Travis, B., Osidacz, P., Kievit, R., Bramley, B., Francis, L. (2009) Yeast modulation of cool-climate Chardonnay sensory profiles and consumer preferences. Proceedings of Les XXIes Entretiens Scientifiques Lallemand, Geisenheim, Germany: Lallemand 7-12.

Finn, A., Louviere, J.J. (1992) Determining the appropriate response to evidence of public concern - the case of food safety. Journal of Public Policy and Marketing 11: 12-25.

Francis, L., Osidacz, P., Bramley, B., King, E., O'Brien, V., Curtin, C., Waters, E., Jeffery, D., Herderich, M.J., Pretorius, I.S. (2010) Linking wine flavour components, sensory properties and consumer quality perceptions. Australian and New Zealand Wine Industry Journal 25 (5): 18-23.

Francis, I.L., Osidacz, P.C., Bramley, B.R., King, E.S., O'Brien, V.T., Curtin, C.D., Waters, E.J., Jeffery, D.W., Herderich, M.J., Pretorius, I.S. (2011) Linking wine flavour components, sensory properties and consumer quality perceptions. Blair, R.J., Lee, T.H., Pretorius, I.S. (eds) Proceedings of the 14th Australian Wine Industry Technical Conference: 3-8 July 2010, Adelaide, South Australia: The Australian Wine Industry Technical Conference Inc.: 48-52.

Francis, I.L., Holt, H., Williamson, P.O. (2013) Consumer testing at the AWRI: sensory science is not market research. Technical Review 202: 15-20.

Herderich, M.J., Siebert, T.E., Parker, M., Capone, D.L., Jeffery, D.W., Osidacz, P., Francis, I.L. (2012) Spice up your life: analysis of key aroma compounds in Shiraz. Qian, M., Shellhammer, T.H. (eds) Flavour Chemistry of Wine and Other Alcoholic Beverages. Washington, D.C. American Chemical Society 3-13.

King, E., Osidacz, P., Francis, I.L. (2008a) Measuring consumer liking and preference in Australian

wineries. Wine Business Magazine *(*October): 47-49.

King, E.S., Swiegers, J.H., Travis, B., Francis, I.L., Bastian, S.E.P., Pretorius, I.S. (2008b) Coinoculated fermentations using *Saccharomyces* yeasts affect the volatile composition and sensory properties of *Vitis vinifera* L. cv. Sauvignon Blanc Wines. Journal of Agricultural and Food Chemistry 56 (22): 10829-10837.

King, E., Francis, I.L., Swiegers, H., Pretorius, S., Bastian, S., Curtin, C. (2010a) Are yeast-derived flavour differences in young Sauvignon Blanc wines retained after a period of bottle age? Australian New Zealand Grapegrower and Winemaker 557a: 60-67.

King, E.S., Kievit, R.L., Curtin, C., Swiegers, J.H., Pretorius, I.S., Bastian, S.E.P., Francis, I. (2010b) The effect of multiple yeasts co-inoculations on Sauvignon Blanc wine aroma composition, sensory properties and consumer preference. Food Chemistry 122 (3): 618-626.

King, E.S., Francis, I.L., Swiegers, J.H., Curtin, C. (2011a) Yeast strain-derived sensory differences are retained in Sauvignon Blanc wines after extended bottle storage. American Journal of Enology and Viticulture 62: 366-370.

King, E.S., Osidacz, P., Curtin, C., Bastian, S.E.P., Francis, I.L. (2011b) Assessing desirable levels of sensory properties in Sauvignon Blanc wines - consumer preferences and contribution of key aroma compounds. Australian Journal of Grape and Wine Research 17 (2): 169-180.

King, E.S., Johnson, T.E., Bastian, S.E.P., Osidacz, P., Francis, I.L. (2012) Consumer liking of white wines: segmentation using self-reported wine liking and wine knowledge. International Journal of Wine Business Research 24 (1): 33-46.

Lattey, K., Bramley, B.R., Francis, I.L. (2007a) Understanding consumer preferences of Shiraz and Cabernet Sauvignon wines. Allen, M., Cameron, W., Francis, M., Goodman, K., Wall, G., Waters, E., Quarisa, J. (eds) ASVO Seminar Maximising the value: Maximising returns through quality and process efficiency. Seminar, Adelaide, South Australia: Australian Society of Viticulture and Oenology Inc.: 7-10.

Lattey, K.A., Bramley, B.R., Francis, I.L., Herderich, M.J., Pretorius, I.S. (2007b) Wine quality and consumer preferences: understanding consumer needs. The Australian and New Zealand Wine Industry Journal 22: 31-39.

Lattey, K.A., Bramley, B.R., Francis, I.L. (2010) Consumer acceptability, sensory properties and expert quality judgements of Australian Cabernet Sauvignon and Shiraz wines. Australian Journal of Grape and Wine Research 16 (1): 189-202.

Marangon, M., Van Sluyter, S.C., Robinson, E.M.C., Muhlack, R.A., Holt, H.E., Haynes, P.A., Godden, P.W., Smith, P.A., Waters, E.J. (2012) Degradation of white wine haze proteins by Aspergillopepsin i and II during juice flash pasteurization. Food Chemistry 135 (3): 1157-1165.

McRae, J.M., Schulkin, A., Kassara, S., Holt, H.E., Smith, P.A. (2013) Sensory properties of wine tannin fractions: Implications for in-mouth sensory properties. Journal of Agricultural and Food Chemistry 61 (3): 719-727.
Mueller, S., Francis, I.L., Lockshin, L. (2009) Comparison of best-worst and hedonic scaling for the measurement of consumer wine preferences. Australian Journal of Grape and Wine Research 15 (3): 205-215.

Mueller, S., Osidacz, P., Francis, I.L., Lockshin, L. (2010) Combining discrete choice and informed sensory testing in a two-stage process: Can it predict wine market share? Food Quality and Preference 21: 741-754.

Nygaard, M., Osidacz, P., Francis, L., Roget, W., Vidal, S., Aagaard, O. (2010) The effect of closure

choice on consumer preference rating of wines: AWRI study series. Australian and New Zealand Grapegrower and Winemaker 563: 55-60.

O'Brien, V.T., Francis, I.L., Osidacz, P. (2009) Packaging choices affect consumer enjoyment of wines. Australian and New Zealand Wine Industry Journal 24 (5): 48-54.
Osidacz, P., Francis, I.L. (2009) What the Chinese want. Wine Business Magazine February: 58-61.
Osidacz, P.C., Robichaud, J.A., Francis, I.L. (2011b) Gan Bei! Wine drinking habits in China. Australia and New Zealand Grapegrower and Winemaker 565: 49-52.

Osidacz, P., Francis, I.L., Bramley, B., Stevens, M. (2011a) The effect of repeated wine exposure on consumer preferences. Blair, R.J., Lee, T.H., Pretorius, I.S. (eds) Proceedings of the 14th Australian Wine Industry Technical Conference: 3-8 July 2010, Adelaide, South Australia: The Australian Wine Industry Technical Conference Inc.: 223-225.

Parker, M., Osidacz, P., Baldock, G.A., Hayasaka, Y., Black, C.A., Pardon, K.H., Jeffery, D.W., Geue, J.P., Herderich, M.J., Francis, I.L. (2012) Contribution of several volatile phenols and their glycoconjugates to smoke-related sensory properties of red wine. Journal of Agricultural and Food Chemistry 60 (10): 2629-2637.

Peryam, D.R., Haynes, J.G. (1957) Prediction of soldiers food preferences by laboratory methods. Journal of Applied Psychology 41 (1): 2-6.

Robinson, E., Francis, L., Cozzolino, D., Smith, P., Godden, P. (2011) Cutting through the confusion around Pinot G. Australian and New Zealand Grapegrower and Winemaker (567): 48-54.

Stone, H., Bleibaum, R.N., Thomas, H.A. (2012) Chapter 6 - Descriptive Analysis. Sensory Evaluation Practices Fourth Edition. San Diego: Academic Press: 233-289.

Swiegers, J.H., Kievit, R.L., Siebert, T., Lattey, K.A., Bramley, B.R., Francis, I.L., King, E.S., Pretorius, I.S. (2009) The influence of yeast on the aroma of Sauvignon Blanc wine. Food Microbiology 26 (2): 204-211.

Torrea, D., Varela, C., Ugliano, M., Ancin-Azpilicueta, C., Francis, I.L., Henschke, P.A. (2011) Comparison of inorganic and organic nitrogen supplementation of grape juice - effect on volatile composition and aroma profile of a Chardonnay wine fermented with *Saccharomyces cerevisiae* yeast. Food Chemistry 127 (3): 1072-1083.

Ugliano, M., Fedrizzi, B., Siebert, T., Travis, B., Magno, F., Versini, G., Henschke, P.A. (2009) Effect of nitrogen supplementation and *Saccharomyces* species on hydrogen sulfide and other volatile sulfur compounds in Shiraz fermentation and wine. Journal of Agricultural and Food Chemistry 57 (11): 4948-4955.

Ugliano, M., Travis, B., Francis, I.L., Henschke, P.A. (2010) Volatile composition and sensory properties of Shiraz wines as affected by nitrogen supplementation and yeast species: Rationalizing nitrogen modulation of wine aroma. Journal of Agricultural and Food Chemistry 58 (23): 12417- 12425.

Williamson, P.O., Robichaud, J.A., Francis, I.L. (2012) Comparison of Chinese and Australian consumer's liking responses for red wines. Australian Journal of Grape and Wine Research 18: 256-267.

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