Characterization of Chenin blanc wines produced by natural fermentation and skin contact: focus on application of rapid sensory profiling methods

by

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Declaration

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Summary

Producers of South African (SA) dry and semi-dry Chenin blanc table wines are currently experimenting with winemaking techniques to modulate the flavours of the predominantly fruity styles of this genre. An important stage during wine style development is sensory profiling paired with consumer acceptance testing, before wine is produced on industrial scale. With those aforementioned goals in mind, this study was conducted in partnership with two commercial SA wine cellars.

The main focus of the study was an investigation into the treatment effects of two winemaking techniques, respectively grape skin contact and natural fermentation, on the sensory profiles of experimentally produced Chenin blanc wines. Results obtained with descriptive sensory analysis (DA) of the wines were compared to those obtained by two rapid sensory profiling methods, namely projective mapping (PM) and frequency of attribute citation (FC). A consumer preference study was also done on the wines. In order to understand the treatment effects better, the dominant non-*Saccharomyces* yeasts that were present during the natural fermentations were identified using polymerase chain reaction (PCR), while the major volatile chemical compounds were identified with chromatography and mass spectrometry.

The sensory and chemical profiles of the naturally fermented wines were significantly different from those of the inoculated wines. PCR analysis identified some of the yeasts present during alcoholic fermentation. In comparison to the inoculated fermented wines, the naturally fermented wines were generally perceived to have more intense and riper tropical fruity aromas, with enhanced sweetness and reduced intensities of sourness, bitterness and astringency.

The wines fermented on the skins (FoS) had lower ester and volatile thiol concentrations than the control wines (with no skin contact) and limited skin contact wines. Sensory attributes linked to the FoS wines included aromas of dried fruit, dried grass and a vegetative character, with an increased sour and bitter taste and astringent mouthfeel. In contrast, the wines that were produced with limited skin contact (12 hours) retained their tropical fruity aromas better than the FoS wines. Limited skin contact seemed to have had a less harsh effect on the taste and mouthfeel than the FoS wines. A consumer study was done to establish a Generation Y consumer group's (18-35 years) preference for the different treated wines. Overall, the naturally fermented wines, which were described as having a strong tropical fruit character, were preferred. The FoS wines were generally disliked by the consumers.

Results obtained from the three sensory analysis methods, respectively DA, PM and FC, were similar, thereby confirming the suitability of the rapid methods PM and FC, to extract qualitative information from the sensory profiling of white wine.

The results of this study made a significant contribution towards validation of rapid sensory methods for wine evaluation, which are particularly valuable in the context of sustainability and technology transfer to research and industry alike. The knowledge gained on the chemical profiles of SA Chenin blanc is novel and this is one of the first reports on the volatile thiol content of SA Chenin blanc wine.

Opsomming

Produsente van Suid-Afrikaanse (SA) droë en semi-droë Chenin blanc tafelwyne eksperimenteer tans met wynmaaktegnieke om die oorwegend vrugtige style van hierdie genre te varieer. ‘n Belangrike fase van wynstylontwikkeling is sensoriese profilering van die produkte met gepaardgaande verbruikersaanvaardingstoetse, voordat die wyne op industriële skaal geproduseer word. Met dié bogenoemde doelwitte in gedagte, was hierdie studie in vennootskap met twee kommersiële SA wynkelders gedoen.

Die hooffokus van die studie was om die invloed van twee wynmaaktegnieke, onderskeidelik druifdopkontak en natuurlike fermentasie, op die sensoriese profiele van eksperimenteel geproduseerde Chenin blanc wyne te ondersoek. Resultate wat met beskrywende sensoriese analise (DA) van die wyne verkry is, is vergelyk met dié wat deur twee vinniger sensoriese profileringsmetodes metodes, naamlik projektiewe kartering (PM) en frekwensie van kenmerkaanhaling (FC) verkry is. 'n Verbruikervoorkeurstudie is ook op die wyne gedoen. Ten einde die behandelingseffekte beter te verstaan, is die dominante nie-*Saccharomyces* giste wat teenwoordig was tydens die natuurlike fermentasie geïdentifiseer met behulp van die polimerasekettingreaksie (PCR), terwyl die vernaamste vlugtige chemiese verbindings geïdentifiseer is met chromatografie en massaspektrometrie.

Die sensoriese en chemiese profiele van die natuurlike gefermenteerde wyne was beduidend anders as dié van die geiinokuleerde wyne. PCR analise het sommige giste wat teenwoordig was tydens alkoholies fermentasie geïdentifiseer. In vergelyking met die geiinokuleerde wyne, het die natuurlik gefermenteerde wyne intenser en ryper tropiese vrugtige aromas getoon, met ‘n verhoogde perspesie van soetheid en laer intensiteite van suurheid, bitterheid en vrankheid.

Die wyne wat berei is deur fermentasie op die druifdoppe (FoS) het laer konsentrasies van esters en vlugtige swawelverbinding gehad, as die kontrole wyne (geen dopkontak) en beperkte dopkontak wyne. Sensoriese eienskappe gekoppel aan die FoS wyne was geasssosieer met gedroogde vrugte, gedroogde gras en 'n vegetatiewe aroma, met gepaardgaande verhoogde suur en bitter smaakpersepsies en ‘n frank mondgevoel. In teenstelling, het die wyne wat geproduseer is met 'n beperkte dopkontak (12 uur) hul tropiese vrugtige aroma beter behou as die FoS wyne. Beperkte dopkontak het ook ‘n minder negatiewe uitwerking op die smaakpersepies van bitterheid en vrankheid gehad. ‘n Verbruikerstudie is gedoen om 'n groep jong *Generasie Y* verbruikers (18-35 jaar) se voorkeure vir die verskillende behandelings te bepaal. Oor die algemeen is die natuurlike gefermenteerde wyne, wat beskryf is met 'n sterk tropiese vrugtekarakter verkies, terwyl die groep nie van die FoS wyne gehou het nie.

Resultate wat verkry is met drie sensoriese analise metodes, onderskeidelik DA, PM en FC, was soortgelyk en die geskiktheid van die vinniger metodes, PM en FC, om kwalitatiewe inligting van witwyn se sensoriese eienskappe te verkry, is bevestig.

Die resultate verkry met hierdie studie maak 'n beduidende bydrae tot die validering van vinniger sensoriese metodes vir wynevaluering, wat veral waardevol is in die konteks van volhoubaarheid en tegnologieoordrag na navorsing en die industrie.

Die nuwe kennis wat in hierdie studie gegenereer is met die chemiese profilering van SA Chenin blanc wyn is baie waardevol en hierdie is een van die eerste narvorsingsprojekte oor die inhoud van vlugtige swawelverbings in SA Chenin blanc wyn.

This thesis is dedicated to my family who encouraged me every step of the way.

“ It always seems impossible until it’ s done.” *Nelson Mandela*

Biographical sketch

Carla Weightman was born in Johannesburg, South Africa on the 6th of March 1991. She attended Beaulieu Preparatory School and matriculated at Beaulieu College in 2008. Carla obtained a 4 year BSc-degree in Food Science in 2012 at Stellenbosch University. In 2013 Carla enrolled for an MSc in Wine Biotechnology at the Institute for Wine Biotechnology, Department of Viticulture & Oenolgy, Stellenbosch University.

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Preface

This thesis is presented as a compilation of 6 chapters as indicated below.

Chapter 1	**Introduction and project aims**
Chapter 2	**Literature review**
Chapter 3	**Research results** Characterization of the effect of skin contact and natural fermentation on the chemical and sensory profiles of Chenin blanc wine
Chapter 4	**Research results** Comparison of two rapid methods, projective mapping and frequency of attribute citation, as sensory analysis tools for Chenin blanc wine
Chapter 5	**Research results** Consumer preference and ranking of experimental Chenin blanc wines
Chapter 6	**General discussion and conclusions**

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Chapter 1

Introduction and project aims

INTRODUCTION AND PROJECT AIMS

1. General Introduction

Chenin blanc is the most highly cultivated white wine grape in South Africa (SAWIS, 2014), in the past the cultivar was not considered as a quality grape, due to its use in the mass production of rather acidic cheap table wines. Given its abundance and the ease with which it can flourish in different terroir, a large percentage of the grapes were used for brandy production (Louw & Lambrechts, 2012). However, over the last 10 years or so, South African (SA) Chenin blanc wine has received considerable international attention and has started to compete with its other white wine cultivar peers (CBA, 2013). Much of the credit due for this remarkable improvement could be ascribed to the dedicated involvement of the Chenin Blanc Association to help the producers to improve viticultural and winemaking practises.

Towards supporting the SA Chenin blanc industry in their endeavour to become a world player in terms of the quality of the wines produced, the Institute for Wine Biotechnology (IWBT), Department of Viticulture and Oenology (IWBT-DVO), Stellenbosch University, has been actively involved with research on the cultivar since 2010. A number of research projects on dry, semi-sweet and sweet Chenin blanc wines that included the chemical and sensory profiling of the different styles have been done (Van Antwerpen, 2012; Lawrence, 2012). Wines produced from old vines (more than 25 years old) and bush vines were also investigated and the sensory and chemical profiles of these wines were also investigated (Hanekom, 2012). The latter project also included consumer studies which looked at the use of ‘bush vine’ and ‘old vine’ as label cues. Van Antwerpen (2012), from her chemical analysis of commercial Chenin blanc wines from different geographic regions, concluded that the most prominent sensory and style differences were the result of winemaking techniques used rather than the geographical origin of the wines.

The current project approached the Chenin blanc wine research from a new angle and instead of working with commercial wines, experimental wines were analysed with the main objective to investigate the effects of different winemaking techniques on the sensory profiles of the wines. Of particular interest was the sensory methodology and the evaluation of rapid sensory profiling methods. Although rapid sensory analysismethods have been applied to different types of foodstuffs, the validation of the methods when applied for wine sensory profiling is still fragmented and incomplete. Three different sensory profiling methods were evaluated. The first was descriptive analysis (Lawless & Heymann, 2010), which was used as the benchmark for the sensory analysis. The results obtained by this method were compared with the results from two more rapid methods, namely projective mapping (Risvik *et al*., 1994) and frequency of attribute citation (Campo *et al*., 2010).

Although not the main aim of the study, the winemaking methods were also of importance, particularly for the industrial collaborators. The effects that skin contact and natural fermentation have on the sensory profile of Chenin blanc wine was investigated. This study also very briefly investigated the yeast diversity on Chenin blanc grapes between the two industrial vineyards. Lastly, establishing consumer preference of new products is an important task that must be completed during product development before a product is put into production (Burgess, 2013). For this reason consumer preference of the experimental wines was also investigated.

Published research on chemical and sensory profiling of Chenin blanc wine is limited, and this is one of the first studies to investigate the effects of skin contact and natural fermentation on the chemical and sensory profile of Chenin blanc

2. Problem statement and research questions

The study was mostly research based, although some objectives had industrial applications.

2.1 Scientific problem statements

Descriptive analysis (DA) is a reliable and well established method of sensory analysis that yields both qualitative and quantitative information, but the method requires large sample volumes and is costly and very time consuming (Lawless & Heymann, 2010). Researchers and industry alike are looking for alternative fit-for-purpose methods which can be used in the place of, or in conjunction with DA. The development and validation of rapid sensory analysis methods are particularly important in the wine research environment, where typically small volumes of wines are available and large numbers of wines need to be evaluated on limited budgets. A current strategic initiative of the IWBT-DVO is to develop a portfolio of more rapid sensory profiling methods that have been validated and adapted for wine research and for the SA Wine Industry, respectively.

This project investigated two rapid methods, respectively projective mapping and frequency of attribute citation and compared the results obtained to those obtained with DA.

Chapter 3 investigated the sensory and chemical profiles of experimental Chenin blanc wines made using two different winemaking techniques, namely extended skin contact, and natural fermentation. The aim of chapter 4 was to validate some rapid sensory methods, by comparing them with the results obtained from the most well known and most used sensory method, conventional descriptive analysis (DA). Chapter 5 investigated consumer liking of wines made using experimental techniques.

2.2 Industrial problem statement

Firstly, industry is looking for alternative methods to conventional descriptive analysis which are faster and more importantly cheaper, in order to speed up their product development time and to reduce product development costs. Secondly, we were approached by two wine farms who wanted to investigate two winemaking techniques, namely natural fermentation and skin contact. They wanted to know if there were significant differences in the sensory profiles of the wine and also if consumers had preferences for either winemaking technique.

3. Project aims

The specific aims and related tasks of this study were to gain both scientific knowledge and insight which can be passed on to industry, regarding the chemical and sensory effects of natural fermentation and skin contact on Chenin blanc.

3.1 Establish the effect of two different vinification techniques on sensory attributes of wine

a) Produce Chenin blanc wines (in collaboration with two industrial cellars) using to different winemaking techniques. First, natural fermentation, with inoculated fermentation as a control and second a skin contact treatment, with no skin contact as a control.
   - Capture the yeast population diversity in natural fermentations and compare between two different vineyards.
   - Investigate volatile chemical profiles using gas chromatography – GC-FID and UPLC MS/MS.
   - Conduct projective mapping to investigate the relationship between sensory profiles of a large number of wines

3.2 Validate rapid methods for sensory analysis with trained panels

a) Do projective mapping and frequency of attribute citation
   - Method development

b) Do frequency of attribute citation
   - Method development
   - Become proficient with statistical analysis of data in XLSTAT software

c) Comparing the rapid methods to conventional descriptive analysis.
   - Comparing results from descriptive analysis with results from projective mapping and frequency of attribute citation
   - Determine RV coefficients

3.3 Test consumer preference of Chenin blanc wines made from the same harvest using different vinification techniques, on the Generation Y consumer group

- Perform degree of liking test
- Perform ranking (most preferred to least preferred) test
- Link descriptive analysis data and consumer preference data using PREFMAP to establish drivers of liking.

3.4 Present findings at South African conference

4. Experimental design summary

The experimental design for this study is illustrated in the following figures. Fig.1 illustrates the origin of the grapes and whether the wine was made in the university cellar or the commercial cellar. Fig. 1 also depicts the winemaking techniques used to make the wine. The grapes from Riebeek cellar were used for one winemaking technique, natural fermentation and was compared to an inoculated fermentation. The wine made form the DGB grapes were made using two different winemaking techniques. Within those two techniques there were five treatments,1) a natural and 2) an inoculated treatment and 3) a control (no skin contact), 4) 12 hours of skin contact, and 5) a fermentation on skins.

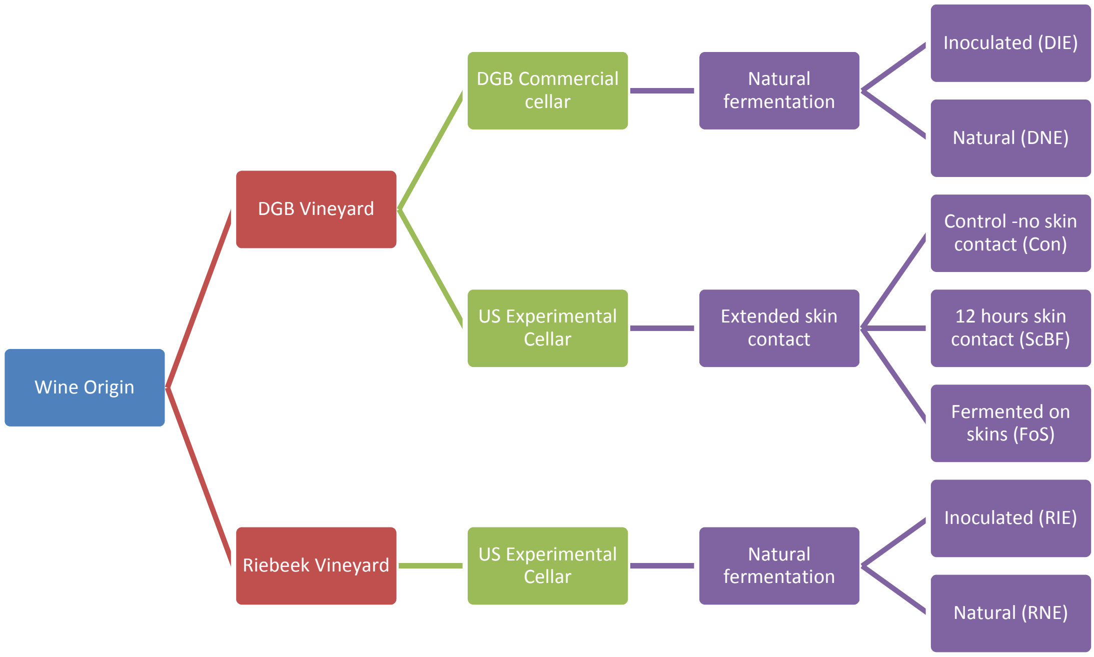

Figure 1 Summary of treatments of grapes and juice from each participating farm.

Chapter 3 is the profiling of the different vinification techniques, where fermentations were monitored using spectroscopy, and yeast in the natural fermentations were identified, the sensory analysis on final wines was done using projective mapping and the volatile composition of the wines was investigated using flame ionisation fitted gas chromatography. For chapter 4, three different sensory analysis experiments were performed on the same samples and the results were compared, namely projective mapping, where a panel of 9 trained judges were used, descriptive analysis, where a panel of 10 trained judges were used and attribute frequency of citation where a panel of 30 trained judges were used (Fig. 2). This was followed up by a consumer preference study using 86 Generation Y consumers, between the age of 18 and 35 (Chapter 5).

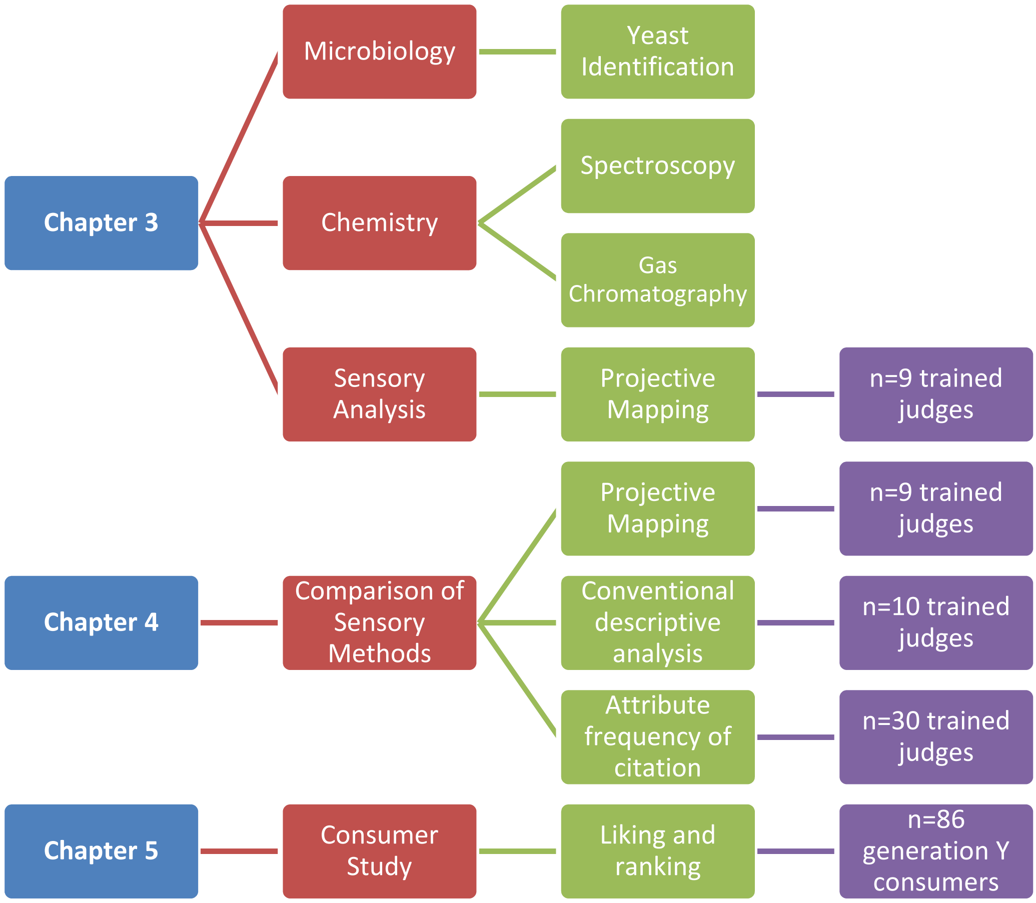

Figure 2 A summary of the project's experimental design split by research chapter.

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Chapter 2

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Literature review

LITERATURE REVIEW

1. Background

Wine is one of the oldest and most sensorially diverse beverages in the world. Although a traditional beverage, it has been subjected to many style innovations over the years. Some of these developments were largely the result of improvements in viticultural and oenological practices (Fischer, 2007), while others were driven by changing consumer preferences (Francis *et al*., 2010).

South Africa is one of the largest wine producing countries in the southern hemisphere and is the 9th largest producer of wine in the world (FAO, 2013). Emerging South African wine export markets in Europe, Asia and Africa (SAWIS, 2014) and the accompanying socio-cultural influences on consumers' product preferences in these segments, have resulted in modulations of South African wine flavours to meet specific segments' requirements. For several of the local South African multi-cultural consumer groups, little is known about their opinions regarding wine consumption and enjoyment, and it is natural to expect that style innovation and flavour modulation will gain even more momentum in the future, as more wine markets, both locally and internationally, are being developed.

Style modulation is also a familiar scenario for Chenin blanc wine; indeed, continuous style developments throughout the long history of Chenin blanc wine production in South Africa have helped to establish this genre's current status of internationally recognised, premium quality (Wine Searcher, 2012). The results of the International Wine Challenge events between 2008 and 2014 showed that South Africa has won the most awards amongst entries in the Chenin blanc category. It is therefore important for the South African Chenin blanc wine industry, to meet modern market challenges by maintaining consistency in quality, while also adapting the viticultural and oenological techniques for the purpose of modulating wine flavour to match new consumer markets' expectations. From a research perspective, the establishment of the sensory profiles of the respective wine styles and relating this information to consumers' preferences and to wine production techniques, is the best route to support the wine industry in this task.

This work reviews the current state of Chenin blanc in South Africa and internationally. The potential effects of two winemaking techniques, respectively extended skin contact and natural fermentation, on the sensory profiles of white wine are also briefly reviewed, based on the prominent role that these two techniques play in the research chapters of this thesis. Sensory analysis methods, in particular the rapid methods, and adapting them for use in the wine industry, including their associated statistical analysis methods (sensometrics) are also discussed, as well as consumer perceptions, with a focus on Generation Y.

2. Chenin blanc: An international perspective

A review of the literature on South African Chenin blanc showed that there is a limited volume of published scientific literature on this topic, especially sensory analysis of Chenin blanc wine. Consequently, the review presented here also relied on popular publications to cover important topics.

Chenin blanc is a white grape variety originating from the Loire Valley, France, where it has been cultivated for thousands of years (CBA, 2013). In France it is known as Pineau de la Loire, in South America as Pinot blanco, whilst its old traditional South African name is Steen (Clarke, 2007).

South Africa is the largest producer of Chenin blanc wine in the world, and based on figures available on the 31st of December 2013, there was a total of 17890 Hectares (Ha) of Chenin blanc vine plantings in South Africa (SAWIS, 2014). The next largest producer is France with 9427 Ha vineyards. The Loire Valley region in France produces a variety of wine styles from this cultivar,including intense dry, semi-sweet and sweet wines (Clarke, 2007). California (USA) is the next largest producer with 8483 Ha under vineyards. Other countries that have minimal Chenin blanc vineyards include Argentina, Chile, Israel and Canada (Wine Searcher, 2012).

Chenin blanc is not generally a highly regarded wine in California, New Zealand or Australia (Professional Friends of Wine, 2011; Higgs, 2013). In these countries, the small amounts of Chenin blanc wine produced get used in the production of white wine blends (Higgs, 2013; Campbell, 2013). There is, however, some lesser known wine producing countries that are making small amounts of award winning single varietal Chenin blanc wine. Mexico, Thailand and India for instance won awards at the 2013 and 2014 International Wine Challenge (IWC, 2014), while Turkey and Argentina entered Chenin blanc and Chardonnay blends that also won awards (IWC, 2014).

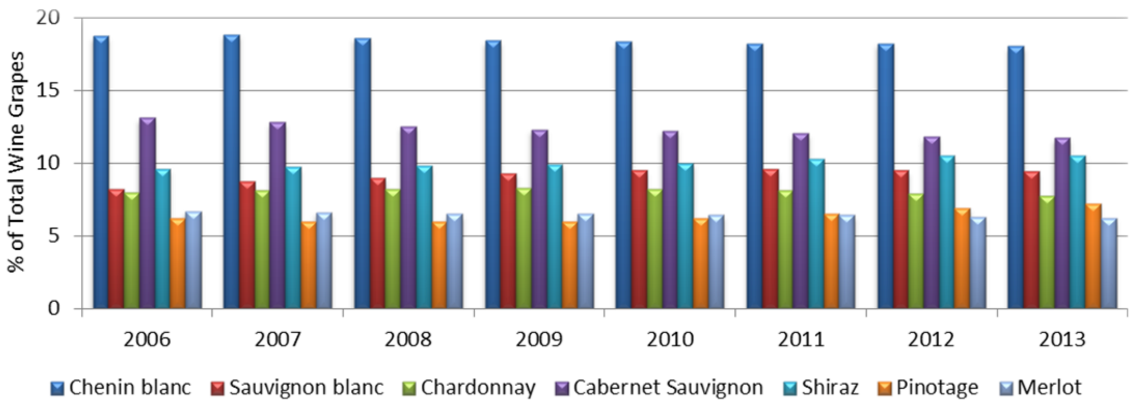
3. Chenin blanc in South Africa

3.1 History

The grape cultivar Steen, was thought to be unique to South Africa until the 1960's, when research conducted at Stellenbosch University, demonstrated that Steen and Chenin blanc plants were the same and this cultivar was then assigned its correct name – Chenin blanc (Wine South Africa, 2001).

The first Chenin blanc vines were brought to South Arica in the 17th century, by the leader of the Dutch East India Company at the Cape, Jan van Riebeeck (CBA, 2013). Chenin blanc endeared itself to the early settlers, because it was able to retain its acidity in the warm climate, while also producing high yields (Clarke, 2007). Chenin blanc is the most planted cultivar in South Africa and makes up approximately 18% of the total amount of grapes intended for wine making purposes (SAWIS, 2014; Fig. 1A) and accounts for 33% of all white wine grapes produced (Fig. 1B). Historically, a large percentage of the Chenin blanc grape harvest used to be distilled for the production of brandy, but nowadays increasing volumes are being used for wine production (van Jaarsveld, 2005; Louw & Lambrechts, 2012).

A



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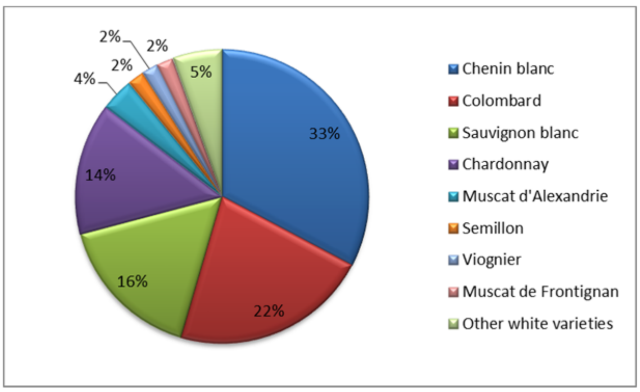

Figure 1 (A) Quantity of seven major South African wine grape cultivars, as a percentage of the total wine grapes harvested, over a period of 8 years (SAWIS, 2014). (B) The percentage of hectares of each South African white wine cultivar in terms of the total hectares of white wine grape plantings, as recorded on 31st December 2013 (SAWIS, 2014).

As illustrated by Fig. 1A, over the last 8 years, Chenin blanc has been the most highly cultivated wine grape in South Africa with minimal fluctuations in quantity of other cultivars during this period. The figures for Chenin blanc do however show a slight downward trend, from a total of 18 325.62 hectares in 2011 to a total of 17 942 hectares in 2013 (SAWIS, 2014).

The majority of South Africa's vineyards are situated near the coastal regions of the Western Cape (SAWIS, 2014). This wine producing region has a Mediterranean climate, due to the meeting of the Atlantic and Indian Oceans (Wine Searcher, 2012). The winelands are spread around the valleys, mountains and plateaus of the Western Cape, allowing for the production of a diverse range of cultivars and styles (Clarke, 2007; WOSA, 2010). The majority of Chenin blanc vines are grown in the regions of Worcester (Breede River Valley, Fig.2) and Paarl (Boberg, Fig.2) in the Western Cape (WOSA, 2010; SAWIS, 2014).

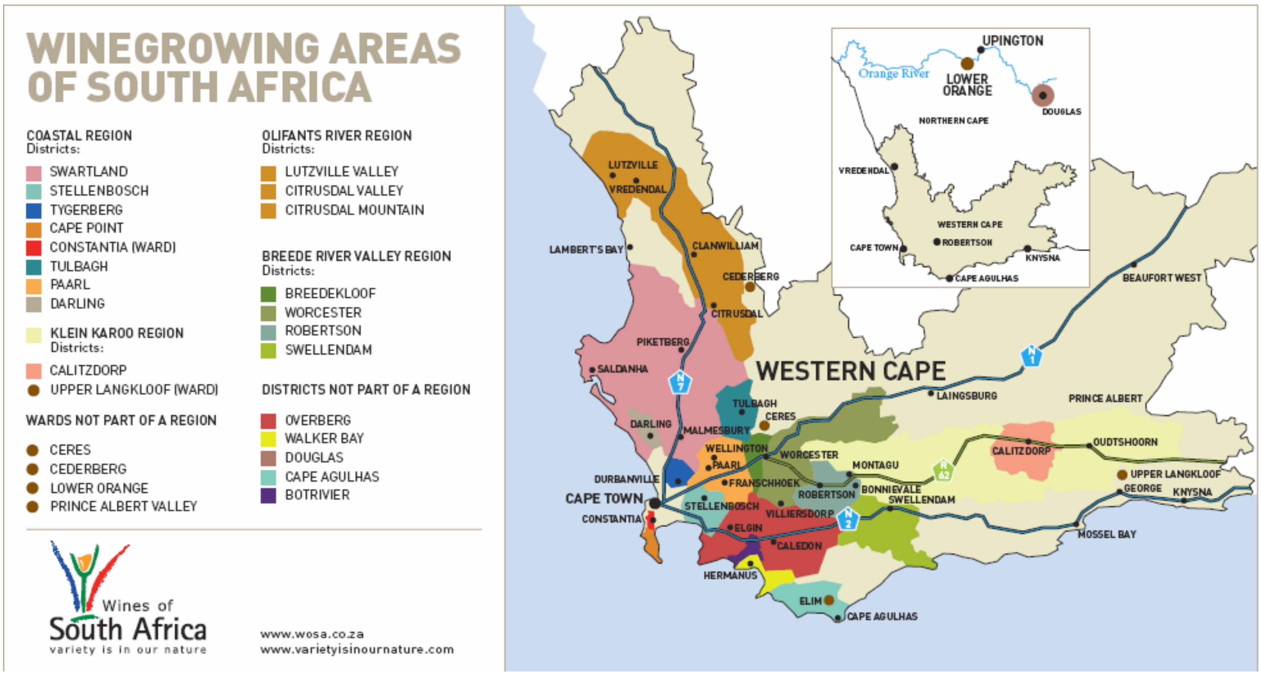

Figure 2 The wine production areas of the Western Cape, South Africa (WOSA, 2010).

3.2 Chenin blanc wine styles

Due to the diversity of suitable terroir available for the cultivation of Chenin blanc grapes, and the large number of different winemaking techniques used, there is an equally large range of Chenin blanc wine styles (Spier, 2012). In the late 1990's South African Chenin blanc producers created an association, *The Chenin Blanc Association of South Africa* (CBA), who classified Chenin blanc wines into six different styles, based on residual sugar content (CBA, 2013; Table 1). This classification was driven by the ambition to clarify consumers' apparent confused perception of Chenin blanc (Brower, 2009), as a result of its huge diversity in style.

Table 1 Six recognised styles of Chenin blanc wine (CBA, 2013).

Style	Sugar content
Fresh & fruity	less than 9 g/ℓ residual sugar
Rich & ripe – unwooded	less than 9 g/ℓ residual sugar
Rich & ripe – wooded	less than 9 g/ℓ residual sugar
Rich & ripe – slightly sweet	between 9 and 30 g/ℓ residual sugar
Sweet	more than 30 g/ℓ residual sugar
Sparkling (Tank fermented or Cap Classique)	ranges from dry to sweet

With the diverse range of Chenin blanc wine styles comes a wide range of sensory flavours. The CBA developed a tasting wheel covering all the identified aroma attributes for the six styles (Fig. 3). From this wheel, the prominence and diversity of especially the fruity attributes, tropical, citrus and stone fruit, is clear. Stellenbosch University, in collaboration with the CBA, did a comprehensive study from 2010 to 2012 (Nieuwoudt *et al*, 2013), where in depth chemical and sensory analysis of some of the Chenin styles was done (Bester, 2011; Hanekom, 2012; Lawrence, 2012; Van Antwerpen, 2012). The research was performed using ~170 commercial wines spanning the three styles, fresh and fruity, rich and ripe wooded, and rich and ripe unwooded. Invaluable information was gained from this research, however, when taking into account that the total number of Chenin blanc wine entries in the Platter's South African Wine Guide 2013 edition, is in excess of 400 wines, it is clear that the complete range of dry and off-dry wines, was not covered in the research. Also not addressed in the previous research where commercial wines were used, were investigations into the effect of winemaking techniques on the sensory profiles of the resulting wines. This aspect is discussed in more detail in section 4 of this chapter.

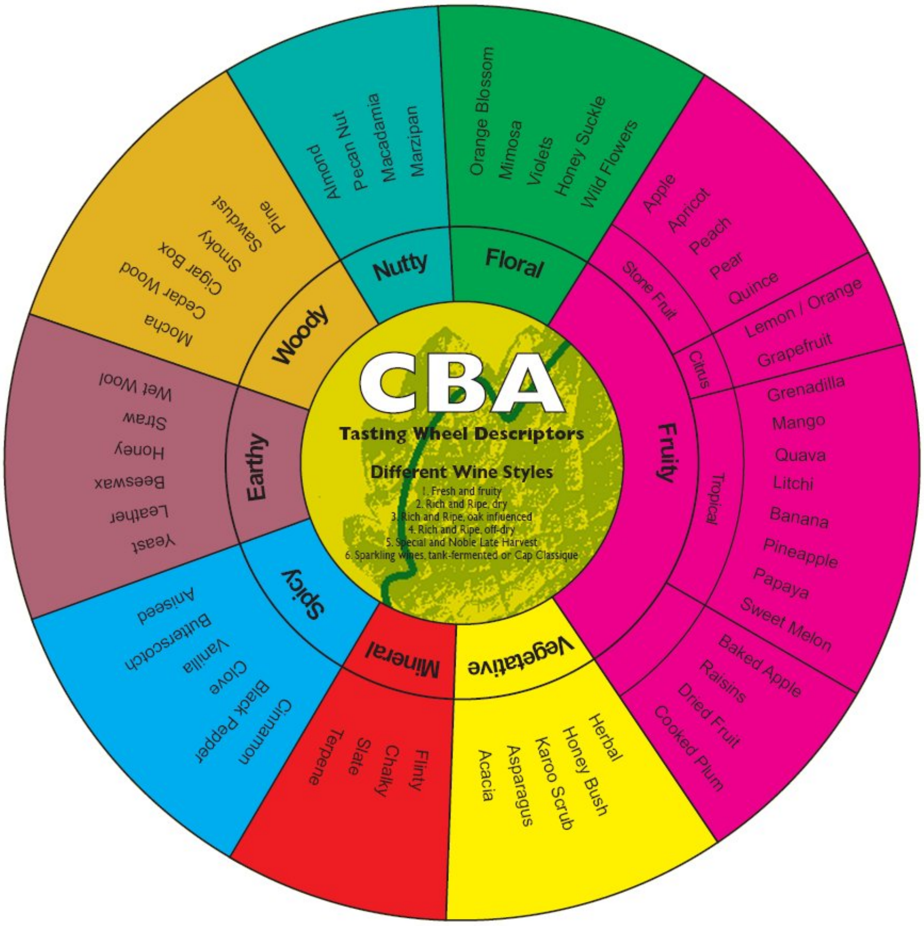

Figure 3 The tasting wheel for Chenin blanc wine, containing descriptors for all six identified styles (CBA, 2012).

The majority of South African Chenin blanc wine is made in the fresh and fruity style, while more complex styles, often with wood contact, are also produced (Hanekom, 2012; Van Antwerpen, 2012). Wines produced from grapes that are harvested from older bush vines (more than 20 years old) are also in demand (Hanekom, 2012). These old vines are not trellised, but pruned to reduce the grape yield and the grapes are harvested later, to ensure higher sugar levels. Current experimentation is driven by a combination of advances in viticultural and oenological techniques, as well as changing consumer tastes. In order to meet consumer demands, it is necessary to focus on specific consumer segments, with the goal of identifying segment specific trends. Bester (2012) investigated the South African generation Y consumer segment (age 21-32), for their style preferences. Results showed that there was no clear preference for a particular style (fresh & fruity, rich & ripe wooded, rich & ripe unwooded) amongst this consumer group.

As part of the on-going Chenin blanc research at Stellenbosch University in collaboration with Platter's South African Wine Guide and the CBA, investigations are now underway to look at the sensory descriptors used across all the dry and semi-dry wines in the Platter's guide, with the aim of expanding the Chenin blanc wine sensory database established in earlier research (Platter's South African Wine Guide, 2014). The outcomes of the research may ultimately identify a need to update the Chenin blanc flavour wheel and re-classify the wine styles.

3.3 South African Chenin blanc wine on the international market

South African wine became unpopular on the international markets, and wine export sales were at an all-time low, during the apartheid era (1948-1994), due to the trade sanctions imposed by the rest of the world (Wine Searcher, 2012). At the end of apartheid, there were new advances in grape cultivation as a result of European and American influences. To satisfy domestic demand for white table wine, Chenin blanc was made into a low quality wine lacking in flavour (Clarke, 2007).

In the late 1990's, winemakers took a closer look at traditional locations for Chenin blanc vine plantings and were able to identify a number of old Chenin blanc vineyards, which could be used to produce much more complex and flavourful wines. This helped South African Chenin blanc wine to lose its cheap, dry and flavourless reputation and allowed it to be seen as a more unique, flavoursome, exciting new world wine (Wine South Africa, 2001).

South Africa currently exports more Chenin blanc wine than any other white cultivar (Table 2). The most important export destinations are the UK, USA, Germany, Denmark, The Netherlands, Belgium, Canada and Sweden (SAWIS, 2014). The total volumes of Chenin blanc exported each year have increased since 2010, but there was a notable increase (more than 10 000 kL) between 2011 and 2012 (Table 2).

Table 2 Total litres of South African Chenin blanc, Sauvignon blanc and Chardonnay wine exported annually between 2010 and 2013 (SAWIS, 2013; SAWIS, 2014).

	Total Litres Exported		
Year	**Chenin blanc**	**Chardonnay**	**Sauvignon blanc**
2010	46 255 791	23 499 300	21 715 401
2011	46 583 998	19 971 980	25 322 774
2012	59 987 650	31 974 276	29 524 733
2013	53 709 247	27 582 641	38 155 619

3.4 Wine awards

South African Chenin blanc wines have won many awards in recent years, including Decanter Regional Trophies, gold medals at the International Wine Challenge (IWC) and Concours Mondial de Bruxelles (Spier, 2012).The IWC is a prestigious competition and has been running for more than 30 years. Each award-winning wine is tasted three times, on separate occasions by a minimum of 10 different judges. Each year, the Chenin blanc wines seem to be improving in quality and winning more awards. At the IWC event in 2010, South African Chenin blanc's received a total of 10 medals, in 2013 the medal tally increased to 19 with the addition of a Trophy (which is the most prestigious award) and in 2014 a total of 37 medals were won (Table 3; IWC, 2014).

Table 3 Medals won by South African Chenin blanc wines at the International Wine Challenge.

			Medals and awards		
Year	**Total**	**Trophy**	**Gold**	**Silver**	**Bronze**
2010	10			5	5
2011	14		2	4	8
2012	15			5	10
2013	20	1	3	4	12
2014	37			10	27

Frans Smit, cellar master from Spier Wine estate, Western Cape, South Africa, was reported as saying that the interesting terroir and the old Chenin blanc vines in South Africa play a large role in the success of our wines. In Smit's opinion, Chenin blanc will be South Africa's flagship cultivar in the not too distant future (Spier, 2012).

4. Factors affecting wine flavour composition

Flavour is defined as the combination of aroma (smell) and taste. Aroma and taste are the main features that are used to differentiate between wines (Swiegers *et al*., 2005). Unlike the vast quantity of published sensory and chemical data for Sauvignon blanc (Swiegers *et al*., 2006; Swiegers *et al*., 2009), there is very little published data on Chenin blanc. Previously, research on Chenin blanc focussed on style classification (Bester, 2011) and chemical and sensory profiling of commercial wines (Hanekom, 2012; Van Antwerpen, 2012; Lawrence, 2012), which may contain up to 15% of another cultivar, without this information being given on the bottle label (Anon., 2004). In order to determine the effects of viticultural practices and different vinification techniques on the flavour profiles of wine, it is therefore necessary to analyse the wines before blending. However, a critically important stage in wine style development is sensory analysis and consumer liking tests, before the wine can be put into large scale production. The effects of different vinification techniques on the sensory profiles of Chenin blanc wine are largely based on anecdotal information and informal evaluations, with very few scientific publications available, as discussed before, to provide scientific data based on controlled experimentation (Ina Smit, manager CBA, personal communication, 2 July 2013).

There are four main origins of wine flavour: grape-, yeast- and wood-derived characters and lastly, bottle aging characters (Swiegers *et al*., 2005). Unlike the other white varietals, Chardonnay and Sauvignon blanc, Chenin blanc grapes have relatively few primary grape derived flavours and the variety is considered as neutral (Wilton, 2013). Their grape-derived flavours are mostly sulphur containing mercaptans, which impart aromas of passion fruit and grapefruit. During alcoholic fermentation yeasts also form esters which can contribute to aromas of tropical fruits, stone fruits, pear and apple (Lourens, 2003).

4.1 Viticultural aspects

Numerous viticultural practices have been shown to have an effect on wine quality. These include: vine age, trellising, vine spacing, row orientation, canopy management, fertilization, irrigation, yield and harvest method (Loubser, 2008). Marais and co-workers investigated the effect of berry size, ripeness and light conditions during berry maturation, on Chenin blanc wine flavour (Marais *et al*., 2005). In general, wines made from smaller berries, those made from riper berries and wines made from berries grown in shaded conditions, had higher levels of esters and were perceived to be of a higher quality, than control wines. It was concluded that smaller berries which were ripened out of direct sunlight and harvested with a sugar level between 21 and 24°B (preferably closer to 24°B), produced higher quality wines. It was therefore recommended that direct sunlight on the ripening bunches should be avoided, while pruning and irrigation should be done in a manner to aid the reduction of berry size.

4.2 Winemaking techniques

Winemaking techniques modify the chemical composition and sensory attributes of wine (Gómez-Míguez *et al*., 2007). All the practices used during winemaking, from the initial pressing of grapes, to final bottling of the wine, can have an influence on the final wine (Loubser, 2008). Since Chenin blanc does not have much grape derived flavour, winemaking practices that benefit the development of a pleasant fermentation “bouquet” are extremely important to elicit the full flavour from the pressed juice (Marais *et al*., 2005). Winemaking techniques used for Chenin blanc include barrel maturation, oak maturation, lees contact, and sequential yeast inoculation (Jolly *et al*., 2003; Marais & Jolly, 2005), however, only extended skin contact and natural fermentation will be discussed in detail in the following sections, as they were the focus of subsequent research chapters.

4.3 Skin contact

The aroma of wine is influenced by varietal characteristics, and the compounds responsible for the aroma are predominantly found in the skin of the grapes (Selli *et al*., 2003). Grape berry pulp and skin contain the important chemical compounds responsible for wine flavour, including: organic acids, terpenes and a number of glycosylated precursors of volatile compounds *(*Selli *et al*., 2006).

Unlike for red wine production, where the pressed grape juice is left to ferment with the skins to allow for the transfer of anthocyanins from the grape skins to the juice to give its red colour (Rustioni *et al*., 2013), this is not the case in white wine production. Skin contact is a term used in white wine production (Cabaroglu *et al*., 1997) and is a treatment applied to grape juice before the onset of fermentation. Skin contact also implies the amount of time that the skins remain in contact with the juice, i.e. the contact time between initial crushing of the grapes and the pressing. The phenolic compounds present in the white grape skins are responsible for the colour and astringency of the wine, include hydroxycinnamic acids, flavonoids and benzoic acids (Recamales *et al*., 2006). This treatment is usually performed at low temperatures, e.g. 5°C (Gómez-Míguez *et al*., 2007), in order to avoid excessive extraction of phenolic compounds that can cause the wines to lose their light yellow colour and turn to a deeper golden yellow (Loubser, 2008). Interestingly, studies have shown that white wines with high phenolic compound levels, have antioxidant properties similar to those of red wines (Furhurman *et al*., 2001, Katalini *et al*., 2004). These antioxidant properties are said to assist in the prevention of heart disease (Fuhrman *et al*., 2001).

Chenin blanc wines have been shown to be responsive to skin contact in a study by Marais *et al*., (2005). Grapes were harvested, gently crushed and left to soak, so that flavour compounds present in the grape skins could be transferred to the juice. The soaking was done overnight, before the grapes were finally pressed. Grape ripeness levels of between 21 and 24°B were recommended (Marais *et al*., 2005), since skin contact with unripe grapes could increase the undesirable herbaceous character of the wine which is undesirable (Gómez-Míguez *et al*., 2007).

Selli *et al.* (2006) investigated the effect of extended skin contact on wine made from *cv.* Muscat grapes in Turkey. In this experiment the control had no skin contact, while the two treatments had 6 hours and 12 hours of skin contact, respectively. Results showed that the skin contact treatment increased the total number of aroma compounds in the wine. In a follow-up preference test with consumers, it was found that the 6 hours of skin contact treatment, was most preferred, followed by the control (Selli *et al*., 2006).

Sokolowsky *et al*. (2015) investigated the effect of extended skin contact on two white German varietals, namely Gewürztraminer and Riesling. For the Gewürztraminer there were four different durations of skin contact respectively none, eight hours, 35 hours and fermentation with the skins that culminated into several days of skin contact. For the Riesling there were three different lengths of skin contact respectively none, eight hours and 24 hours. Sensory analysis of the Riesling wines showed that increased skin contact resulted in increased perception of bitterness, while for the Gewürztraminer wines, increased skin contact did not only increase the perceived bitterness, but also the sourness. The Gewürztraminer wine which was fermented on the skins was perceived to be lower in sweetness, higher in bitterness and sourness and more astringent.

Taking into account all the research that could be found on skin contact and white wine, the general trend seemed to be that limited skin contact added to the complexity of wine, but too much contact could result in increased bitterness and astringency, as a result of over extraction of phenolic compounds from the skins. Therefore, it can be concluded that skin contact does have the potential to affect the sensory profile of white wine. However, the sensorial effects of extended skin contact at low temperatures and the effect of fermentation on skins have not been tested on Chenin blanc wine under scientifically controlled conditions.

4.4 Wine yeast selection

Grape must fermentation involves complex biochemical reactions of fermentative yeasts and lactic acid bacteria present. In the most basic terms, it is the conversion of sugars, present in grape must, to ethanol and carbon dioxide by fermentative yeasts (Ugliano & Henschke, 2009). In addition, a number of volatile compounds including esters, higher alcohols, fatty acids, carbonyl and sulphur containing compounds are also produced (Swiegers *et al*., 2005). Grape crushing releases sugars, volatile and non-volatile chemical compounds. The sensory characteristics of wine, particularly the appearance, aroma and mouthfeel, are a direct result of the wine's chemical profile. The different flavours present in wine are a result of the specific chemical compounds that are produced or modified by the yeast and their complex interactions (Ugliano & Henschke, 2009).

Modern winemaking relies on the use of selected commercial strains of *Saccharomyces cerevisiae* (*S. cerevisiae*). These strains are reliable fermenters and have good flavour production properties (Molina *et al*., 2009). As the knowledge of the fermentative behaviour of wine yeasts has increased, improved *S. cerevisiae* strains have been identified and made commercially available. The characterisation of *S. cerevisiae* strains revealed genetic and metabolic variability that allowed winemakers to use different strains to modify wine flavour. With the current interest in even more diverse flavour in wine, the non-*Saccharomyces* yeasts are also being investigated (Ciani *et al*., 2009). Strains originating from the vineyards are being isolated and evaluated. Researchers are investigating the addition of these non-*Saccharomyces* yeasts to starter cultures to utilise their unique flavour producing properties (Ugliano & Henschke, 2009; Tartaridis *et al*., 2013).

Indigenous yeasts (found on grapes and winery equipment) consist of a number of species and strains and the unique flavour profiles they produce cannot easily be replicated using other vinification techniques (Ugliano & Henschke, 2009). Sadoudi and co-workers investigated the effect of the interactions between *S. cerevisiae* and non-*Saccharomyces* yeasts on the aromatic profile of Sauvignon blanc wine. Results showed that depending on the combination of yeasts used, the sensory profiles could be significantly altered, both positively and negatively (Sadoudi *et al*., 2012). Numerous similar studies have been carried out on other cultivars (Ciani *et al*., 2009) and Jolly *et al.* (2001) investigated the effect of using co-inoculation of *Candida pulcherrima* in the production of Chenin blanc.

Table 4 shows some of the sensorially-active (able to be perceived orthonasally or retronasally) compounds present in wine, along with their associated sensory aroma attributes and their source of origin (Ugliano & Henschke, 2009). Compounds are considered sensorially-active, or able to be perceived, if they have an odour activity value that is larger than one. Odour activity is discussed in more detail in section 2.5.2.of this chapter.

Table 4 Sensorially-active compounds in wine, produced as a results of yeast metabolism (adapted from Ugliano & Henschke 2009), TDN: 1,1,6-Trimethyl-1,Z-dihydronaphthalin.

Compounds	**Origin***	**Sensory attribute**
Volatile compounds		
Acetate esters Fatty acid ethyl esters Branched chain ethyl esters	A	Flowery, fruity, estery
Higher alcohols	A, B	Alcohol, herbaceous
Volatile fatty acids	A	Sour, sweat, cheese
Monoterpene alcohols	A, B, C	Flowery, citrus
cis-Rose oxide	B, C	Flowery
Rotundone	C	Spicy
B-Damascenone	B, C	Quince paste, stewed apple
TDN and Vitispiranes	B	Kerosene
B-Ionone	B	Violet
Methoxypyrazines	C	Capsicum (green pepper)
H_2S and mercaptans	A	Rotten egg, onion, garlic, cabbage
Sulfides	A, B	Asparagus, truffle, blackcurrant
4-Mercapto-4-methylpentan-2-one	B	Box tree
3-Mercaptohexan-1-ol	B	Green mango, box tree
3-Mercaptohexyl acetate	B	Tropical fruit
Furfurylthiol	A	Coffee-like
Methional	A	Boiled potatoes
Methionol	A	Boiled potatoes
Diacetyl	A	Buttery
Sotolon	B	Spicy
Volatile phenols	B	Spicy, clove-like
Aliphatic aldehydes	A, B	Green, grassy
Aliphatic lactones	B	Sweet, apricot
Whiskey lactone	D	Coconut
Vanillin and derivatives	B, D	Vanilla, spicy, sweet
Non-volatile compounds		
Sugars	C	Sweet
Polyols	A	Sweet
Organic acids	C	Acid
Phenolics	C	Colour, astringent, bitter
Polysaccharides/mannoproteins	A, C	Modifies astringency

* A: Compounds largely synthesised by yeast; B: Compounds present in the form of non-volatile precursors; C: Compounds present in significant concentrations in grapes; D: Compounds derived from other sources e.g. oak wood

As can be seen in Table 4, a large percentage of the flavour compounds are synthesized by yeast and are products of their metabolism. This shows the significant role that yeasts play in aroma production in wine. Research done by Lawrence (2012) and Van Antwerpen (2012) showed that some of the most important chemical compounds for Chenin blanc are 3-mercaptohexanol, 3-mercaptohexylacetate, acetate esters, monoterpenes, alcohols and volatile fatty acids, as they are the compounds that make the strongest contribution to the wine aroma.

4.5 Inoculated fermentation

The addition of commercial yeast at the start of alcoholic fermentation is done to guarantee a controlled fermentation, and generally results in a wine with somewhat of predictable sensory profile (Simon, 2011; Jolly *et al*., 2003). This procedure is referred to as inoculated fermentation and it is the most common and widely used method of fermentation. Inoculated yeast fermentation generally runs to completion without any glitches, but has been known to reduce the sensorial complexity of wine. Winemakers have observed less individuality between wines (Simon, 2011), which prompted researchers to investigate the effects of wild yeasts on wine chemical compounds, and whether they had a significant effect on the sensory qualities of finished wine (Egli et al., 1998; Jolly et al., 2003; Tartaridis *et al*., 2013).

4.6 Natural fermentation

If left, grape juice will naturally or 'spontaneously' start to ferment. Natural fermentation, also known as indigenous, spontaneous or wild yeast fermentation, is the 'original' way of winemaking (Romano *et al*., 2003). Traditionally, wine was produced via natural fermentation, where the yeasts present on the grapes and on winery equipment were responsible for the fermentation (Combina et al. 2005). Wild yeasts exist on grapes in much smaller numbers than a dose of 10^6 cfu/mL of commercial yeast and it therefore takes longer for the wild yeasts to dominate in numbers (Chorniak, 2005). This leaves the fermentation open to contamination (from spoilage organisms) and it can become stuck. A stuck fermentation is defined as one with a higher residual sugar level at the end of alcoholic fermentation than desired (Malherbe *et al.*, 2007). Stuck fermentations can occur as a result of the low tolerance of wild yeast to ethanol, which in the past led winemakers to inoculate with yeast starter cultures to make sure fermentations ran to completion and sugar was depleted to the desired level.

The effectiveness of natural fermentation depends solely on the yeast population present on the grapes and the resident yeast population in the winery. The natural yeast population present on the surface of a grape is dependent on various intrinsic and extrinsic factors. Some of the most important factors are the climate (amount of rainfall and the temperature), the use of pesticides in the vineyard and damage to berries caused by insects, birds and moulds (Combina *et al.*, 2005).

With inoculated fermentations, the addition of high levels of commercial *S. cerevisiae*, renders the non-*Saccharomyces* yeasts unable to compete, whilst in natural fermentation, non-*Saccharomyces* yeasts have sufficient time to proliferate before the *Saccharomyces* yeasts dominate. There are a number of yeasts naturally present on grapes, however, only less than 3% of the total wild yeasts are *S. cerevisiae* and the majority are non-*Saccharomyces* yeasts of which some are undesirable types that can cause taints (Simon, 2011). However, most non-*Saccharomyces* yeasts are more sensitive to ethanol than *S. cerevisiae*. Non-*Saccharomyces* yeasts that manage to grow to 10^6 – 10^7 colony forming units per mL can affect the growth and metabolism of *Saccharomyces* yeasts. They are also capable of growing in both aerobic and anaerobic conditions. They ultimately compete with *Saccharomyces* spp. for nutrients and are capable of producing secondary metabolites which can have an effect on the overall aroma of the finished wine (Romano *et al*., 2003; Setati *et al*., 2012).

Winemakers claim that the contribution that non-*Saccharomyces* yeasts make to the sensory profile of wine is important, and that mixed starter cultures could lead to wines with more complexity in the aroma. This hypothesis was tested on Riesling, where significant differences in aroma profiles between inoculated or un-inoculated (natural) fermentations were observed (Moreira *et al.*, 2008). Higher scores for fruit descriptors were noted in the un-inoculated wines, and the inoculated wines had higher scores for unfavourable descriptors. *Hanseniaspora uvarum* and *Hanseniaspora guilliermondii* were the main non-*Saccharomyces* yeasts present during alcoholic fermentation (Moreira *et al*., 2008).

There are a number of yeasts and other micro-organisms naturally present on grapes that produce a number of by-products during fermentation, other than alcohol. Not all of these by-products are desirable. One of the most common undesirable by-products is acetic acid, a volatile acid which gives wine a vinegary flavour (Jolly *et al*., 2013).

Overall, pure natural fermentation is a much longer and slower process than inoculated fermentation. It is also accompanied by high risks as there is no guarantee that the fermentation will run to completion, while off-flavours may be produced by some naturally occurring yeasts (Rojas *et al.*, 2001). As a result of the increased risk associated with spontaneous fermentation, these wines are often expensive.

5. The role of chemical compounds in determining wine flavour

The sensory profile variation that exists among wines is a result of varietal, geographical origin of grapes, the role that yeasts and bacteria play during fermentation, changes in viticultural and oenological practices and wine aging (Fischer, 2007). The sensory attributes of wine are a result of the chemical compounds present in the wine. Non-volatile chemical compounds (e.g. sugar, organic acids and phenolics) are responsible for the taste and mouthfeel of wine, namely sweetness, sourness, bitterness and astringency (Swiegers *et al*., 2005). In order to be detected sensorially, these non-volatile compounds must be present in a concentration of between 10^{-3} and 10^{1} g/L. Volatile compounds are responsible for aroma and are perceivable at much lower levels of 10^{-4} to 10^{-12} g/L. For example, isobutyl methoxypyrazine elicits an aroma of green bell pepper at concentrations of as low as 2 ng/L (2 x10^{-9} g/L) (Lacey *et al*., 1991). Volatile compounds are detected orthonasally and retronasally (Francis & Newton, 2005).

5.1 Odour perception

The odour potential or activity of volatile compounds can be evaluated on the basis of different properties. One is absolute threshold, which by definition, is the lowest concentration that can be perceived by the human nose (Delahunty *et al*., 2006). Different compounds have very different thresholds, and some can be as low as parts per trillion. Therefore, it is not uncommon in an aroma composed of numerous different volatile compounds, that only a few of them will be present above their threshold and only those few compounds will have a direct effect on the aroma perception. Another important property relates to intensity as a function of concentration (Delahunty *et al*., 2006). This is the observer's ability to perceive an odour on the basis of its concentration. The perceived intensity of a volatile compound increases as the concentration of that compound increases, however, not linearly. Therefore, the intensity by which a compound is perceived will depend on how much the compound exceeds its threshold (Delahunty, *et al*., 2006). As depicted in Fig. 4, the relationship between the perceived intensity of a compound and its actual concentration results in a sigmoidal curve. Initially, where concentrations rise to threshold level and above, there is a gradual increase in the slope; as the concentration approaches saturation point (the maximum perceived intensity) the graph plateaus. At this saturation point, even though the concentration of the odour may still increase, the perceived intensity will remain the same. The human nose will not be able to perceive the odour more strongly than the perception at the saturation point.

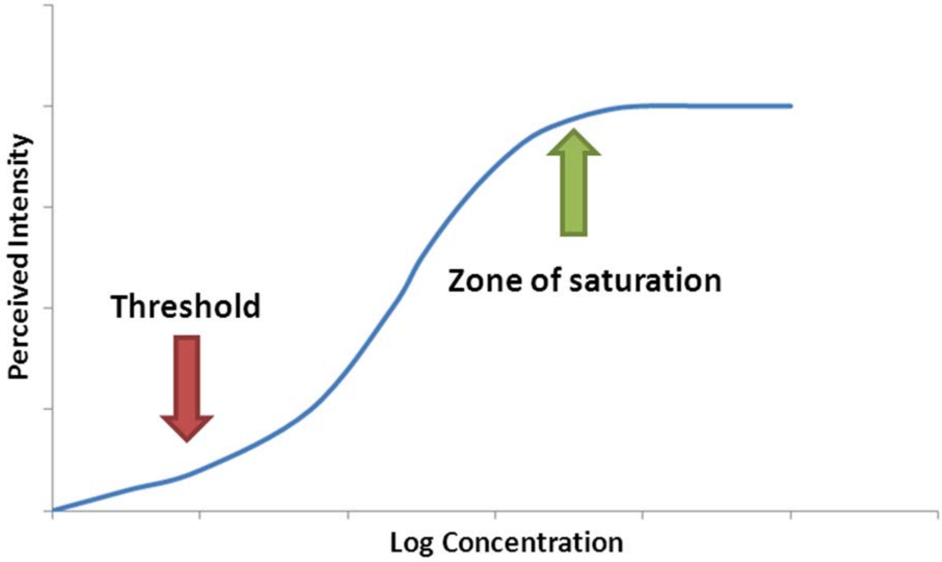

Figure 4 Theoretical curve for a volatile compound with logarithmic concentration vs. perceived odour intensity (Delahunty *et al*., 2006).

In nature and daily life individual odour compounds are seldom encountered. Most odours are a blend of numerous volatile compounds. The human olfactory system has a limited ability to identify individual odorants, even in the simplest of mixtures. The quality of individual odours can affect the overall aroma of a mixture. Odours of different quality can occasionally supress other odours within a mixture. Odours that have similar qualities have a tendency to blend and produce a third odour. How a mixture is sensorially perceived, is ultimately affected by the odour thresholds. Odours present below their thresholds, which would normally, individually have no odour activity, can in fact contribute to the odour when present in a mixture. The majority of these volatile odour compounds present in wine, can be identified using gas chromatography (Delahunty *et al*., 2006).

5.2 Analytical techniques to measure flavour compounds

There are two ways to analyse aroma; the first is sensory analysis and the second is instrumental chemical analysis (Le Fur *et al*., 2003). For the chemical analysis, volatile and non-volatile aroma compounds are measured and methods of choice include gas chromatography coupled to a flame ionization detection (GC-FID), gas chromatography mass spectrometry (GC-MS), gas chromatography coupled to olfactometry (GC-O) (Lawrence, 2012), and recently, also the electronic tongue and electronic nose (Escuder-Gilabert & Peris, 2010).

GC-FID has been applied extensively to investigate the volatile aroma compounds present in wine (Gil *et al*., 2006; Vilanova *et al.,* 2010), since it allows for non-selective quantification of volatile compounds in complex samples. The technique has some limitations; GC-FID is not as sensitive as

GC-MS and it is also not possible to identify unknown compounds with certainty, since the method requires reference standards for the volatile compounds and external calibration (Gil *et al*., 2006). Once the concentrations of compounds have been measured in a sample, the odour activity value (OAV) can be calculated in order to determine whether the compound is present at high enough levels to have a perceivable effect on the overall aroma. In order to calculate the OAV, the odour detection threshold values for each compound is required, information can be retrieved from chemical libraries. The OAV is calculated by dividing the mean concentration of the compound of interest, by its OAV. A compound with an OAV greater than one, OAV>1, is likely to contribute to the odour of wine (Malherbe *et al*., 2012).

Chemical measurements done with chromatography or mass spectrometry should ideally also be done in combination with sensory analysis, as the chemical compound that is present at the highest level may not correspond with the strongest perceived aroma in the wine. Techniques for sensory analysis are described in the following section.

6. Sensory profiling techniques

With the development of new wine styles, comes the need for sensory profiling and consumer studies. Descriptive analysis (DA) is the most well-known and widely used method for sensory analysis (Lawless & Heymann, 2010). However, the method is very expensive and time consuming. Researchers and industry are now looking at ways to speed up the sensory analysis, in order to speed up the product development process, and ultimately the release of the product. In order to satisfy this need, the current study investigated a few of the rapid methods, currently being used in the food industry with the goal of comparing the results obtained with those methods, to results obtained from DA. These sensory profiling techniques are described in the following sections.

Descriptive profiling of products is important in the field of food and beverage science. Being able to identify the characteristic sensory aspects of products is essential (Cartier *et al*., 2006). Sensory tests are used for a number of reasons, including product development or optimisation, quality control, flavour research and to gauge consumer reactions to products.

Flavour is an interaction between the product and the consumer and therefore cannot be easily measured by an instrument, although the electronic tongue and electronic nose (Escuder-Gilabert & Peris, 2010) have been used in attempts to mimick human smell and taste measurements. With sensory analysis the instrument is a human panellist (Piggott, 1995). Sensory testing can be done using three different types of panels namely consumers (non-experts), trained professionals or experts. There are many different methods of sensory analysis including difference tests, scaling, sorting and profiling techniques. It is important to choose the correct method and panel, in order to acquire the correct data (Meilgaard *et al*., 1999).

A number of sensory profiling methods have been developed, of which some require training of judges on the use of a specific vocabulary, while others allow judges to indicate differences in samples more freely. Sensory analysis methods can be divided into two groups; classic methods and novel methods respectively (Varela & Ares, 2012). The classic method would be quantitative descriptive analysis, also referred to as descriptive sensory analysis), which is costly and the training of a panel can take between 10 and 120 hours, depending on how sensorially complex the product is (Lawless & Heymann, 2010). The novel rapid methods require less time and money, and trained panels or consumers can be used. The novel methods include, sorting, flash profiling and mapping (de Saldamando *et al*., 2013). Recently, the more rapid methods have been gaining popularity (Dehlholm *et al*., 2012).

6.1 Descriptive analysis

Descriptive analysis (DA) is used to identify sensory characteristics of a product and score their intensities (Cartier *et al*., 2006). DA therefore gives quantitative, as well as qualitative data. A well trained panel is essential for quality testing. The standard procedure requires that a panel of between 8 and 12 judges is trained and maintained for the product evaluations (Lawless & Heymann, 2010). During the training phase, panellists are presented with reference standards and must understand and agree on the meaning of these attributes. Panellists must familiarise themselves with the products in a sample set and generate a list of attributes to describe the products. The list of attributes is then reduced and redundant terms are grouped or eliminated (Campo *et al*., 2010). From that list a concise list of attributes that best describe the products is generated. Judges must reach consensus on how the samples differ in terms of this list of attributes.

When samples are tested, standard sensory practices are followed. The judges sit in a temperature and lighting controlled room, in separate booths. The samples are labelled with unique three digit codes, and are presented in a randomised order unique for each judge. Judges are required to expectorate and rinse their mouth between samples (Lawless & Heymann 2010). Judges use an structured or unstructured line scale (between 10 - 15 cm) to mark the intensity of each of the attributes perceived in each sample. The anchors on the extreme ends of the scales are words chosen by the panel during training. Testing is done in triplicate (at least) so that the consistency and repeatability of the panel can be checked. The data is then statistically analysed using methods like analysis of variance (ANOVA) and principal component analysis (PCA) and a sensory profile is generated for each sample (Varela & Ares, 2012). Panel performance, i.e. efficiency, repeatability and accuracy, can be accessed using PanelCheck software (Tomic *et al*., 2010)

The DA method is optimal when detailed sensory information of the products is required, when a comprehensive list of all the attributes of a single product is required, or when one wants to quantify specific sensory differences between a few products (Lawless & Heymann, 2010). A disadvantage of this method is that it forces panellists to come to an agreement, which can lead to false agreement and erroneous results. Lawless (1999) suggests that this method of breaking up of sensory flavour into individual descriptors, and using individual scales when the product has a complex aroma may give the illusion that the notes are independently analysable, when they are not.

6.2 Check-All-That-Apply

The use of Check-all-that-apply (CATA) questionnaires is a new sensory method being developed (Ares *et al*., 2013). CATA can be done by trained panellists or by consumers. A list of descriptors is provided to panellists and they are instructed to choose the descriptors that best describe a given sample. Figure 5 is an example of a general CATA list used for the description of wine aroma. Panellists would be required to tick the boxes next to the appropriate attributes for a particular sample. CATA can also be done by consumers and descriptors such as ‘dislike extremely’, ‘like very much’ and ‘I would buy it again’ can be included.

Studies have shown that when a CATA list was used with consumers and with trained panels, the results were similar (Ares *et al*., 2013; Ares & Jaeger, 2013). Arez *et al.* (2011) found that consumers considered CATA a simple task. With the increasing use of CATA there is a need for a set of guidelines on the best practices (Ares *et al*., 2013). One of the most important factors to keep in mind when setting up a CATA list is that the order which the terms appear in can affect the results. Terms at the top of the list are used more often than those at the bottom. To combat this problem it has been suggested that the order of the terms on the list should be change for each assessor. It has also been suggested that using multiple shorter lists is better than using one long list. CATA lists can be used in combination with other sensory tests like sorting or mapping. Figure 5 is an example of a CATA list for general aromas associated with wine.

AROMATIC DESCRIPTORS LIST

FRUITY

WHITE FRUITS
- [ ] Quince
- [ ] Pear
- [ ] Yellow Apple
- [ ] Green Apple
- [ ] Oxidized Apple

YELLOW FRUITS
- [ ] Apricot
- [ ] Peach
- [ ] Melon

CITRUS
- [ ] Grapefruit
- [ ] Lemon
- [ ] Orange

RED FRUITS
- [ ] Cherry
- [ ] Raspberry
- [ ] Redcurrant
- [ ] Strawberry

BLACK FRUITS
- [ ] Blackberry
- [ ] Blackcurrant
- [ ] Blueberry

DRIED FRUITS
- [ ] Dried Peach
- [ ] Dried Apricot
- [ ] Dried Pear
- [ ] Dried Apple
- [ ] Dried Fig
- [ ] Date
- [ ] Prune
- [ ] Raisin

NUTS
- [ ] Almond
- [ ] Hazelnut
- [ ] Walnut

TROPICAL FRUITS
- [ ] Pineapple
- [ ] Banana
- [ ] Guava
- [ ] Passion Fruit
- [ ] Litchi
- [ ] Mango
- [ ] Gooseberry
- [ ] Coconut

SWEET ASSOCIATED
- [ ] Ripe Fruit
- [ ] Marmelade
- [ ] Honey
- [ ] Fruit Jam
- [ ] Glazed / Crystallized Fruit
- [ ] Artificial / Chemical Fruit
- [ ] Muscat
- [ ] Cider

VEGETATIVE / GREEN

VEGETABLES
- [ ] Artichoke
- [ ] Asparagus
- [ ] Cabbage
- [ ] Green Beans
- [ ] Green Pepper
- [ ] Green Olive

FRESH
- [ ] Eucalyptus
- [ ] Herbaceous
- [ ] Tomato leaf
- [ ] Celery
- [ ] Green / Cut Grass
- [ ] Lemon Grass
- [ ] Mint

DRIED
- [ ] Hay / Dried Grass
- [ ] Tobacco

SPICY
- [ ] Bay Leaf / Laurel
- [ ] Thyme
- [ ] Juniper
- [ ] Nutmeg
- [ ] Cinnamon
- [ ] Ginger
- [ ] Clove
- [ ] Anise / Fennel
- [ ] Liquorice
- [ ] Curry
- [ ] Black Pepper
- [ ] White Pepper

FLORAL
- [ ] Camomile
- [ ] Linden Tree Flower
- [ ] Honeysuckle
- [ ] Orange Blossom
- [ ] Jasmine
- [ ] Rose
- [ ] Violet
- [ ] Lilac
- [ ] Geranium

TOASTED / WOOD

TOASTED
- [ ] Caramel / Burnt Sugar
- [ ] Toffee
- [ ] Vanilla
- [ ] Chocolate
- [ ] Roasted Coffee
- [ ] Toated Bread

WOODY
- [ ] Planky
- [ ] Oaky
- [ ] Burnt / Smoked Wood

ANIMAL
- [ ] Cat urine
- [ ] Horsy / Sweaty
- [ ] Leather
- [ ] Meat Stock
- [ ] Musk / Civet
- [ ] Smoked Meat
- [ ] Wet dog

FOREST FLOOR
- [ ] Humus / Earthy
- [ ] Mouldy
- [ ] Mushroom

OTHER
- [ ] Alcohol
- [ ] Butter / Lactic
- [ ] Chalky
- [ ] Iodine / Salty
- [ ] Mineral / Flinty
- [ ] Rubber
- [ ] Solvent / Chemical
- [ ] Sulphur
- [ ] Stuffy / Fusty / Dusty
- [ ] Tar
- [ ] Wet mop
- [ ] Yeast

Figure 5 CATA list of general aroma descriptor.

6.3 Sorting technique

Sorting as a method of sensory profiling, was first introduced to sensory science by Lawless *et al*., (1995) and is a similarity-based test, where samples are categorised according to similarities or differences. Each panellist sorts the samples in a way that makes sense to him/her (Dehlholm *et al*., 2012). The sorting technique requires panellist to sort samples into groups according to their aroma, taste, visual appearance or other criteria. Samples are given to a panellist who sorts the samples into as many groups as he/she chooses. Panellist can also be asked to write down a list of attributes to describe each group. The data is analysed using multidimensional scaling (MDS) and DISTATIS. Sorting is fast and can be done by trained or inexperienced panellists, because it does not require consensus from panellists and there is no quantitative rating. Sorting can also be done with a large number of samples, usually between 9 and 20 (Cartier *et al*., 2006). Cartier *et al* (2006) found that sorting of breakfast cereals done by trained panellists and DA gave similar product maps. Grouping of products and the attributes given to the groups were similar for trained and untrained panels, leading to the conclusion that untrained panellists can be used for sorting (Cartier *et al*., 2006). One disadvantage of using sorting is that the differences between samples are not quantified. Despite all the positive aspects, it is clear that several practical aspects related to repeats, number of panellists, number of samples and suitability for different wine styles, must still be tested for the sorting technique.

6.4 Flash profiling

Flash profiling (FP) is a descriptive sensory method where panellists use their own words/descriptors to describe a set of samples (Dairou & Sieffermann, 2002). Flash profiling uses a number of different methods for data analysis including, ANOVA, PCA and cluster analysis. Dairou and Sieffermann (2002) investigated rapid techniques to describe sensory properties. FP combines the use of free-choice descriptors with a ranking method. The entire sample set is presented simultaneously, so that panellists can better compare and discriminate between them. FP does not require training as panellists do not rate the intensity of an attribute; they simply rank the samples in terms of that attribute (Dairou & Sieffermann, 2002). Dairou and Sieffermann compared descriptive analysis and FP on a set of jams. They found that the descriptive profiles generated by the different methodologies were similar, but flash profiling was less time consuming. Flash profiling is a good method to use when one needs to rapidly identify a product set’s most important attributes (Louw *et al*., 2013).

6.5 Polarised sensory positioning

Polarised sensory positioning (PSP) is a rapid method whereby products are compared to fixed reference samples, also called poles. The advantage of this strategy is that samples can be tested in different sessions using the same poles (reference samples), whereas with sorting or projective mapping, all the samples must be tested in one session (De Saldamando *et al*., 2013). PSP was originally developed by Teillet *et al.* (2010) to analyse sensory differences in the sensory perception of water.

There are two methods of PSP; the general method and the Triadic method. The general method uses a 10 cm unstructured line scale anchored by the phrases “completely different” and “exactly the same” (De Saldamando *et al.,* 2013), to quantify the difference between samples. Assessors indicate to which pole the sample is most similar. The Triadic method (T-PSP) is based on sorting, and assessors only indicate to which pole a sample is most similar and least similar (Ares *et al*., 2013). De Saldamando *et al.* (2013) used this method to investigate sensory differences in powered orange drinks. They found that the chosen poles defined the sensory space. The poles they chose were two extremes, and the samples fell in the space between them depending on their similarities or differences to the poles. They suggested that further research should be done, as when the poles were changed it gave different answers regarding the similarities and differences between products. Although this method has not been used for wine sensory evaluation, it definitely deserves further investigation, particularly for the purpose of quality benchmarking in new wine style developments.

6.6 Projective mapping or napping®

Projective mapping was proposed for use in the food industry (Risvik *et al*., 1994). The procedure requires that samples are mapped onto a sensory space (e.g. a sheet of paper) according to product similarities and differences. Descriptors can be generated for the samples (or groups of samples), or a CATA list can be completed for each sample. Napping® is a special case of projective mapping (Pagès, 2005). Originally, napping was done by arranging samples on a table cloth (Pagès, 2005), now it is mostly done using a large blank piece of paper (Usually A2, 420 mm X 594 mm). Napping data is not scaled and multiple factor analysis (MFA) must be used to analyse data (Dehlholm *et al*., 2012). It has also been proposed that the tasting sheets on which the mapping is done should be rectangular (Dehlholm *et al*., 2012). However, in a recent study of brandy sensory profiling, the shape of the tasting sheet (round, square or rectangular) did not seem to affect the results (Louw *et al*., 2014). More work on this aspect is, however, required.

For projective mapping, assessors are given a number of samples (coded with unique three-digit codes) and a blank page (usually A2 420 mm X 594 mm), and they instructed to group the samples, so that similar ones are close together and different ones, far apart. When all the samples have been placed on the sheet, the samples’ positions are marked with a cross (x) and the corresponding code of the sample is recorded. Using the bottom left hand corner of the page as the origin, X and Y co-ordinates are obtained for each sample. This data is analysed using MFA (Dehlholm *et al*., 2012).

6.7 Polarized projective mapping

Polarized projective mapping (PPM) is a combination of polarized sensory positioning (PSP) and projective mapping (PM). It was first described for consumer profiling of orange flavoured powder drinks (Ares *et al*., 2013). With this method, one sample is used as a reference and all other samples are sorted/ mapped according to how similar to or different from the reference they are. A preliminary PPM can be done to identify poles, or alternatively the poles can be chosen by the panel leader. Data analysis is done using MFA and hierarchical cluster analysis (HCA).

6.8 Frequency of citation method

Frequency of citation (FC) involves the generation of a list of attributes, by approximately 30 panellists, to describe, for example, the aroma, of the samples to be evaluated. It can be used as an alternative to descriptive analysis to generate a detailed description of wine aroma (Campo *et al*., 2010). The panel has to be trained, since panellists need to become familiar with the list of aroma attributes for the specific product being studied. During training, aroma reference standards are given to the panel to smell. Panellists are then given three to four samples and asked to describe them by choosing descriptors from the given list. There is then a panel discussion of the most frequently cited terms and a subset of these attributes is chosen by consensus and the list of terms is then modified. For testing, samples are presented in duplicate (or triplicate) in a Latin square design. Panellists must choose three to five descriptors from the given (modified) list, which accurately describe each of the given samples (Campo *et al*., 2010). Data is analysed by correspondence analysis and HCA.

Table 5 provides a summary of the different sensory methods discussed.

Table 5 Summary of different sensory methodologies (Varela & Ares 2012). ANOVA: analysis of variance, MDS: Multidimensional scaling, MFA; Multiple factor analysis, GPA: generalised procrustes analysis, MCA: multiple correspondence analysis, CA: correspondence analysis, HCA: Hierarchal cluster analysis, PCA: principal component analysis.

Method	Type of evaluation	Vocabulary	Statistical method	Limitations
Descriptive Sensory Analysis (DA)	Rating the intensity of a set of attributes using line scales	Consensus by panel	ANOVA, PCA	Possible lack of consensus in consumers' responses Very time consuming and costly
Sorting	Classification of samples based on their similarities and differences	Generated by the assessors or provided by the panel leader	MDS, DISTATIS, MFA	All samples should be presented simultaneously
Flash Profiling	Ranking of samples on a set of selected attributes	Generated by the assessors	GPA	All samples should be presented simultaneously
Projective mapping or Napping®	Generating samples on a two-dimensional map according to their similarities and difference	Generated by the assessors	MFA	All samples should be presented simultaneously It could be difficult for naïve consumers to understand
Check-all-that-apply (CATA) questions	Selection of terms from a list that are appropriate to describe the samples	Provided by the panel leader	Cochran Q test, MCA, MFA	The design of the attribute list could strongly affect the responses Not recommended for evaluating very similar samples
Frequency attribute citation	Selection of terms from a list that are appropriate to describe the samples	Provided by the panel leader	CA, HCA	The design of the attribute list could strongly affect the responses
Polarized sensory positioning	Evaluation of global differences between samples and a set of fixed references	Generated by the assessors	MDS or PCA	Stable and readily-available references are needed Selection of references could strongly affect the results

6.9 Comparison of descriptive analysis and projective mapping

DA is an expensive and time consuming method and both researchers and industry need to investigate methods which are both faster and cheaper, but still give reliable results. In this project the emphasis was on an evaluation of PM as a rapid sensory method, with the goal of using it as an alternative to DA when possible. DA of wine, typically requires some eight to 10 training sessions and two testing sessions, a maximum of only nine samples and a minimum of six bottles of wine per sample is required. Training is done with the samples to be tested. DA is thus, very cost and time consuming. By comparison, PM does not require training, but it can be done to help induce homogeneity in descriptors used by the panel (Piombino *et al*., 2004). PM has been reported to have been done comfortably with up to 18 samples (Pagés, 2005; Hopfer & Heymann, 2013). Table 6 provides a summary of the main differences between these two methods.

Table 6 Summary of comparison of descriptive analysis (DA) and projective mapping (PM). Anova: analysis of variance, PCA: principal component analysis, MFA: multiple factor analysis.

DA	**Projective Mapping**
ANOVA, PCA	PCA, MFA
Trained Panel (6-12 members)	Trained panel (6-12 members)
Training ≈ 8 sessions	Training ≈ 1-2 sessions
Testing ≈ 1-2 sessions	Testing 1 session
Time consuming	More rapid
Training done with samples to be evaluated	Training does not have to be done with samples to be evaluated
Expensive	Lower cost
Panel must reach consensus on sensory attributes	No consensus needed
Complex evaluation of samples	Simpler evaluation of samples
Individual sample sensory description	Global sensory description
Quantitative and qualitative information	Qualitative information

Several of the rapid methods were originally developed for the sensory analysis of other types of food and beverages than wine, and therefore, the sensory facility at The Institute for Wine Biotechnology, Department of Viticulture and Oenology (IWBT-DVO), Stellenbosch University, have several research projects where some of these methods are being tested out, and optimised to adapt them for wine, with the eventual goal of validating them for use in the wine industry.

7. Sensometrics

Sensometrics is defined as the scientific discipline that applies mathematics, statistics and multivariate data analysis techniques to analyse sensory perception and consumer data (Nofima, 2014) Different methods of sensory analysis, capture different types of data and therefore require different methods for sensory analysis. Various univariate and multivariate data analysis methods are used to summarize and visualise sensory data (Husson & Josse, 2013). A lot of work is being done on improving existing methods and developing new approaches to the analysis of both sensory and consumer data (Endrizzi *et al*., 2014) and linking this with chemical data (Dong et al., 2014; Thomsen *et al*., 2014). The following section discusses some of the statistical methods used to analyse sensory data.

7.1 Analysis of variance

Analysis of variance (ANOVA) is a statistical technique used to compare groups/treatments/products and determine whether there is a significant difference between them (Lawless & Heymann, 2010). ANOVA generally investigates the null hypothesis that the means of the different treatments/groups are equal to each other. There are two types of ANOVA, one-way and two-way ANOVA. The two-way ANOVA is used when an experiment has a complete block design, e.g. all samples scored by all panellists in all replications (Lawless & Heymann, 2010). This method of analysis is typically used to investigate the effects that different treatments have on the sensory perceptions of a product, as perceived by a panel of judges. Once an ANOVA is done, and it is found that there are significant differences between groups/treatments, the null hypothesis is rejected and the differences between the groups /treatments can be further investigated using post-hoc tests.

7.2 Principal component analysis

Principal component analysis (PCA) was developed by Karl Pearson (Wold et al., 1987) and it is a multivariate analysis technique that describes interrelationships among multiple dependant variables. PCA is done using on a data matrix (table) consisting of products and descriptors. The rows in the table are the objects, or samples being tested, and the columns are the variables. The main goal of PCA in sensory analysis is to find relationships between the samples and variables. It gives the average score given by all panellists to a sample taking a descriptor into consideration. PCA plots can be normalised, where identical weighting is given to each descriptor, or unnormalised, where the weight of each descriptor is proportional to its variance. The number of principal components calculated is less than, or equal to the original number of variables. PC1 accounts for the majority of the variance in the data. One shortcoming of this method is that the weights that are given to descriptors do not always correspond to the actual importance with regards to the samples (Pagès, 2005). PCA is usually done on DA data.

7.3 Multiple Factor Analysis (MFA)

Multiple factor analysis (MFA) (Escofier & Pagès, 1994) can be used in a number of disciplines including, sensory analysis, chemistry, ecology and economic studies (Abdi & Valentin, 2007). The outcome of MFA is a graphical display that highlights structures which are common to a set of groups of variables observed for the same samples (Pagès & Tenenhaus, 2001). MFA is used in particular for analysis of mapping/napping data (Pagès, 2005). The method analyses data defined by a number of sets of variables. Pagès (2005) investigated using MFA to analyse data from a napping study done on 10 white wines. The X and Y co-ordinates (using the bottom left hand corner of the tasting sheet on which the napping was done as the origin) were captured for each sample and then complied for all panellists. MFA can be seen as enhanced PCA.

MFA is done using statistics software such as FactoMineR and XLSTAT. MFA is used when data is described by several sets of variables. The objective is to incorporate the different variables used to describe the same observations and identify common structures that appear in all, or a portion of the sets. There are two main steps in MFA. Firstly, PCA analyses are conducted on each individual set of data. Each plot then has to be normalised, by dividing all the elements by the first singular number (the square root of the eigenvalue) obtained from its PCA. The normalised data sets are then combined to create a new matrix, and a (global) PCA is performed. The original (individual) data sets are then superimposed onto the global plot and similarities and differences are observed (Abdi & Valentin, 2007).

7.4 RV Coefficients

With regards to sensory analysis, it is often necessary to compare product configuration plots obtained by different sensory evaluation methods for instance, to see whether similar results were obtained with the different methods. The RV coefficient is used as a measure of similarity between two different configurations. The closer the RV coefficient is to one, the more similar the results are (Abdi, 2007; Robert & Escoufier, 1976). Cartier *et al.* (2006) reported that an RV-value of 0.7 could be considered as a good level of agreement. In order to compare the validity of the results obtained from the rapid methods, with those obtained from DA, RV coefficients can be used to evaluate the rapid methods' outputs.

8. Consumer perception

Wine consumption and enjoyment is growing in popularity and academics are becoming more interested in consumer behaviour regarding its consumption (Lockshin & Corsi, 2012).

South African consumers consumed a total of approximately 37 000 kL of wine in 2013, and looking at the trend over the past 5 years, this number is likely to increase in the coming years (Fig. 6).

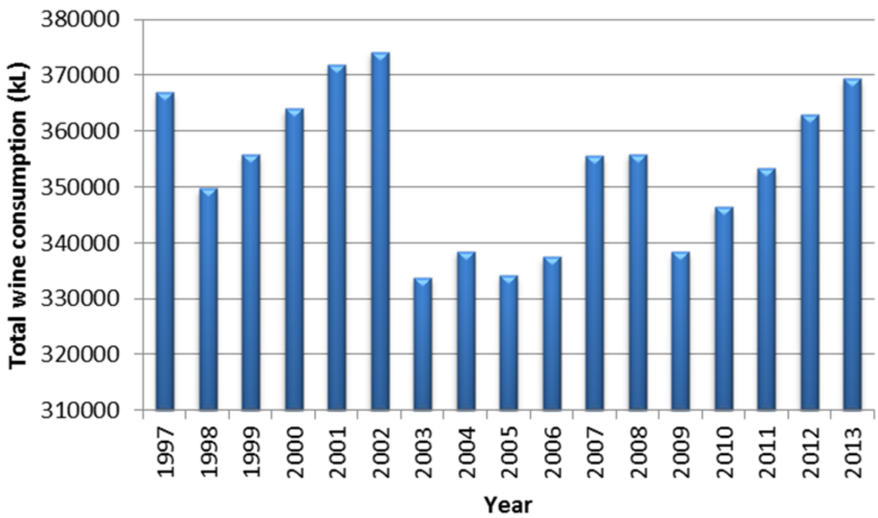

Figure 6 The total amount of wine (kL) consumed by South Africans anually, from 1997 to 2013 (SAWIS, 2014).

In recent years it has become apparent that the wine industry needs to pay more attention to consumers and their preferences. In order to benefit from the growing wine consumer group, wine producers should understand that consumers do not only have preferences when it comes to wine styles, aroma and quality, but also closure types, labels and even bottles (Swiegers *et al*., 2006).

One of the most important points when it comes to consumer preference profiling, is segmentation. Consumers can be split into different groups for many reasons, and each segment could have different preferences. Marketing procedures will also differ depending on which group you are attempting to target.

8.1 Consumer segmentation

Initially academics in Australia suggsted four general segments for wine consumers, namely: New wine drinkers, beverage wine consumers, aspirational drinkers and connosseurs (Charters, 2006; Table 7). Since then a lot more research has been done and many other consumer segments have been identified.

Table 7 The four segments of the wine drinker (Charters, 2006).

Segment	Description
Connoisseurs	Knowledgeable, regular drinkers, broad spectrum of tastes
Aspirational drinkers	Focus on social aspects of drinking, risk averse and like to learn
Beverage wine consumers	Very keen consumers, little desire to 'appreciate' the product, loyal to one style
New wine drinkers	Yet to establish preferences, drink socially eg. coolers, unsophisticated

Barber (2009) segmented consumers based on gender and found that female consumers were generally more willing than male consumers, to use more sources of information to assist in making their purchase decisions. Atiken *et al*. (2007) also segmented purchase behaviour on gender, and found that if women were unsure of what wine to purchase, they were more likely (than men) to ask a shop assistant for advice, or alternatively, make a purchase decision based on awards or medals won by the wine. A survey done on Italian wine consumers found they could be divided into 4 segments; habitual consumers, rational wine buyers, interested consumers and promotional wine buyers (Seghieri *et al*., 2007). In research done by Green (2010) on South African wine consumers, it was found that the South African wine market can be divided into segments based on how much they are willing to pay for a bottle of wine (Table 8). The statistical technique conjoint analysis, is used to determine what combination of attributes/features are most important in consumer decision making (Green & Kriege1993).

Table 8 South African wine market segmentation based on wine price (Green, 2010).

Price	Consumer Age Group	Consumer segment
< R25	Any age	Consumers who generally pay for low priced wines
R26 – R49	Any age	Consumers with an average income and preference for affordable wines
> R50	Particularly young up-and-coming, and more mature consumers	Connoisseurs, concerned about what they serve guests,

Green (2010) also found that the average age of the wine consumer is older than 25 years, and she concluded from that, that wine appeals to the more sophisticated consumers, who find image and status important.

The wine market is not only segmented by price but also by generation. Bester (2012) shows that the use of generations to segment the market is a more promising approach to take as it gives better results than segmenting by race, gender or any other demographics. Purchase decisions are influenced by age. Persons, who grow up as part of the same generation, are exposed to the same "conditions", e.g. social or political, and so they have more similar values and outlooks on life. A specific consumer generation is usually homogenous when it comes to their attitudes and beliefs, as they experience similar 'external' events and are shaped by lifestyle, age and the economic and social climate (Schewe & Noble, 2000). It therefore makes sense to analyse the consumer market based on generation.

Six consumer generations have been identified, namely; the great depression generation (born between 1912 and 1921), World War II generation (born between 1922 and 1927), the post-World War II generation (born between 1928 and 1945), the baby boomers (born between 1946 and 1964), Generation X (born between 1966 and 1976), and Generation Y (born between 1977 and 2000). The Generation Y population ranges between the ages of 13 and 36, but those allowed to consume alcohol are between the ages of 18 and 36 (Bester, 2011). Generation Y is therefore the "young adult" consumer group. Generation Y is also referred to as the 'Millenials'. This consumer group differs greatly from the others; they are more likely to travel, live in cities, have university educations and have usually changed careers three times before they turn 30.

With regard to international studies done on Generation Y, it was found that they preferred to drink wine at social gatherings in bars or restaurants (Agnoli *et al*., 2011). They also generally drink wine in groups, as a bottle is too large to consume on one's own (Ritchie, 2011). Wine was typically drunk in situations where copious amounts of alcohol were consumed and not to accompany a meal. A study done in New Zealand on a random sample of Generation Y and Generation X consumers, ten years apart, found that Generation Y consumers drank more wine more often and in more situations than Generation X (Fountain & Lamb, 2011).

It is clear that wine cannot be marketed to Generation Y in the same way as to their parents. Generation Y has been described as lacking in wine knowledge, but adventurous enough to try new styles. Research conducted in the United States shows that the relationship that this generation has with wine is driven more by parental influence and social image than income. Marketing of new wine styles should be aimed at generation Y consumers, as they are more adventurous, and willing to try new things and can still be shaped, whereas the older consumers are generally set in their ways with regards to wine preferences (Bester, 2012). The two biggest influences on Generation Y are their parents and social media (Goneos-Malka, 2012).

8.2 Factors affecting purchase decisions

When consumers are deciding what wine to purchase they generally have to rely on cues provided by the wine bottle's label. These are known as extrinsic cues and can be divided into two groups. The first group is cues related to the product, like grape variety, whether or not the wine is wooded and the origin of the wine. The second group is cues that can change without changing the product itself, like price, packaging and names (Chrea *et al*., 2010).

At the point of purchase there are many aspects that affect the consumers' final choice. Jaeger *et al.* (2009) looked at consumer purchase decisions and consumption behaviour of New Zealand wine drinkers. Consumers ranked the factors affecting purchase from most to least important. The factors were: *Tasted the wine previously, Grape variety, Brand name, Medal/award, Someone recommended it, Origin of the wine, I read about it, Matching to food, Promotional display in-store, Information on the shelf, Information on the back label, Attractive front label, Alcohol level below 13%. Tasted the wine previously* was the most important factor to both consumers with high and low involvement, and an *alcohol level below 13%* was the least important factor. They also asked consumers to recall the last bottle of wine they had purchased, and consumers who were more involved gave a more detailed description of the wine than consumers who were less involved (Jaeger *et al*., 2009).

Hanekom (2012) investigated the terms "bush vine" and "old bush vine" as label cues. The results showed that the over-all degree of liking, with and without cues, differed significantly. The degree of liking increased significantly when the wine was labelled with cues, as compared to when they were tasted blind. Wines served with the cue 'Bush vine' and 'Old bush vine' had no effect ($p > 0.05$) on the group of consumers not associated with the wine industry. These consumers are not aware of the meaning of these terms and the potential affect that it could have on wine quality. Consumers therefore need to be educated on the importance of aspects such as bush vine training systems or vine age, and their effect on Chenin blanc wine quality. Label cues such as "bush vine" can then be used to inform consumers about what to expect with regard to quality when purchasing wine. For the wine industry one of the most important things is repurchasing, and research has shown that a when a consumers expectation is confirmed they are more likely to re-purchase a product (Grunert, 2002).

8.3 Natural fermentation as a label cue?

Natural fermentation would be classified in the first group of extrinsic cues, as it directly affects the product. This needs to be investigated using consumers to see if it affects their preferences. Natural fermentation is also known as spontaneous or wild yeast fermentation, and using the different terminology may have different effects on preference, due to personal associations. The word ‘natural’ to some consumers may have positive connotations like ‘healthier’ or ‘less harmful to the environment’ and to others more negative connotations like ‘expensive’ and ‘not necessary’. The choice of words could attract some consumers and repel others. Some people will respond well to natural/ indigenous, some to spontaneous. The reaction of consumers ultimately depends on how much wine knowledge they have.

Raab and Grobe (2005) investigated word association with the label cue ‘organic’. Two thirds of their sample group gave positive word associations, the most frequently mentioned words were: alternative life-style, chemical free, natural, home-grown, pure/clean and healthier/more-nutritious. Approximately 20% of their sample group gave negative word associations including: expensive, scam, lack of credibility, not necessary, inconsistent, ‘trendy’, spoils easily. They found in particular that to most consumers the word ‘organic’ meant expensive. They ultimately showed that one word on a label can drastically affect the perception of the product by the consumer, and their consequent purchase intent.

9. Concluding remarks

Chenin blanc is an important varietal in South Africa; it covers the vast majority of our vineyards and is the most exported of the white varietals. There is minimal chemical and sensory data available for Chenin blanc wine. Previous research has focussed on characterising the three dry and semi-sweet styles of Chenin blanc as well as wines produced from bush vines and old vines. There is currently very limited published work on the potential effects of spontaneous fermentation and extended skin contact, two important and emerging winemaking techniques, on Chenin. Given the notion and popular belief that Chenin blanc is considered as South Africa’s flagship white wine, the more research that can be done to better ‘understand’ it, improve it, and gauge consumer opinions, the better.

The traditional method of sensory analysis, descriptive analysis, is an expensive and time consuming process, and the development of reliable quicker alternatives would be beneficial to both researchers and industry.

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Chapter 3

Characterization of the effect of skin contact and natural fermentation on the chemical and sensory profiles of Chenin blanc wine

Characterization of the effect of skin contact and natural fermentation on the chemical and sensory profiles of Chenin blanc wine

1. Introduction

A number of oenological treatments have been shown to influence white wine flavour. Changes in oxygen parameters such as oxidative (Mattivi *et al*., 2012; Cejudo-Bastante *et al*., 2013) and reductive (Di Lecce *et al*., 2013) winemaking; extended contact of skins with grape juice (Baumes *et al*., 1989; Cabaroglu *et al*.,1997; Darias-Martin *et al.*, 2000; Selli *et al*., 2006a; Bavcar *et al*., 2011; Cejudo-Bastante *et al*., 2013; Gawel *et al.*, 2014), natural fermentation and the use of non-*Saccharomyces* yeasts (Jolly *et al*., 2003bc; Combina *et al*., 2005; Swiegers *et al*., 2009) have all been investigated.

Chenin blanc is considered a neutral cultivar (Marais *et al*., 2005) and lends itself to be a good vehicle for flavour modulation. The flavour of wine can be varietal dependant, as found with the grape derived methoxypyrazines responsible for the green pepper aroma of Sauvignon blanc (Swiegers *et al*., 2005), but can also be altered by using different viticultural and oenological treatments. Grape berry size, ripeness, and the conditions they were ripened under have been shown to affect the flavour of Chenin blanc (Marais *et al*., 2005). Two winemaking techniques have been reported to be used for flavour modulation in white wine namely, natural fermentation and skin contact. The current research focused on these two winemaking techniques and their effect on Chenin blanc.

Natural fermentation, also known as indigenous, spontaneous, or wild yeast fermentation, is the traditional way of winemaking, where naturally occurring yeasts (present on the grapes and on winery equipment) are responsible for the alcoholic and malolactic fermentation (where desired) (Romano *et al*., 2003; Combina *et al*., 2005). The fermentation is therefore performed without any addition of commercial, well-characterised yeast starter cultures. The indigenous yeasts consist of a number of non-*Saccharomyces* species and strains and the unique flavour profiles they are capable of producing cannot easily be replicated using other winemaking techniques (Ugliano & Henschke, 2009; Jolly *et al*., 2013). In a regular inoculated fermentation where *Saccharomyces cerevisiae* (*S. cerevisiae*) is typically inoculated at high dosage, the non-*Saccharomyces* yeasts would generally be rapidly outcompeted. Natural fermentation allows the proliferation of naturally occurring non-*Saccharomyces* yeasts present on the grapes. During fermentation, yeasts primarily produce ethanol and CO_2 and a myriad of secondary chemical compounds such as organic acids, higher alcohols, esters and fatty acids which are the main compounds responsible for the “fermentation bouquet” and taste (Romano *et al.*, 2003; Moreira *et al*., 2008). The concentrations of these compounds are determined by the yeast species that participate in fermentation. Romano *et al.* (2003) reported that grape juice fermented with individual yeast strains, generally had the same chemical compounds present at the end of fermentation, but their final concentrations differed for each individual strain. The yeast diversity, or lack thereof, is therefore an important factor and can affect the flavour of the finished wine. The most frequently observed non-*Saccharomyces* yeast species in wine include *Hanseniaspora uvarum*, *Torulaspora delbrueckii*, *Kloeckera apiculata*, *Candida stellata* and *Metschnikowia pulcherrima* (Ciani & Maccarelli, 1998; Combina *et al*., 2005; Chavan *et al*., 2009). Although natural fermentation has been suggested to generate wines with more aroma complexity than inoculated wines, there are potential risks associated with this form of fermentation, which include sluggish/stuck fermentations (which don't run to completion) and the proliferation of spoilage organisms (Malherbe *et al*., 2007). Stuck fermentations typically have high residual sugars which would allow the growth of spoilage organisms that can produce high levels of unwanted compounds such as acetic acid or ethyl acetate, which respectively impart vinegary or solvent-like aromas to wine (Fleet, 2003; Loureiro & Malfeito-Ferreira, 2003). In South Africa natural fermentation is used by a select few industrial cellars but is becoming more popular.

Skin contact is a term used in white wine production and is a treatment normally applied to grape juice before the onset of fermentation (Rustioni *et al*., 2013). It is the period of time that the skins of the grapes remain in contact with the juice, i.e. the contact time between the initial crushing of the grapes and pressing to extract the juice. Phenolic compounds present in the skin of grapes, which impart colour and astringency to wine, are transferred from the skins to the juice during this contact time (Gomez-Miguez *et al*., 2007). The effects of skin contact on white wine flavour have been widely researched, studies include: the effect of skin contact of different times and temperatures on colour and phenolic content of cv. Zalema (Gomez-Miguez *et al*., 2007); the effect of grape skin contact and the amount of pressure applied during grape pressing on the volatile chemistry of Sauvignon blanc (Maggu *et al*., 2013); the effect of different grape treatment time and temperatures on the concentration of monoterpenes and phenolic compounds in *Vitis vinifera* cv. Malvazija istarska bijela (Croatian white wine) wine (Radeka *et al*., 2008), to name a few. Increasing the length of time that the skins are in contact with the juice, generally increased the concentration of extracted tannins and phenolic compounds from the grape skins, and extended skin contact has been shown to unlock fruity and floral flavours in several wines, as described by Selli *et al*. (2006b) and their work in *Vitis vinifera* L. cv Narince.

While both natural fermentation and extended skin contact have been shown to generate wines with improved aroma and flavour for several white cultivars, research on their influence on Chenin blanc is limited. The current study evaluated the effect that these two oenological practices have on the chemical signature and sensory character of Chenin blanc. Grapes from two different industrial cellars were used for the natural fermentation. There were two treatments; the naturally fermented wine was compared to an inoculated wine. The yeast diversity within the natural fermentations from the two different vineyards was investigated using polymerase chain reaction (PCR). For the skin contact wines, grapes from one cellar were used and there were three treatments, a control which had no skin contact, a wine which was subjected to 12 hours of skin contact before fermentation and a wine which was fermented on the skins.

2. Materials and methods

All wines were made with Chenin blanc grapes from the 2013 harvest, and the winemaking processes are described below.

2.1 Grape origin and winemaking procedures

Grapes from two different vineyards in the Western Cape province of South Africa were used for this project.

2.1.1 Natural fermentation

The first vineyard was block 17 of Riebeek Cellars vineyards, located in Riebeek Kasteel, Western Cape, South Africa. Grapes were harvested from every fourth row, picked using latex gloves that were sterilised with alcohol and placed into sterile plastic bags in order to preserve the yeasts present on the surface of the bunches. Approximately 50 kg of Chenin blanc grapes were harvested and transported to Stellenbosch University Experimental Cellar for processing. There the grapes were destemmed, crushed and placed in 25 L buckets. The crushed grapes were subsequently treated with pectolytic enzyme at a concentration of 0.03 mL/L (Rapidase Vino Super, DSM Food Specialities, Lot: 212160250, BB: 05/2014) .The addition of pectolytic enzyme facilitates the extraction of juice from skins (Ribereau-Gayon *et al*., 2006). After the addition of the enzyme, the crushed grapes were stored at 4°C overnight. The grapes were then pressed and approximately 50 L of juice was recovered. The juice was allowed to settle overnight at 4°C, racked and placed into six sterile 4 L glass fermentation flasks fitted with fermentation caps. As illustrated in Fig. 1, three flasks were left to ferment naturally, while the other three were inoculated with *S. cerevisiae* Vin 7 (Anchor Yeast, South Africa) at a concentration of 0.3 g/L (10^6 cfu/mL). These fermentations served as a control. Fermentation was performed at 15°C. Routine wine parameters, specifically: glucose, fructose and ethanol were monitored throughout the fermentations. A 30 mL sample from each fermentation was taken at 24 hour intervals and analysed using Fourier transform mid-infrared spectroscopy (WineScan Instrument, Foss Analytical, Hillerød, Denmark). The PLS calibration models used were those described by Nieuwoudt *et al.* (2004). At the end of fermentation the sulphur dioxide content of the wines was increased to 50 ppm. Bentonite was added to clarify the wine (Marchal

& Waters, 2010), which was left at room temperature for 2 hours before being placed at -4°C for 2 weeks. The wine was then filtered, bottled and stored at 15°C.

The second set of grapes came from a vineyard in Durbanville, Cape Town, owned by Douglas Green Bellingham (DGB) commercial cellar (Wellington, Western Cape, South Africa). An inoculated and a naturally fermented wine were produced at the commercial cellar, on a larger scale (300 L) than the Riebeek wines. As the wine was made at the cellar, the yeasts used were the combination usually selected for Chenin blanc. In addition, grapes from the same harvest were transported to the university cellar, where wines with varying periods of skin contact were made (described in section 2.1.2.).

The inoculated and naturally fermented wines were made on an industrial scale at the DGB commercial cellar in Wellington, using four, 5th fill 2009 Francois Feres (France) barrels of 300 L capacity (Fig. 1). Two barrels were inoculated with a mixture of D47, D256, Cy3079 and L2056 *S. cerevisiae* yeast (Lalvin, Lallemand, South Africa). The yeasts were rehydrated separately and then added individually to the grape juice at dosages of 0.07 g/L. The other two barrels were left to ferment naturally. Thirty millilitre samples were taken at the cellar daily and frozen for analysis with spectroscopy, as previously described. Once alcoholic fermentation was complete, i.e. fermented to dryness (less than 9 g/L glucose and fructose, as monitored with the Winescan instrument) 20 L samples were removed from each barrel and taken to the university cellar where the wines were filtered and bottled. The bottled wine was stored at 15°C.

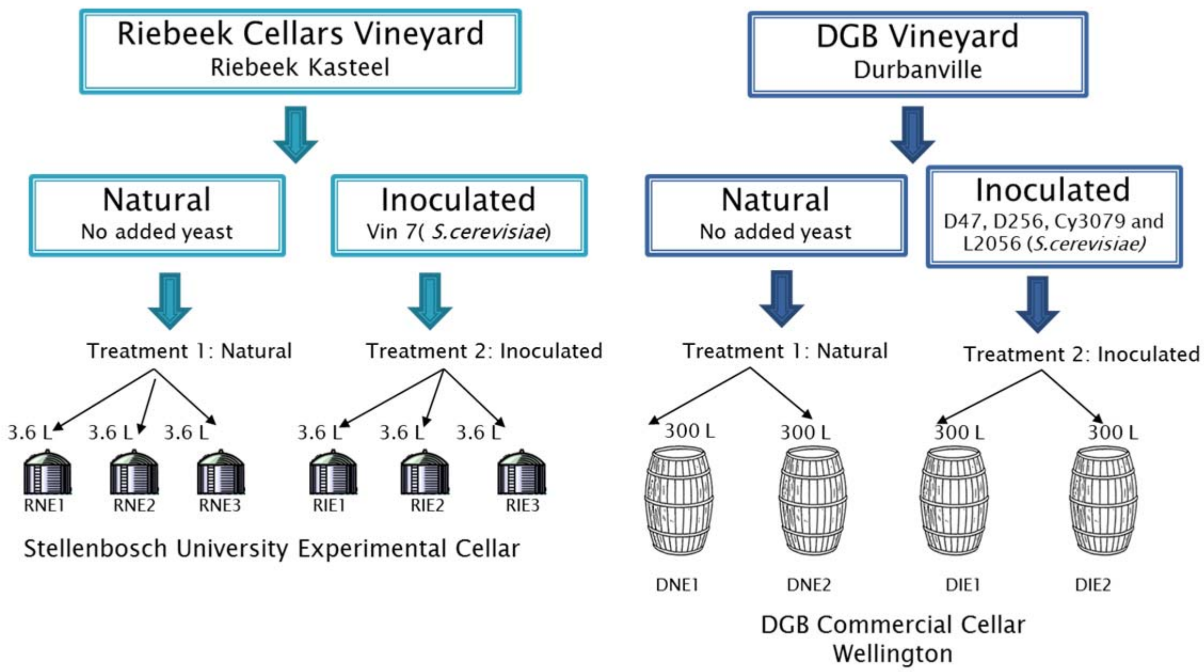


Figure 1 A schematic representation of the winemaking process for the grapes from both Riebeek and DGB cellars, for the naturally fermented and inoculated wines. RNE: Riebeek natural fermentation, RIE: Riebeek inoculated fermentation, DNE: DGB natural fermentation, DIE: DGB inoculated fermentation. (number after sample denotes the repeat).

2.1.2 Skin contact fermentation

Another 500 kg of grapes from the DGB vineyard were brought to the university experimental cellar. The grapes were destemmed and crushed and the juice split into nine 50 L buckets. Pectolytic enzyme was added to each bucket at a concentration of 0.03 mL/L along with sulphur dioxide at a concentration of 30 mg/L. The nine buckets were split between three treatments, as illustrated in Fig. 2.

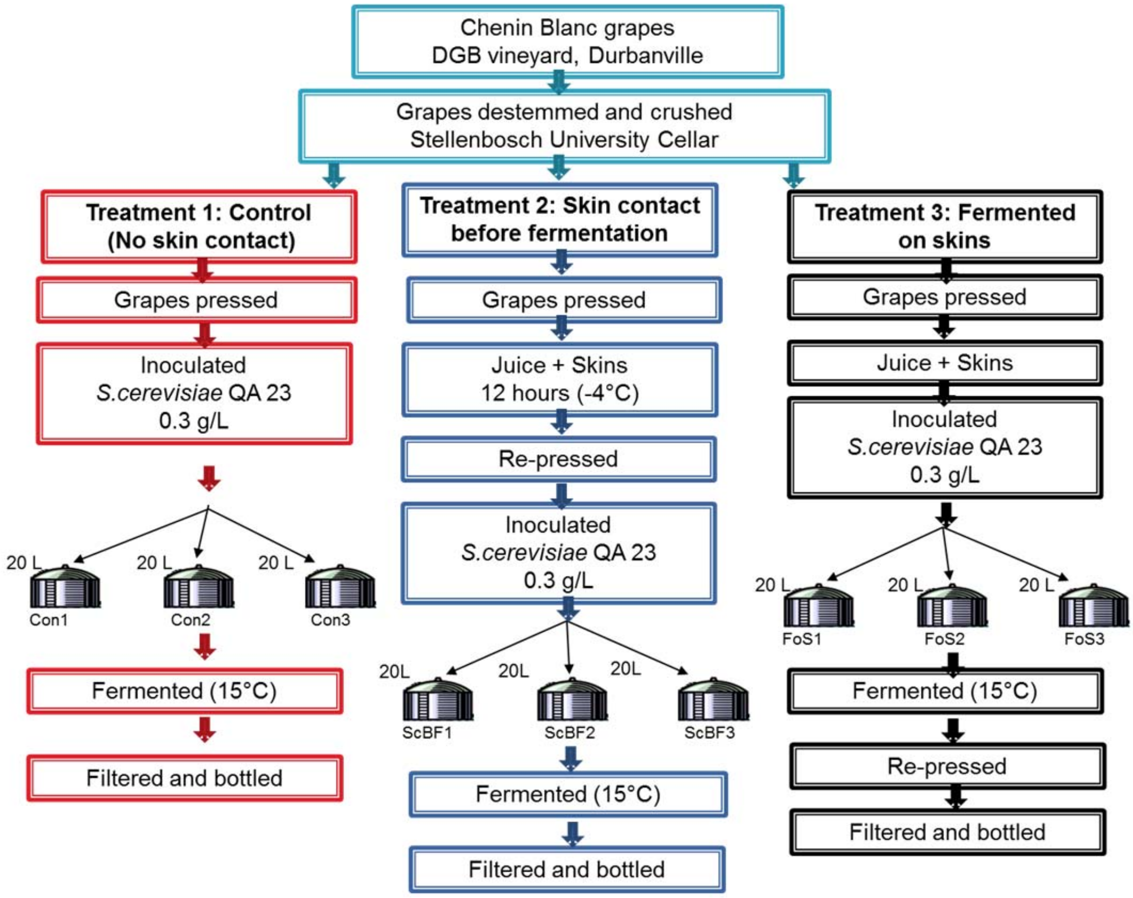


Figure 2 Winemaking process flow for skin contact wines. Con: Control (no skin contact), ScBF: 12 hours skin contact before fermentation, FoS: fermented on skins.

For the control (Treatment 1, Fig. 2), following enzyme treatment and settling, the juice was inoculated with 0.3 g/L of *S. cerevisiae* QA 23 (Lalvin, Lallemand, South Africa) and left to ferment at 15°C.

For the second treatment, skin contact before fermentation (ScBF), (Treatment 2, Fig. 2), a third of the volume of skins was added back to the juice, and treated with 0.3 g/L pectolytic enzyme at placed at -4°C for 12 hours. This mixture was re-pressed and the juice was then placed in a 20 L fermentation canister, inoculated with 0.3 g/L of *S. cerevisiae* QA 23 and left to ferment to dryness at 15°C.

For the third treatment, fermentation on skins (FoS), (Treatment 3, Fig. 2), a third of the volume of skins was added back into the juice followed by addition of pectolytic enzyme and 0.3 g/L of QA 23 , South Africa. The juice was left at room temperature overnight and thereafter moved to 15°C for the duration of the alcoholic fermentation. The grape skins were punched down once a day throughout the fermentation process. The wine containing the skins was re-pressed at the end of fermentation.

All three treatments were done in triplicate. The fermentations were monitored daily by weighing the canisters. The conversion of the sugars to carbon dioxide is proportional to the weight loss and when no further weight loss was observed, the sugar concentrations were checked with the Winescan. At the end of fermentation the sulphur dioxide content of the wines was increased to 50 ppm. Bentonite was added to clarify the wine (Marchal & Waters, 2010), which was left at room temperature for two hours before being placed at -4°C for two weeks. The wine was subsequently filtered and bottled and stored at 15°C.

2.2 Microbiological analysis of naturally fermented and inoculated wines

Samples from the experimental Riebeek wine fermentations, as well as samples received from the DGB cellar, from the early stages of natural fermentation, were serially diluted with sterile physiological salt solution (0.9% (w/v) NaCl). For the enumeration of yeasts, 100 µL samples were spread onto two different sets of Wallerstein (WL) nutrient agar (Fluka Analytical) plates, in triplicate. The plates were supplemented with 100 mg/L chloramphenicol (Sigma-Aldrich) to inhibit the growth of bacteria (Li *et al*., 2010). One set of plates contained 1 mg/ L cycloheximide (Sigma-Aldrich) which was used to identify non-*Saccharomyces* as it inhibits the growth of *S. cerevisae.* The plates were incubated at 30°C for a week. A representative of the colonies were chosen and streaked onto WL in triplicate.

Test tubes containing 10 mL of yeast extract-peptone-dextrose (YPD) broth were inoculated with single pure colonies. These tubes were then incubated on a roller drum, at 30°C for 24 hours. The genomic DNA of each representative yeast strain was extracted using a yeast genomic DNA extraction kit (Promega) according to the manufacturer's instructions. The primers used for amplification of ITS1-5.8S rRNA-ITS2 region were ITS1 (5′-TCCGTAGGTGAACCTGCGG-+3′) and ITS4 (5′-TCCTCCGCTTATTGATATGC-3′) (Li *et al*., 2010). The DNA amplifications were carried out in a total volume of 50 µL containing 1 U GoTaq DNA polymerase (Promega), 1×GoTaq® flexi reaction buffer, 2.5 mM of each dNTP, 1.5 mM $MgCl_2$, 0.3 µM of each primer and 5–25 ng template DNA. The PCR reaction was performed on a GeneAMP® PCR System 9700 (Applied Biosystems). The PCR conditions were as follows: initial denaturation at 95 °C for 5 min; 35 cycles of denaturing at 94 °C for 1 min; annealing at 55.5 °C for 2 min, an extension at 72 °C for 2 min; and a final extension step of 10 min at 72 °C (Li *et al*., 2010). The PCR products were subsequently subjected to restriction analysis with the restriction endonucleases *Cfo*I (Promega) and *Hin*fI (Thermoscientific), according to the manufacturer's instructions. PCR products and their restriction fragments were separated on 1% and 2% (w/v) agrose gels respectively, containing GelRed (Biotium), at 120 V constant voltage for 1 hour. A 100-bp plus (Thermoscientific) DNA ladder marker was used as size standard. The gels were photographed using a UV Trans-illuminator geneXviewer.

2.3 Chemical analysis of major volatiles and thiols

Gas chromatography with flame ionisation detection (GC-FID) (AJ & W DB-FFAP capillary GC column; Agilent, Little Falls, Wilmington, DE) was used to analyse all the wine samples for major volatiles in the Chemical Analytical Laboratory, Department of Viticulture and Oenology, Stellenbosch University. One bottle of each treatment was freshly opened for the analysis. One extraction per wine was done and injected in triplicate as described by Louw *et al*. (2009). The average values per treatment were then calculated. The major volatiles quantified with GC-FID were: ethyl acetate, methanol, ethyl butyrate, propanol, isobutanol, isoamyl acetate, butanol, isoamyl alcohol, ethyl hexanoate, pentanol, hexyl acetate, acetoin, 3-methyl-1-pentanol, ethyl lactate, hexanol, 3-ethoxy-1-propanol, ethyl caprylate, acetic acid, ethyl-3-hydroxybutanoate, propionic acid, isobutyric acid, butyric acid, ethyl caprate, isovaleric acid, diethyl succinate, valeric acid, ethyl phenylacetate, 2-phenylethyl acetate, hexanoic acid, 2-phenylethanol, octanoic acid and decanoic acid.

The three skin contact treatments, and their replicates, nine wines in total, were also analysed for two volatile thiols, namely 3-mercaptohexylacetate (3MHA) and 3-mercaptohexanol (3MH). Ultraperformance liquid chromatography with triple quadrupole mass spectrometry UPLC-MS/MS (XEVO-TQ, Waters) was used to quantify the volatile thiols, according to the method described by Piano *et al*. (*in press*) based on work by Roland *et al*. (2011). The analysis was done by the Stellenbosch University Central Analytical Facility.

2.4 Sensory analysis

2.4.1 Projective mapping and wines used

Given the large number of samples and the limited amount of some of the wines, projective mapping, a version of napping (Risvik *et al*., 1994) was used. A holistic approach to projective mapping was taken and the wines were mapped according to aroma, taste and mouthfeel, as described by (Dehlholm *et al*., 2012).

2.4.2 Panel

Stellenbosch University’s Department of Viticulture and Oenology’s trained panel of nine judges was used. The panel consisted of nine females, ranging between the ages of 27 and 45; they had experience in descriptive sensory analysis of wine and were paid for their participation.

2.4.3 Panel training

Panel training consisted of three 2-hour sessions. The panel was trained and calibrated on aroma and taste. Basic taste, solutions at varying concentrations were given to the panellists, who had to identify the taste/mouth-feel (sweet, sour, bitter and astringent) and rate it. For aroma calibration panellists were given aroma standards for all the aromas on the Chenin blanc tasting wheel (Addendum A) and had to identify them blind. The aroma training was done to ensure some level of consistency in descriptors used. The panellists then practiced the mapping procedure using commercial Chenin blanc wines, they arranged samples according to sensory similarities and then described the aroma and taste of individual or groups of samples. This "practice" session was done to make sure the panel understood what would be required of them during testing.

2.4.4 Wine samples and evaluation

Nineteen Chenin blanc wines, (natural, inoculated and skin contact) were evaluated (Table 1). Thirty millilitre samples were presented in black wine glasses (ISO NORM 3591, 1977). Samples were covered with petri dish lids and kept at 15°C. Testing took place in air conditioned, light controlled rooms (ISO NORM 8589, 1988). Samples were coded with unique three-digit codes and presented in a randomised order. Panellists were supplied with a large piece of white A2 paper dimensions (420 mm X 594 mm), water and crackers. They were instructed to position samples on the sheet of paper according to sensory similarity, i.e. samples with very similar aroma and/or taste close together and samples that are very different far apart. Panellists were also asked to generate aroma and taste descriptors for each sample or group of samples. Two repeats were done in one session, with a 15 minute break between them. Once the glasses were arranged to their liking, they were asked to mark the position on the page with a cross and write the samples' codes next to it, as shown in Addendum B.

The bottom left hand corner of the page was taken as the origin and the co-ordinates of the middle of each cross marked on the pages by the panellists, was measured in centimetres (Addendum C). The attributes generated for each sample and the X and Y co-ordinates were captured in *Microsoft Excel 2010*. When an attribute was present it was given a score of 1 and when it was absent, it is given a 0 score (Addendum C).

Table 1 Chenin blanc wines evaluated by projective mapping.

Wine	Grape Origin	Code	Treatment	Volume (L)
A	DGB	DIE1	Inoculated Barrel 1	300
B	DGB	DIE 2	Inoculated Barrel 2	300
C	DGB	DNE 1	Natural Barrel 1	300
D	DGB	DNE 2	Natural Barrel 2	300
E	Riebeek	RNE 1	Natural	4
F	Riebeek	RIE 1	Inoculated	4
G	Riebeek	RNE2	Natural	4
H	Riebeek	RIE 2	Inoculated	4
I	Riebeek	RNE 3	Natural	4
J	Riebeek	RIE 3	Inoculated	4
K	DGB	Con 1	Control	20
L	DGB	Con 2	Control	20
M	DGB	Con 3	Control	20
N	DGB	ScBF 1	12 hr skin contact before fermentation	20
O	DGB	ScBF 2	12 hr skin contact before fermentation	20
P	DGB	ScBF 3	12 hr skin contact before fermentation	20
Q	DGB	FoS 1	Fermented on skins	20
R	DGB	FoS 2	Fermented on skins	20
S	DGB	FoS 3	Fermented on skins	20

2.5. Data analysis

2.5.1 Statistical analysis of chemical data

One-way analysis of variance (ANOVA) was performed on the GC-FID and volatile thiols data using Addinsoft XLStat v2013.5.04, in order to determine if there were significant differences between compounds, and to establish whether there was a treatment effect. The ANOVA was followed by Fisher's least significant difference (LSD) test. Differences between samples with a significance level of 5% ($p \leq 0.05$) were considered significant. This was followed by multivariate analysis, specifically principal component analysis (PCA) using SIMCA-P 13.0 software, (Umetrics, Sweden) in order to obtain a clearer overview of the chemical differences between samples and any possible correlations that could be made. PCA is a data compression technique that is useful for obtaining an overview of the relationships between samples and variables, while the main variation in the data is projected onto a few latent variables (Wold et al., 1987). The chemical data was scaled by unit variance.

The odour activity value (OAV) for each chemical compound measured, was also calculated, by dividing the mean concentration of the compound by its odour activity level (Guth, 1997). Chemical compounds with OAV's greater than one are likely to contribute to the odour of wine (Malherbe *et al*., 2012).

2.5.2 Statistical analysis of projective mapping data

Correspondence analysis was done on the descriptor data using StatSoft STATSTICA 12®. This was followed by a multiple factor analysis (MFA) on the co-ordinates captured for all panellists. The MFA was done in Addinsoft XLSTAT v.2013.5.04, as described by Abdi and Valentin (2007) and Louw *et al*. (2013).

3. Results and discussion

3.1 Wine fermentation

3.1.1 Fermentation kinetics

The fructose, glucose and ethanol concentrations of both the Riebeek and DGB natural and inoculated wines were monitored throughout the fermentation process. Figures 3 and 4 depict the sugar consumption and ethanol production rates of the different fermentations. All the wines fermented to dryness, in varying periods of time. The Riebeek inoculated fermentation took 10 days to complete, where the natural took 15 days (Fig. 3) and the DGB inoculated fermentation took seven days, while the natural took 16 days (Fig. 4).

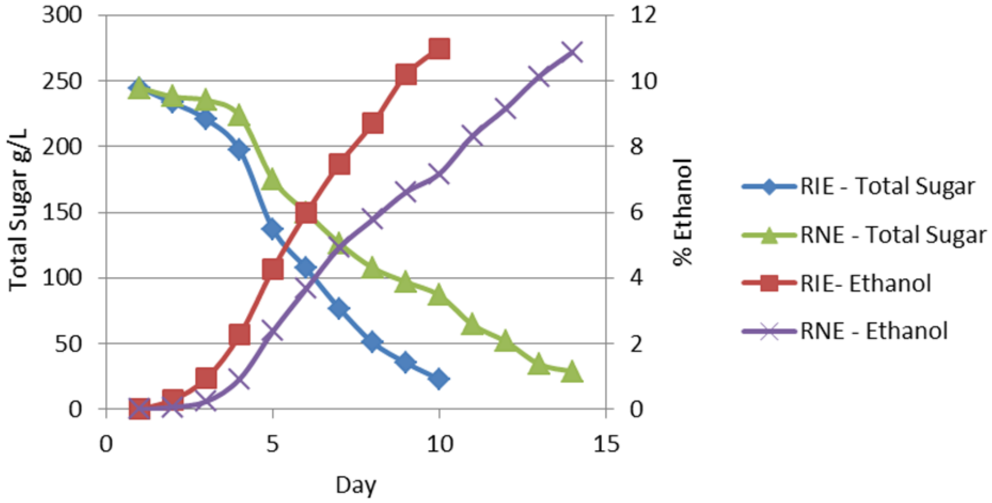


Figure 3 Scatterplot of total sugar (glucose+fructose) depletion vs. ethanol evolution rate for the Riebeek natural and inoculated fermentations. RIE: Riebeek inoculated, RNE: Riebeek natural.

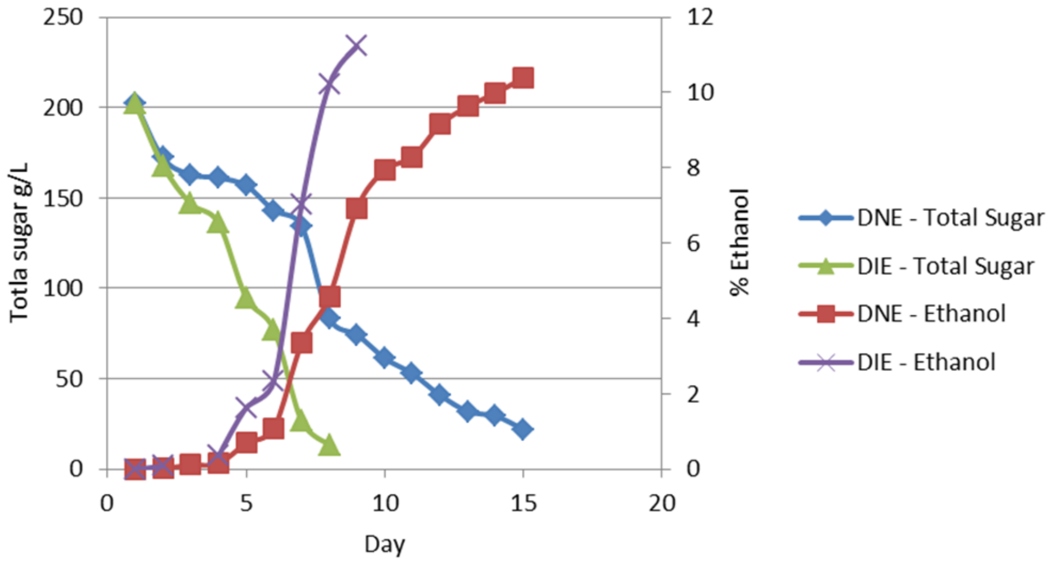


Figure 4 Scatterplot of total sugar (glucose+ fructose) depletion vs. ethanol evolution rate for the DGB natural and inoculated fermentations. DNE: DGB natural fermentation, DIE: DGB inoculated fermentation.

Both cellars fermentations displayed similar kinetics, with the inoculated fermentations generally being faster than the natural fermentation (Fig. 3; Fig. 4).

The final ethanol level in both the RIE and RNE fermentations was the same (Fig. 3), however with the DGB fermentations, the final level of ethanol was 1% (v/v) higher in the DIE fermentation (Fig. 4). When comparing the DGB and Riebeek fermentations it is evident that they follow the same general trend, although the ethanol production in the DGB wine is slower, but this could be due to the fact that the DGB fermentation (Fig. 4) was conducted at a much larger industrial scale, 300 L barrels, than the Riebeek fermentation (Fig.3), which were in 4 L vessels in the university's experimental cellar. Natural fermentation has been found to be slower because wild yeast exists on grapes in much smaller numbers than a dose of inoculated yeast. It therefore takes longer for wild yeast to colonize and for the consumption of the sugars to begin (Chorniak, 2005).

3.1.2 Yeast diversity during fermentation

It was of interest to look at whether the yeast populations present in fermenting must differed between vineyards. Based on the ITS region and *Cfo*I and *Hin*f I RFLP patterns, the Riebeek cellar juice sample had 6 different yeast profiles and DGB had 5 different profiles. However, the following table shows the most dominant yeast species identified during the natural fermentations (Table 2).

Table 2 The dominant yeast species identified in naturally fermenting grape musts.

Vineyard	Yeast Species
Riebeek	*Hanseniaspora* spp. (mainly *H. uvarum*)
	Saccharomyces cerevisiae
	Zygosaccharomyces bailii
DGB	*Hanseniaspora* spp. (mainly *H. uvarum*)
	Torulaspora delbrueckii
	Saccharomyces cerevisiae

From the results of the profiles of the isolates that were identified, it was clear that the non-*Saccharomyces* yeasts identified in the natural fermentations differed between the two vineyards. The must from the Riebeek vineyard contained *Hansenispora and Zygosaccharomyces* (Table 2), while the must from the DGB vineyards contained *Torulaspora and Hanseniaspora* (Table 2).

Hanseniaspora uvarum was present in both fermentations, and is one of the most common non-*Saccharomyces* yeasts that are found in wine (Romano *et al*., 2003b). In mixed fermentation, with *S. cerevisae*, it has been shown to produce higher concentrations of alcohols, esters and fatty acids (Jolly *et al*., 2013). Although *H. uvarum* was previously known for its production of off flavours, studies have shown it to have a positive influence on Sauvignon blanc wine flavour, when fermented in combination with *S. cerevisae* (Jolly *et al*., 2003b). From research on Riesling wine it was found that naturally fermented musts that contained yeasts belonging to the *Hanseniaspora* genus, had higher fruity aromas, than inoculated fermentations (Moreira *et al*., 2008).

Torulaspora delbrueckii (*T. delbrueckii)*, was one of the first non-*Saccharomyces* yeast strains to be commercialised (Jolly *et al*., 2013). Jolly and co-workers (2003b) did research on the effect of co-inoculation of *T. delbrueckii* and *S. cerevisiae* on Chenin blanc wine quality. Results showed the co-inoculated wines to be of a higher quality than the wines inoculated with *S. cerevisae* only.

Zygosaccharomyces bailii (Z. bailii) was previously considered to be a spoilage organism as it is able to withstand unfavourable conditions (high sugar levels, high ethanol levels, low pH, SO_2) as well as initiate re-fermentation during the storage of wine (Loureiro & Malfeito-Ferreira, 2003). However, more recent research has shown that when used in combination with *S. cerevisiae*, *Z. bailii* had positive effects on wine taste, and a commercial strain of this yeast have been produced, with the main function of re-starting stuck fermentations (Jolly *et al*., 2013).

3.2 Volatile composition of the wines

A total of 32 major volatiles were quantified with GC-FID in the naturally fermented and inoculated bottled wines. The analysis was done 7 months after bottling. Table 3 shows the results of the ANOVA, as well as the calculated OAV’s for the naturally fermented and inoculated wines from both Riebeek and DGB.

Table 3 The mean concentrations (mg/L) and OAV values of the major volatiles for the natural and inoculated wines. OAV: Odour activity value, RNE: Riebeek natural wine, RIE: Riebeek inoculated wine, DNE: DGB natural wine, DIE: DGB inoculated wine. Different alphabetical letters in the same row indicate significant differences (p<0.05).

Chemical Compound	**RNE**		**RIE**		**DNE**		**DIE**	
	Mean	**OAV**	**Mean**	**OAV**	**Mean**	**OAV**	**Mean**	**OAV**
Esters								
Ethyl acetate	72.15ab	>1	100.13c	>1	75.97a	>1	87.86b	>1
Ethyl butyrate	0.55c	>1	0.47b	>1	0.40a	>1	0.35a	>1
Ethyl caprate	1.85b	N.A	1.45a	N.A	2.02b	N.A	1.44a	NA
Ethyl caprylate	1.06b	>1	0.95a	>1	1.22c	>1	0.93a	>1
Ethyl hexanoate	25.13a	0.16	27.00b	0.17	87.13c	0.56	24.18a	0.16
Ethyl lactate	1.32c	0.07	1.23ab	0.06	1.19a	0.06	1.26bc	0.06
Ethyl-3-hydroxybutanoate	5.06b	>1	6.88c	>1	2.87a	>1	4.03ab	>1
Ethyl phenylacetate	0.10b	0.15	0.13c	0.20	0.09b	0.14	0.05a	0.08
Isoamyl acetate	0.02a	0.01	0.06a	0.04	0.07a	0.05	0.07a	0.05
Hexyl acetate	0.53a		0.48a		1.08c		0.73b	
Diethyl succinate	0.82a	0.00	0.89a	0.00	2.93c	0.01	1.78b	0.01
2-Phenylethyl acetate	0.84b	>1	0.90b	>1	0.70a	>1	0.84b	>1
Total esters	109.43		140.57		175.67		123.52	
Higher alcohols								
Methanol	102.36ab	0.20	104.57ab	0.21	91.66a	0.18	92.57a	0.19
Propanol	27.56a	0.09	33.47b	0.11	33.61b	0.11	29.61a	0.10
Isobutanol	20.23a	0.51	30.56c	0.76	23.53b	0.59	40.88d	>1
Butanol	1.02a	0.01	0.97a	0.01	1.93c	0.01	1.62b	0.01
Isoamyl alcohol	132.97a	>1	168.30c	>1	147.51b	>1	193.08d	>1
Pentanol	0.39a	0.01	0.39a	0.01	0.41ab	0.01	0.41ab	0.01
3-Methyl-1-pentanol	0.11ab	0.11	0.01a	0.01	0.13ab	0.13	0.14b	0.14
Hexanol	1.07a	0.13	0.98a	0.12	1.74bc	0.22	1.49b	0.19
3-Ethoxy-1-propanol	1.83a	>1	2.12a	>1	1.66a	>1	2.12a	>1
2-Phenylethanol	13.57a	0.97	15.78b	>1	11.71a	0.84	23.18c	>1
Total higher alcohols	301.11		357.15		313.89		385.1	
Carbonyl compounds								
Acetoin	2.29a	0.02	2.44ab	0.02	16.62c	0.11	3.70b	0.02
Acids and fatty acids								
Acetic acid	437.64a	>1	807.18d	>1	714.59c	>1	577.95b	>1
Propionic acid	1.33a	0.07	1.81a	0.09	0.75a	0.04	0.73a	0.04
Isobutyric acid	1.03a	0.45	1.98bc	0.86	1.34a	0.58	2.51c	>1
Butyric acid	1.97bc	>1	1.81ab	>1	1.90bc	>1	1.63a	>1
Isovaleric acid	0.88a	>1	1.17ab	>1	0.94a	>1	1.44b	>1
Valeric acid	0.41a		0.50a		0.42a		0.40a	
Hexanoic acid	6.28d	>1	5.27b	>1	5.77c	>1	4.62a	>1
Octanoic acid	10.05d	>1	7.66b	>1	8.84c	>1	6.97a	>1
Decanoic acid	4.08bc	>1	3.50a	>1	4.99d	>1	4.28c	>1
Total acids and fatty acids	463.67		830.88		739.54		600.53	

For nine of the quantified compounds there were no significant differences between the wines; namely: isoamyl acetate, methanol, pentanol, 3-methyl-1-pentanol, 3-ethoxy-1-pentanol, and propionic, butyric, isovaleric, and valeric acids (Table 3).

With regard to the esters, both naturally fermented wines (DNE and RNE) had higher concentrations of ethyl caprylate and lower concentrations of ethyl acetate, ethyl-3-hydroxybutanoate than the inoculated wines DIE and RIE, respectively. When comparing the ester concentration in RNE and RIE, RNE was higher in ethyl butyrate, ethyl caprate, ethyl caprylate and ethyl lactate; and lower in ethyl acetate, ethyl hexanoate, ethyl-3-hydroxybutanoate and ethyl phenylacetate. The esters that had OAV's >1 are ethyl acetate, ethyl butyrate, ethyl caprylate, ethyl-3-hydroxbutanoate and 2-phenylethyl acetate.

When comparing the total ester concentrations, RIE had a higher concentration than RNE, but DNE had a higher concentration than DIE. The increased ester concentration in DNE could be due to the two most dominant non-Saccharomyces species identified in the wine, *Torulaspora* and *Hanseniaspora* (Table 2). Both of these non-saccharomyces yeasts are known for their increased ester production in wine (Jolly *et al*., 2013).

Looking at the total alcohol concentrations, both natural fermentations had lower concentration than the inoculated ones. The alcohols with OAV's >1, were isoamyl alcohol, 3-ethoxy-1-propanol and 2-phenylethanol (Table 3).

The DNE (DGB natural) had significantly higher concentrations of acetoin, than the DIE (DGB inoculated) and the Riebeek wines (RIE and RNE). A possible reason for the increased levels of acetoin in the DNE could suggest a significant contribution by *Hanseniaspora* spp. in this fermentation (Table 2) since these yeasts, especially *Hanseniaspora uvarum,* are known for their production of high levels of acetoin (Romano *et al*., 1993). Although the acetoin concentration in DNE was significantly higher, 16.62 mg/L, compared to 2.29, 2.44 and 3.07 mg/L in the other wines, it was still below the threshold concentration of 150 mg/L. It also had an OAV <1, and was therefore not likely to contribute significantly to the aroma of the wine.

The DNE wine had a higher concentration of acetic acid than the DIE wine, whereas the RIE wine had almost a two-fold increase in acetic acid concentration over the RNE wine (Table 3). The elevated concentration of acetic acid in the DNE wine could be due to the presence of *Zygosccharomyces* in the fermentation (Table 2), which is known for its production of acetic acid (Jolly et al., 2013).

Both the naturally fermented wines, RNE and DNE, had significantly higher concentrations of hexanoic acid, octanoic acid and decanoic acid (Table 3). A possible reason for the increased concentrations is that both of these naturally fermented wines contained *Hanseniaspora spp*., specifically *H.uvarum* which is also known to cause increased concentrations of fatty acids in wine (Table 2).

In general, the types of yeasts present in the fermentations seem to have a significant effect on the ester, carbonyl compound, acid and fatty acid concentrations, as there were no trends that could be observed, however, both the inoculated wines had higher concentrations of higher alcohols than their respective natural wines.

A total of 32 major volatiles were quantified in the nine (three treatments and three repeats) skin contact wines. The concentration of two volatile thiols (3MHA 3-mercaptohexylacetate and 3MH 3-mercaptohexanol) was also measured. The odour activity values for each of the chemical compounds were calculated, for each wine. Table 4 shows the results for the DGB skin contact wines.

Table 4 The mean concentrations and OAV values of the major volatiles (mg/L) and thiols (µg/L) for the skin contact wines. OAV: odour activity value, Con: Control wine (no skin contact), ScBF: 12 hours skin contact before fermentation wine, FoS: fermented on skins wine, n.d: not detected. Different alphabetical letters in the same row indicate significant differences ($p<0.05$)

Chemical Compound	**Con**		**ScBF**		**FoS**	
	Mean	**OAV**	**Mean**	**OAV**	**Mean**	**OAV**
Esters						
Ethyl acetate	72.71c	>1	65.99b	>1	56.94a	>1
Ethyl butyrate	0.59c	>1	0.52b	>1	0.26a	>1
Ethyl caprate	1.60c		1.39b		0.29a	
Ethyl caprylate	1.36c	>1	1.14b	>1	0.56a	>1
Ethyl hexanoate	17.58a	0.11	18.36a	0.12	21.94b	0.14
Ethyl lactate	1.33a	0.07	1.37ab	0.07	1.39b	0.07
Ethyl-3-hydroxybutanoate	4.73c	>1	3.25b	>1	1.805a	>1
Ethyl phenylacetate	0.63b	0.97	0.67c	>1	0.08a	0.12
Isoamyl acetate	0.14b	0.09	0.05a	0.03	n.d*	
Hexyl acetate	0.76b		0.68b		0.18a	
Diethyl succinate	1.09a	0.01	1.20a	0.01	1.44b	0.01
2-Phenylethyl acetate	0.85c	>1	0.72b	>1	0.59a	>1
Total esters	103.37		95.34		85.48	
Higher alcohols						
Methanol	78.86a	0.16	102.76b	0.21	224.30c	0.45
Propanol	48.07a	0.16	59.80b	0.20	74.82c	0.24
Isobutanol	27.87a	0.70	31.51b	0.79	48.08c	>1
Butanol	1.57b	0.01	1.47a	0.01	2.51c	0.02
Isoamyl alcohol	237.56a	>1	269.80b	>1	369.35c	>1
Pentanol	0.41a	0.01	0.42a	0.01	0.52b	0.01
3-Methyl-1-pentanol	0.25a	0.25	0.24a	0.24	0.30b	0.30
Hexanol	1.96a	0.25	2.34b	0.29	3.80c	0.48
3-Ethoxy-1-propanol	8.26a	>1	10.35c	>1	9.16b	>1
2-Phenylethanol	28.81a	>1	33.00b	>1	57.37c	>1
Total higher alcohols	433.62		511.69		420.86	
Carbonyl compounds						
Acetoin	3.12a	0.02	2.83a	0.02	5.50b	0.04
Acids and fatty acids						
Acetic acid	556.33bc	>1	511.81b	>1	403.10a	>1
Propionic acid	5.26ab	0.26	3.59ab	>1	10.13b	0.51
Isobutyric acid	1.91a	0.83	2.34ab	>1	2.64c	>1
Butyric acid	2.26c	>1	2.13bc	>1	1.79a	>1
Isovaleric acid	2.05a	>1	2.20a	>1	3.37b	>1
Valeric acid	0.40a		0.40a		0.52a	
Hexanoic acid	5.18c	>1	4.49b	>1	2.83a	>1
Octanoic acid	6.67c	>1	5.74b	>1	2.05a	>1
Decanoic acid	3.96bc	>1	3.60b	>1	2.38a	>1
Total acids and fatty acids	584.02		536.3		428.81	

Table 4 continued

Chemical Compound	**Con**		**ScBF**		**FoS**	
	Mean	**OAV**	**Mean**	**OAV**	**Mean**	**OAV**
Thiols						
3MHA(3-mercaptohexylacetate)	34.76a	>1	19.26a	>1	n.d	
3MH (3-mercaptohexanol)	395.71a	>1	554.23b	>1	365.11a	>1
Total thiols	430.47		573.49		365.11	

A vast amount of literature dealing with chemistry of skin contact in white wines, looks at phenolic compounds (Rodriguez-Bencomo *et al*., 2008; Maggu *et al*., 2013), not much information is available about the aroma compounds, esters, higher alcohols, acids and fatty acids. The general trend observed with the total esters was a decline in concentration as the duration of skin contact time increased (Table 4). There were two exceptions ethyl hexanoate and ethyl lactate, which increased proportionately with prolonged skin contact, but had OAV's <1 (Table 4). The concentration of ethyl phenylacetate, was higher with the limited (12 hours) skin contact, but decreased when the wine was fermented on the skins (Table 4), while the isoamyl acetate concentration decreased from 0.14 to 0.05 mg/L with 12 hours of skin contact and was not detected in the FoS sample (Table 4). The hexyl acetate concentration was significantly decreased and diethyl succinate concentration was significantly increased with the fermentation on skin treatment (Table 4). Research on Chenin blanc (Baumes *et al*., 1989) and on other white varietals (Selli *et al*., 2006a; Rodriguez-Bencomo *et al*., 2008) showed a general increase in ester concentration. The difference in findings may be due to a number of reasons including, different time and temperature combinations for the treatment, the use of different yeast, as well as the terroir in which the grapes were grown and the resultant volatile precursors in the grapes.

The general trend observed for the higher alcohol concentrations was an increase, as the length of skin contact time increased (Table 4). This confirms what was found by Selli *et al*. (2003; 2006a) and their work on *Vitis vinifera* L. cv Narince wine. The two exceptions to this trend were butanol and 3-ethoxy-1-propanol, which increased in concentration with limited skin contact (12 hours), but decreased when the wine was fermented with the skins (Table 4). Methanol production is a result of enzymatic degradation of pectin in grape berries and is therefore skin contact dependant (Cabaroglu, 2005), hence the increased levels in the ScBF and FoS treatments. The average methanol concentration measured by Lawrence in her work on chemical profiling of commercial Chenin blancs was 90.95 mg/L (2012). White wine generally contains methanol in much lower concentrations (>150) as the period of contact with the grape skins is normally of short duration. However, with an OAV value of 0.45 (Table 4), it can be assumed that methanol did not strongly affect the overall aroma of the wine.

Acetoin was the only carbonyl compound quantified in these Chenin blanc samples. There was no significant difference between the control (Con) and the limited skin contact wine (ScBF), but the concentration increased significantly from 3.12 and 2.83 mg/L to 5.05 mg /L when the wine was fermented on the skins (Table 4). Acetoin had an OAV <1, was present far below the threshold concentration of 150 mg/L, and was therefore not likely to contribute to the overall aroma of the wine.

With regard to the fatty acid and acid concentrations, acetic-, butyric-, hexanoic-, octanoic-, and decanoic acids concentrations decreased as the duration of skin contact increased (Table 4). Propionic-, isobutyric-, and isovaleric acid concentrations increased significantly in the FoS wine but not in the ScBF wine (Table 4). In general, the skin contact treatments on Chenin blanc showed mixed effects on the acid and fatty acid concentrations confirmed by multiple studies on other cultivars (Falque and Fernandez, 1996; Cabarogul & Canbas, 2002; Selli et al., 2006a). Skin contact, as a treatment, does not seem to significantly affect the concentration of valeric acid, as is remained the same in all treatments. Acetic acid, butyric acid, isovaleric acid, hexanoic acid, octanoic acid and decanoic acid, all have OAV's >1 (Table 4) and are therefore likely to make a contribution to the final aroma of the wine.

Baumes *et al*. (1989) compared the effect of four hours of skin contact at 18°C to a control without skin contact on Chenin blanc wine quality. Although the chemical compounds measured differed a great deal, the general trends were an increase in alcohols, esters and carbonyl compound concentrations, and a decrease in acid and fatty acid concentrations. When comparing those results to what was found here for the Con and ScBF samples, although like Baumes found there was an increase in alcohols, and a decrease in acid and fatty acid concentrations, there was however a decrease in ester concentrations (Table 4). This was not what was found in this research, however, there are a number of reasons why the findings could differ. Firstly the Chenin blanc grapes were grown in different parts of the world, the grapes used by Baumes and co-workers were grown in France. The difference in terroir and climate could have had an effect on the volatile precursors in the grapes and thus effect the final concentrations of the volatiles present in the wine. A second reason why the findings could differ, is the vast difference in treatments, Baumes did a treatment of 4 hours at 18°C, where in this research, two treatments were done, skin contact of 12 hours at -4°C, and a fermentation on the skins. More investigations are necessary to evaluate the full extent of the effects of skin contact.

The volatile thiols, 3MHA and 3MH, had OAV's >1 (Table 4) and were present above their odour threshold levels. The skin contact treatment seems to effect 3MHA concentrations negatively since decreased in the ScBF treatment (Table 4 and sp values), and was notdetected in the FoS treatment. It would seem as though fermentation of Chenin blanc on the skins, completely removed the 3MHA from the wine. As for the 3MH, the ScBF treatment increased the concentration significantly, and the FoS treatment decreased the concentration, but not significantly. It would seem that 3MHA is more sensitive to the skin contact treatment that the 3MH. It is not clear what the mechanism of the effect of the skin contact o the concentrations of 3MHA is and this aspect needs further investigation.

The aroma compounds with OAV >1 and which therefore were likely to contribute to the aroma of the wines are listed in Table 5, along with their associated aromas.

Table 5 Aroma compounds with an OAV >1 and their associated odour descriptors. RIE: Riebeek inoculated wine, RNE: Riebeek natural wine, DIE: DGB inoculated wine, DNE: DGB natural wine, Con: Control wine (no skin contact), ScBF: 12 hours skin contact before fermentation wine, FoS: fermented on skins wine.

Chemical Compound	Odour Descriptors	RIE, RNE, DIE, DNE	Con, ScBF, FoS
Esters			
Ethyl Acetate	Fruity, nail polish[a]	All	All
Ethyl Butyrate	Fruity, apple[a]	All	All
Ethyl Caprylate	Fruity, apple[d]	All	All
Ethyl-3-hydroxybutanoate	Fruity, strawberry[ab]	All	All
Ethyl phenylacetate	Rose, floral[a]	All	ScBF
2-Phenylethyl acetate	Fruity, fruit jam, floral[ab]	All	All
Alcohols			
Isobutanol	Wine, solvent, bitter[a]	DIE	FoS
Isoamyl alcohol	Whiskey, malt [a]	All	All
3-Ethoxy-1-propanol	Fruity[a]	All	All
2-Phenylethanol	Honey, spice, floral[ab]	RIE, DIE	All
Acids and fatty acids			
Acetic acid	Vinegar[a]	All	All
Propionic acid	Rancid[e]		ScBF
Isobutyric acid	Butter, cheese[a]	DIE	ScBF, FoS
Butyric acid	Cheese[a]	All	All
Isovaleric acid	Cheese[a]	All	All
Hexanoic acid	Sweat[a]	All	All
Octanoic acid	Sweat, cheese[a]	All	All
Decanoic acid	Rancid, fat[a]	All	All
Volatile thiols			
3MHA (3-mercaptohexylacetate)	Passion fruit, gooseberry, guava[c]		Con, ScBF
3MH (3-mercaptohexanol)	Passion fruit, grapefruit, citrus[c]		All

[a] Malherbe et al., 2012; [b] Selli *et al*., 2006b; [c] Wilton, 2013; [d] Rojas *et al*., 2001, [e] Louw et al., 2010

The chemical compounds present in all four natural and inoculated fermentations, with an OAV >1 were mostly the same. The aromas associated with these compounds include: fruity, apple, banana, fruit jam, whiskey, malt, vinegar, sweat and cheese (Table 5). The two inoculated fermentations contained 2-phenylethanol which is associated with honey, floral and spicy aromas, and the DIE wine also contained isobutyric acid, which imparts a dairy aroma of butter or cheese (Table 5).

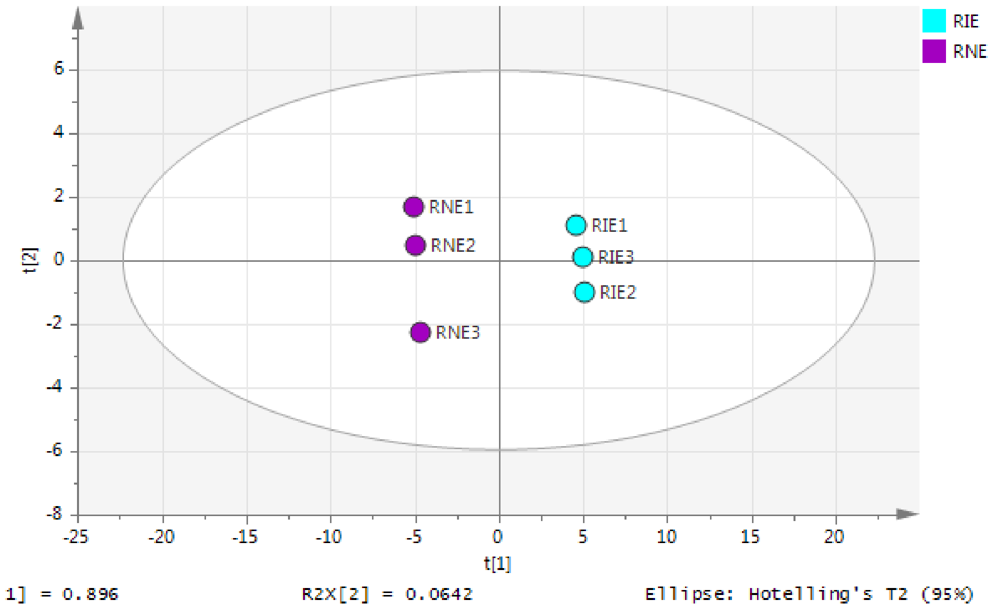
For the skin contact treatments, the majority of the chemical compounds present in the wine with an OAV > 1, were also largely the same (Table 5) and those chemical compounds were associated with, fruity, apple, passion fruit, gooseberry, guava, fruit jam, whiskey, malt, honey, floral, spicy, vinegar, cheese and sweat aromas. The ScBF wine contained ethyl phenylacetate, isobutyric acid and propionic acid which impart aromas of floral, butter and rancid respectively (Table 5). The FoS wine also contained isobutanol and isobutyric acid which impart aromas of solvent and butter/cheese respectively. The Con and ScBF wines contained 3MHA (passionfuit, gooseberry, guava aroma) while the FoS wine did not (Table 5). The lack of 3MHA in the FoS wine (Table 4), left it lacking in fruit aromas, which was noted during sensory analysis. The results are presented in the following section.

3.2.1 Multivariate analysis

Multivariate analysis was performed on the chemistry data, to determine which compounds contributed most to the differences between the samples. A PCA score plot and a contribution loadings plot were made for each treatment.

Figure 5 A and B, are the PCA plot and loadings plot, respectively, of the volatile chemistry of the Riebeek wines. The data set consisted of six observations (wines in this study), and 32 variables. For this plot there were two significant components extracted. Component 1 (t1) explained 89% of the variance between these samples (Fig. 5A).

A



B

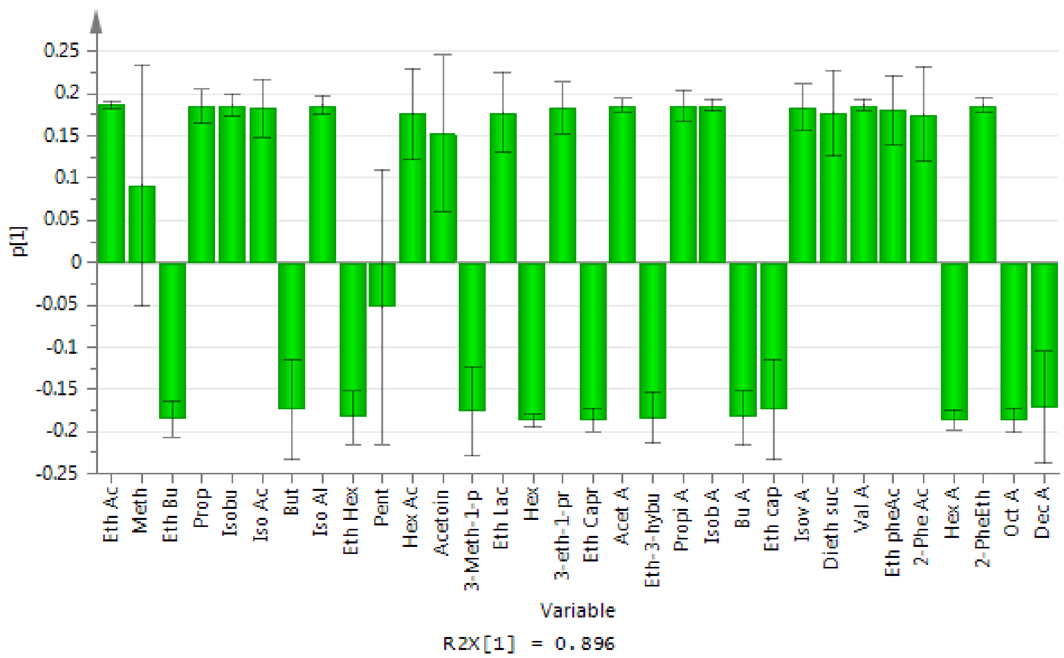


Figure 5 A) PCA scores plot; B) contribution plots for Riebeek natural (RNE) and inoculated (RIE) wines. B) Contribution plot showing the loadings for the chemical compounds (obtained from SIMCA-P 13.0). Variables in the loadings plot that have error bars that cross the origin are not significant (Abbreviations and full names of chemical compounds are in addendum D).

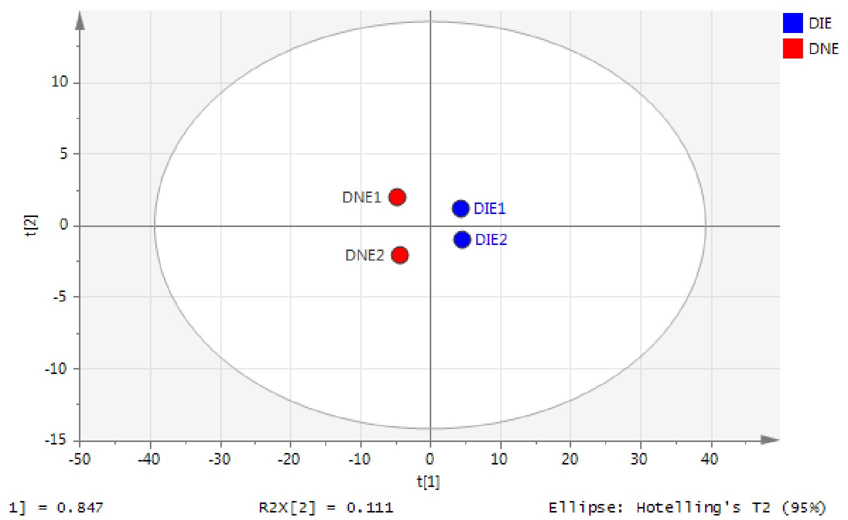
For Fig. 5 A, it is evident that the treatments are significantly different. With regard to Fig.5B, the chemical compounds that do not contribute significantly are methanol and pentanol, which is confirmed by the ANOVA results in Table 3.

The RIE samples are positively and RNE samples are negatively correlated with ethyl acetate, propanol, isobutanol, isoamyl acetate, isoamyl alcohol, hexyl acetate, acetoin, ethyl lactate, 3-

ethoxy-1-propanol, acetic acid, propionic acid, isobutyric acid, isovaleric acid, diethyl succinate, valeric acid, ethylphenyl acetate and 2-phenylacetate. The RNE samples are positively and the RIE samples are negatively correlated with, ethyl butyrate, butanol, ethyl hexanoate, 3-methyl-1-propanol, hexanol, ethyl caprate, ethyl-3-hydroxybutanoate, butyric acid, ethyl caprylate, hexanoic acid, octanoic acid and decanoic acid.

Figure 6 is the PCA and loadings plot of the volatile chemistry of the DGB naturally fermented and inoculated wines. The data set consisted of 4 observations, and 32 variables. For this plot there were two components extracted, but only the first component was significant. Component 1 (t1) explains 84% of the variance between these samples (Fig.6A).

A



B

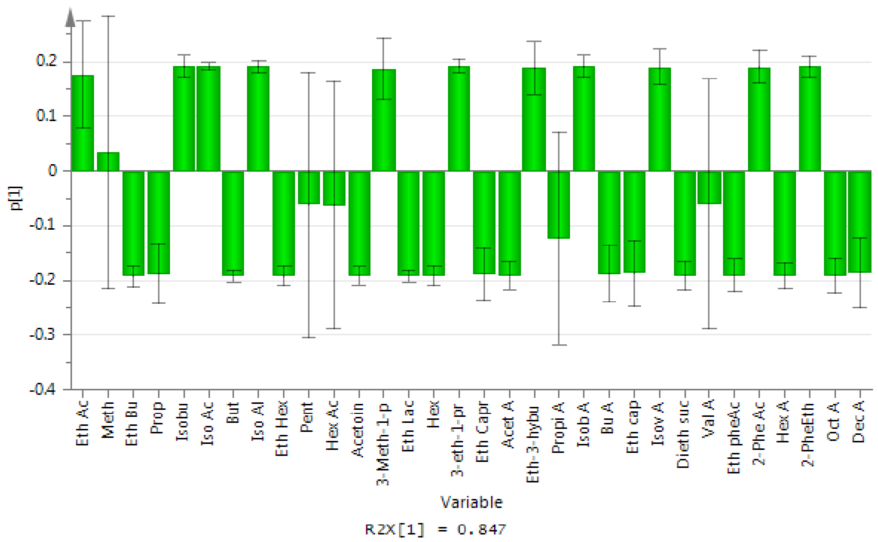


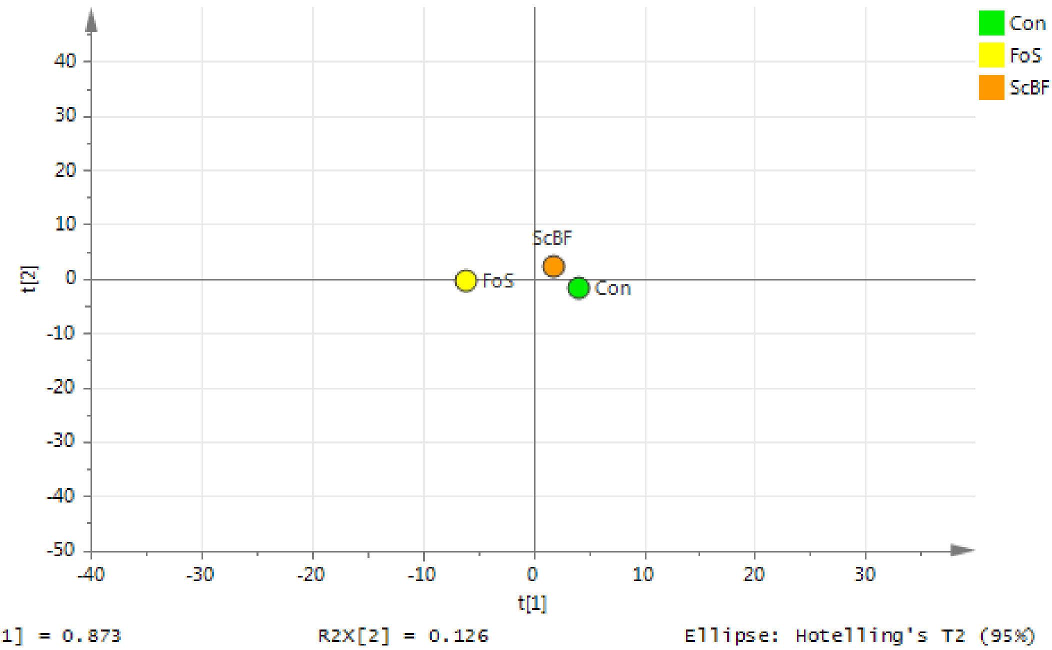
Figure 6 A) PCA scores plot; B) contribution plots for DGB natural (DNE) and inoculated (DIE) wines. B) Contribution plot showing the loadings for the chemical compounds (obtained from SIMCA-P 13.0). Variables in the loadings plot that have error bars that cross the origin are not significant (Abbreviations and full names of chemical compounds are in addendum D).

With regard to Fig. 6 B, the chemical compounds which are not significant are ethyl acetate, methanol, pentanol, hexyl acetate, propionic acid and valeric acid, confirming what was found in the ANOVA, except for the hexyl acetate which was deemed significant by the ANOVA (Table 3) but after multivariate analysis was found not to be significant.

The DIE samples are positively and DNE samples are negatively correlated with ethyl acetate, isobutanol, isoamyl acetate, isoamyl alcohol, 3-methyl-1-propanol, 3-ethoxy-1-propanol, ethyl-3-hydroxybutanoate, isobutyric acid, isovaleric acid, 2-phenylethyl acetate, 2-phenylethanol. The DNE samples are positively and the DIE samples are negatively correlated with, ethyl butyrate, propanol, butanol, ethyl hexanoate, acetoin, ethyl lactate, hexanol, ethyl caprate, acetic acid, butyric acid, ethyl caprylate, diethyl succinate, ethylphenyl acetate, hexanoic acid, octanoic acid and decanoic acid.

Figure 7 is the PCA and loadings plot of the volatile chemistry of the DGB skin contact wines. The data set consisted of 3 observations, and 34 variables. For this plot there were 2 components extracted, but only the first component was significant. Component 1 (t1) explains 87% of the variance between these samples (Fig.7A).

A



B

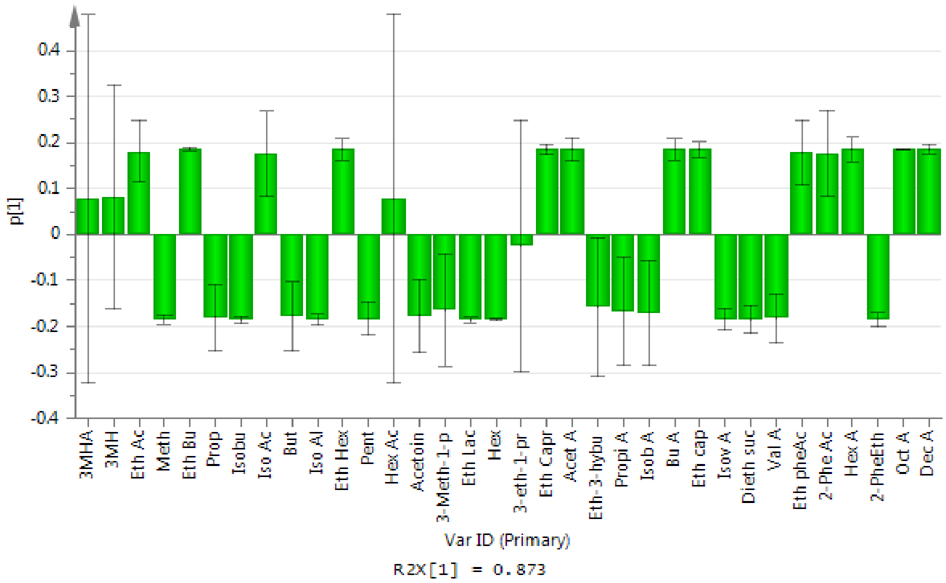


Figure 7 A) PCA scores plot; B) contribution plots for DGB skin contact wine treatments control (Con), 12 hours skin contact before fermentation (ScBF) and fermentation on skins (FoS) B) Contribution plot showing the loadings for the chemical compounds (obtained from SIMCA-P 13.0). Variables in the loadings plot that have error bars that cross the origin are not significant (Abbreviations and full names of chemical compounds are in addendum D).

There was less of a significant volatile chemical compound composition between the skin contact treatments, as they all lie very close to the origin. The Con and ScBF samples were more positively correlated and the FoS, more negatively correlated to ethyl acetate, ethyl butyrate, isoamyl acetate, ethyl hexanoate, ethyl caprate, acetic acid, butyric acid, ethyl caprylate, ethylphenyl acetate, 2-phenyl acetate, hexanoic acid, octanoic acid and decanoic acid. The FoS sample is more positively and the Con and ScBF samples, more negatively correlated to methanol, propanol, isobutanol, butanol, isoamyl alcohol, pentanol, acetoin, 3-methyl-1-propanol, ethyl lactate, hexanol, ethyl-3-hydroxybutanoate, propionic acid, isobutyric acid, isovaleric acid, diethyl succinate, valeric acid and 2-phenylethanol.

With regards to Figure 7B, the chemical compounds which were not significant were 3MHA, 3MH, hexyl acetate, 3-ethoxy-1-propanol.

Figure 8 is the PCA and loadings plot of the volatile chemistry for all wines (natural, inoculated and skin contact wines). The data set consisted of 7 observations, and 34 variables. For this plot there were 3 significant components extracted. Component 1 (t1) explains 57% of the variance and component 2 explains 22% of the variance between these samples (Fig.7A). A total of 80% of the variance is explained by this plot.

A

B

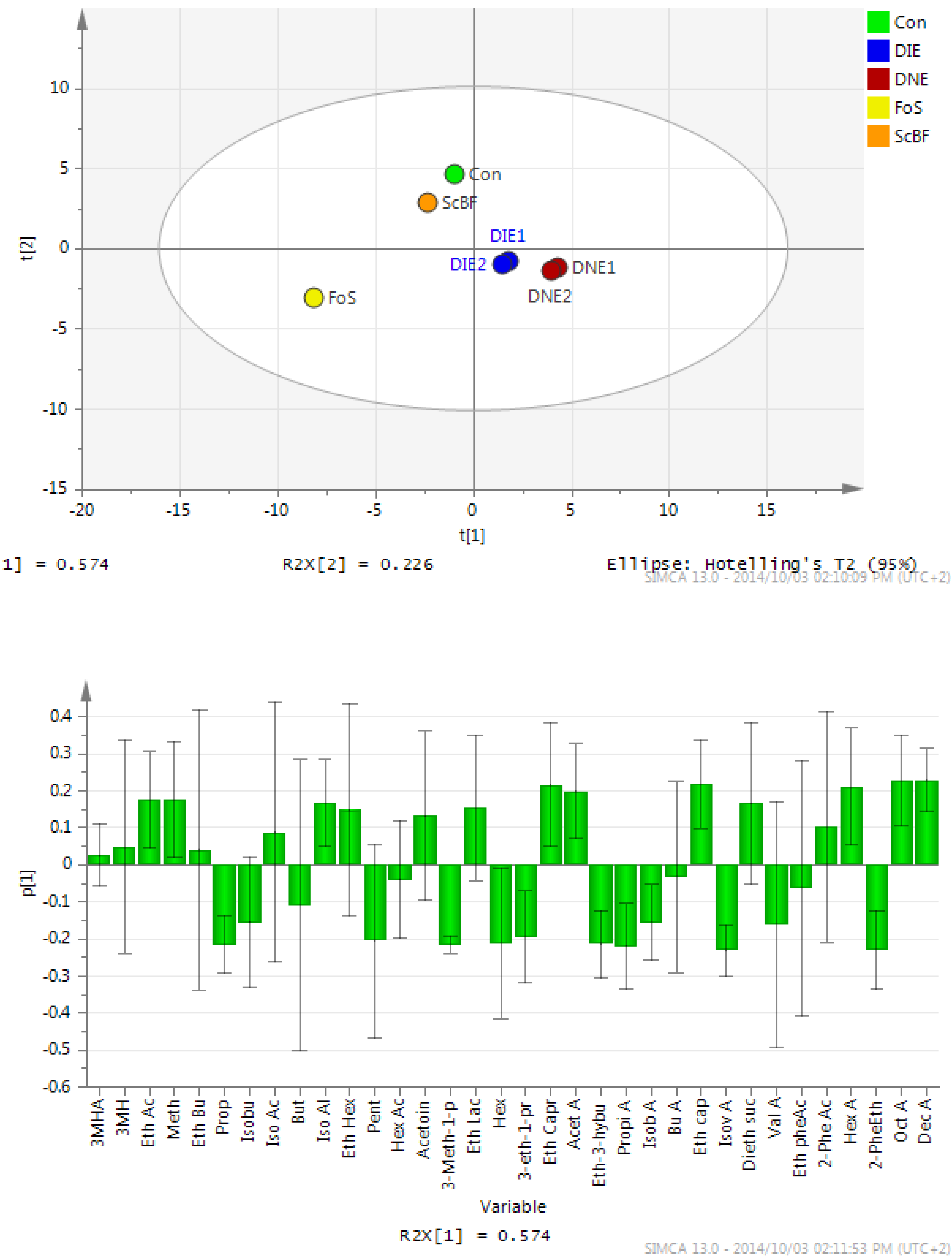


Figure 8 A) PCA scores plot; B) contribution plots for all the DGB samples, DGB natural (DNE), inoculated (DIE), Control - no skin contact (Con), 12 hours skin contact before fermentation (ScBF) and fermentation on skins (FoS). B) Contribution plot showing the loadings for the chemical compounds (obtained from SIMCA-P 13.0). Variables in the loadings plot that have error bars that cross the origin are not significant (Abbreviations and full names of chemical compounds are in addendum D).

With regard to Fig. 8A, the chemical compounds that were more positively correlated to the natural and inoculated fermentation and negatively correlated to the skin contact fermentation were, ethyl acetate, methanol, isoamyl alcohol, ethyl caprate, acetic acid, ethyl caprate, hexanoic acod, octanoic acid and decanoic acid. The compounds that were more positively correlated to the skin contact treatments and negatively correlated to the inoculated treatments were, propanol, 3-methyl-1-propanol, hexanol, 3-ethoxy-1-propanol, ethyl-3-hydroxybutanoate, propionic acid, isobutyric acid, isovaleric acid and 2-phenylethanol.

It would seem that the skin contact fermentations in general are higher in alcohols and that the natural and inoculated fermentations are generally higher in esters; and there were mixed effects on the acids. From Fig. 8B, it is evident that the FoS treatment is the most significantly different in terms of chemistry.

3.3 Sensory analysis

3.3.1 Projective mapping

There were two different types of data obtained from the mapping, firstly the descriptors and secondly the sample X and Y co-ordinates. Correspondence analysis was carried out on the projective mapping descriptor data and the following plot was obtained (Fig. 9). Figure 9 shows a total of 63.34% explained variance. The first component explains 47.48% and the second explains 15.86%.

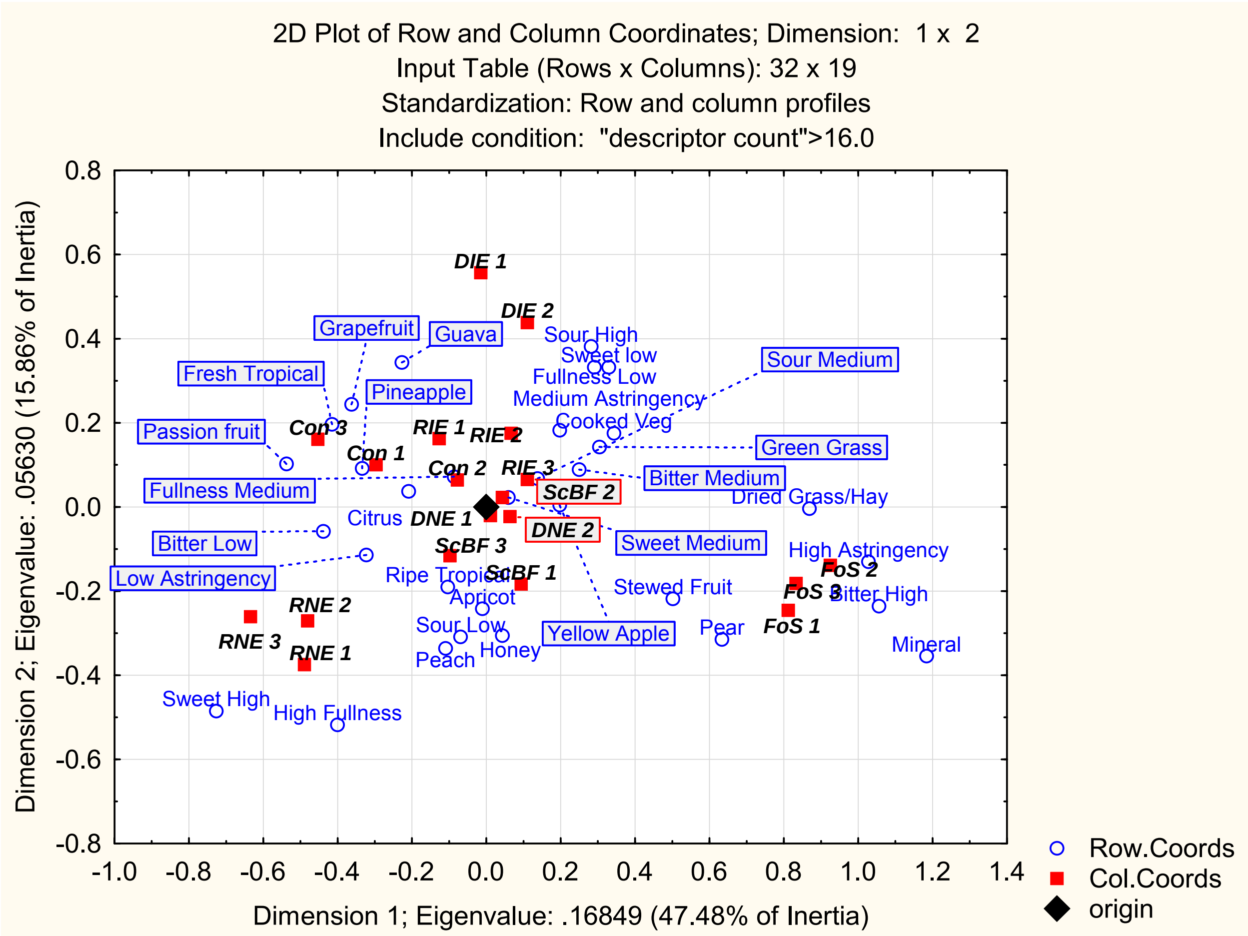


Figure 9 Correspondence analysis of the projective mapping descriptor data, for all Riebeek and DGB samples. Red -samples, blue-descriptors (obtained from StatSoft STATISTICA). Some titles are in boxes as they have been moved away from their corresponding data points, in order to aid readability of the plot.

Following the correspondence analysis, a multiple factor analysis was done on the co-ordinate data (Fig. 10).

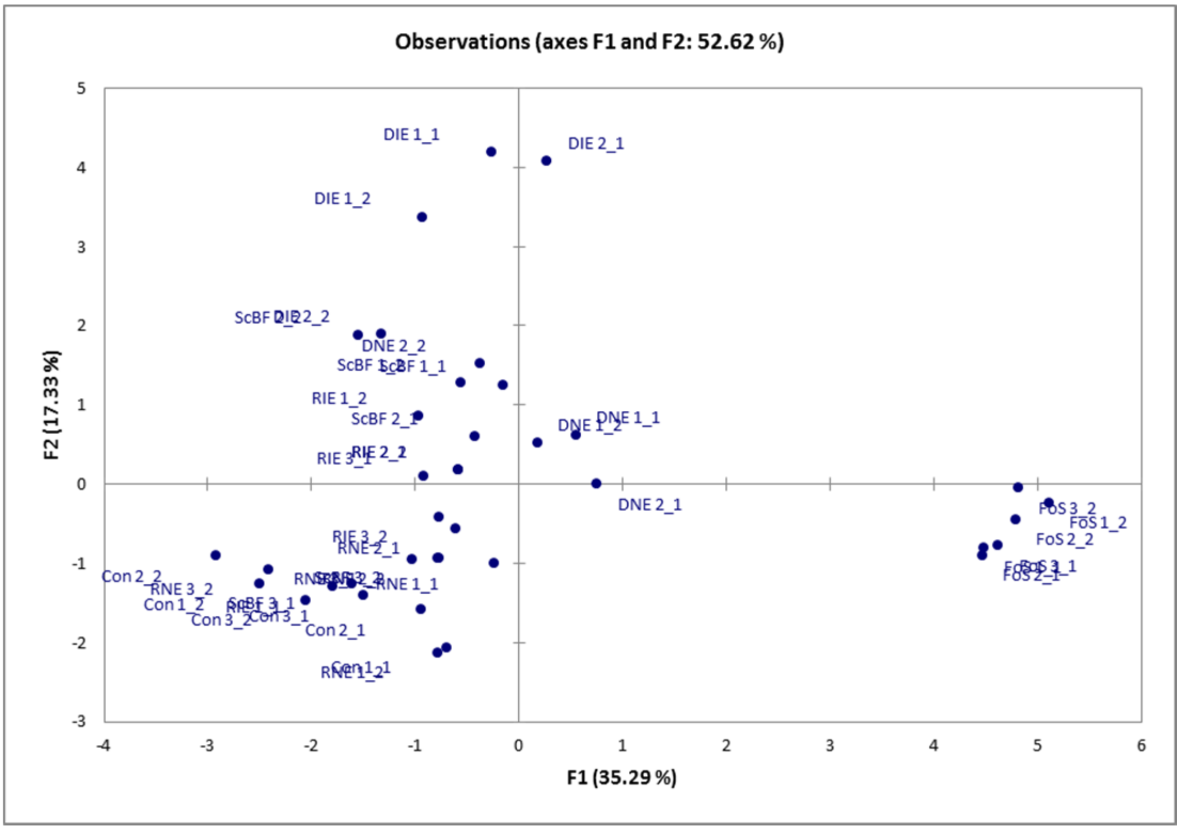


Figure 10 Product map obtained from doing multiple factor analysis (MFA) on projective mapping data. Riebeek natural (RNE) and inoculated (RIE), DGB natural (DNE), inoculated (DIE), Control - no skin contact (Con), 12 hours skin contact before fermentation (ScBF) and fermentation on skins (FoS). (obtained from Addinsoft XLSTAT version 2013.5.04). The number after the underscore denotes the repeat.

Figure 10 has a total of 52,62% explained variance by factor 1 and 2. This figure shows the average of how the samples were grouped. The most variance, 35.29%, is explained by F1. F2 explains 17.33% of the variance. From Fig. 10 it is clear that the samples that were perceived to be the most sensorially different were the FoS samples. The FoS samples were clearly separated from the other samples in the set (on component F1), and were therefore, consistently seen as the most sensorially different from the rest of the samples in the set. FoS was characterised by high astringency, intense bitter taste, with stewed fruit, dried and mineral character (Fig. 9). The increased bitterness and astringency associated with the FoS sample mirrors what Sokolowsky and co-workers (2015) found when they fermented Gewürztraminer on its skins. The less fruity character can also be explained by the volatile chemical profile of the wine, which was lower in esters and volatile thiols (which contribute to fruity aroma) that the other samples (Table 4, 5).

The Riebeek naturally fermented samples, RNE 1 and 2 were grouped and characterised as high in sweeteness, low in astringency, low in sourness, with a ripe tropical and stone fruit character (Fig. 9). The control samples from DGB, Con 1, 2 and 3, which were mapped near to the RNE samples (Fig. 10) were also characterised as tropical, but had more pineapple, passion fruit and grapefruit aromas. The Inoculated samples from DGB, DIE 1 and 2 were grouped together and mapped further from the rest of the sample set (Fig. 20), as they had a tropical fruit character, but were found to be higher in sourness, with medium astringency, lower in sweetness (Fig. 9). The DGB natural (DNE 1 and 2), the Riebeek inoculated (RIE 1, 2 and 3) and the Skin contact before fermentation wines (ScBF), were perceived to be more sensorially similar and were mapped relatively close together (Fig.10). They were described as having yellow apple, citrus and ripe tropical aromas, and in the case of RIE the addition of the cooked vegetable aroma; as well as a having medium (intensity) sour, bitter and sweet taste (Fig. 9).

4. Conclusions

The aim of this study was to investigate the treatment effects on natural fermentation and extended skin contact on Chenin blanc, in particular the effects on the chemical and sensory profiles. For both natural fermentation and skin contact, there were significant differences across treatments.

The different yeasts present on the grapes from the different vineyards, definitely had an effect on the chemistry and ultimately the final aromas of the wine. The aromatic chemical and sensory profiles of the naturally fermented and inoculated wines were significantly different. The general trend was that the naturally fermented wines had stronger riper tropical fruit aromas than the inoculated fermentations and were perceived to be sweeter and lower in sourness, bitterness and astringency.

The treatment that resulted in the greatest difference between the wines was the fermentation on skins (FoS). Fermentation on skins seems to lower the ester concentrations and completely remove the 3MHA from the wine, which results in a dried fruit, dried grass and vegetative aroma, and lack of tropical fruit character. The fermented on skins treatment was very extreme and gave the wine an increased sour and bitter taste and an astringent mouth-feel. The wine with limited skin contact (12 hours) before fermentation was able to retain more of its tropical fruity aroma, and this treatment did not seem to have as much of an effect on the intensity of bitterness and astringency.

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Chapter 4

Comparison of two rapid methods, projective mapping and frequency of attribute citation, as sensory evaluation tools for Chenin blanc wine

Comparison of two rapid methods, projective mapping and frequency of attribute citation, as sensory evaluation tools for Chenin blanc wine

1. Introduction

Sensory profiling of wine is a pivotal step in its product development cycle. In the wine industry, this evaluation is generally performed by wine professionals, in an empirical fashion. In the research environment, the most used method for sensory evaluation of foodstuffs, including wine, is descriptive analysis (DA). DA uses trained sensory assessors to describe products (Næs *et al*., 2010) and entails the description of samples based on aroma, taste, appearance and/or mouthfeel, in order to highlight their similarities and differences. The intensity of attributes is rated using line scales, from which continuous data is obtained which is easy to analyse statistically (Lawless & Heymann, 2010). Although DA is the best established and most informative sensory evaluation method, it does have limitations. It has high cost and time implications and requires extensive training of the panel (Da Silva *et al*., 2013).

Due to these and other practical challenges associated with DA, the wine industry and researchers have expressed the need for more rapid, but still reliable methods for sensory profiling. Consequently, alternative methods such as sorting, projective mapping (PM) and frequency of attribute citation (FC) have been developed as recently reviewed (Valentin *et al*., 2012). The efficiency or effectiveness of rapid methods are usually accessed by comparing the results obtained to that obtained with DA on the same set of products (Mielby *et al*., 2014; Cartier *et al*., 2006).

PM is a rapid alternative method for DA that has been successfully applied to various foodstuffs (Risvik *et al*., 1994; Hopfer & Heymann, 2013). This two-dimensional sorting method was originally introduced by Risvik and co-workers (1994) and was done using an A4 sized page with an unstructured line scale. This method was re-visited by Pagés (2005), who termed it Napping® and along with it, developed a new method for data analysis, namely multiple factor analysis (MFA). In essence, PM requires panellists to sort products in a two dimensional space according to similarities and differences. MFA is applied to results to compare similarities in the assessors' maps (Abdi & Valentin, 2007; Escofier & Pages, 1994). An advantage of using PM is that a large sample set (12-20 samples) can be tested in one session and relationships between the wines can be identified. A minimum of nine samples is required, but a sample set size of between 12 and 18 is ideal (Pagés, 2005; Hopfer & Heymann, 2013).

Frequency of attribute citation (FC) was developed as an alternative to intensity based techniques, such as DA, and was originally used to characterise Chardonnay and Burgundy wines (McCloskey *et al*., 1996; Le Fur *et al*., 2003). Judges were provided with a list of descriptors and asked to choose the descriptors that they felt best described each sample.

Campo *et al*. (2010) further developed this method and used a panel of ~30 judges that were pre-trained with a list of generic wine descriptors. The authors decided that a maximum of five descriptors should be used per sample (Campo *et al*., 2010). Advantages of using FC (in comparison to DA) include that a much larger range of descriptors is available to judges and far less training is required. Correspondence analysis is done to analyse this category type data.

The aim of this study was to compare the results obtained with two more rapid sensory testing methods, PM and FC respectively, with the results obtained from DA. For this purpose, Chenin blanc produced using different winemaking techniques was used. The study was done in collaboration with two commercial cellars, Douglas Green Bellingham (DGB) and Riebeek Cellars, both from the Western Cape province of South Africa.

2. Materials and methods

2.1 Wines

The wines for this study were all experimental and were made with grapes from two different vineyards namely, DGB and Riebeek Cellars (Table 1). The winemaking processes were previously described in Chapter 3.

Table 1 Treatment, wine production site and volume of experimental Chenin blanc wines.

Grape Origin	Wine production site	Treatment	Volume (L)	Repeats
DGB[1]	DGB[2]	Inoculated Barrel 1	300	1
DGB[1]	DGB[2]	Inoculated Barrel 2	300	1
DGB[1]	DGB[2]	Natural Barrel 1	300	1
DGB[1]	DGB[2]	Natural Barrel 2	300	1
DGB[1]	SU[3]	Control	20	3
DGB[1]	SU[3]	12 hours skin contact before fermentation	20	3
DGB[1]	SU[3]	Fermented on skins	20	3

[1]DGB: Douglas Green Bellingham Vineyard, Phisantekraal, Durbanville Hills, Cape Town, South Africa.
[2]DGB: Douglas Green Bellingham Cellar, Wellington, Western Cape, South Africa.
[3]Stellenbosch University Experimental Cellar, Stellenbosch, Western Cape, South Africa.

2.2 Descriptive analysis (DA)

DA is the most established and important method for sensory evaluation of foodstuffs (Næs *et al*., 2010) and based on the accurate data that this method obtains, DA was used as the reference in the current study. There are three main steps involved in descriptive analysis namely panel recruitment, panel training and blind testing (Lawless & Heymann, 2010).

2.2.1 Panel

The panel used consisted of 10 oenology and wine biotechnology students and staff members (seven women, three men; mean age: 28), selected based on interest and availability. The panel was paid for their participation.

2.2.2 Training

Panellists attended seven 1 hour training sessions over a period of five weeks. Panellists were trained using the consensus method (Lawless & Heymann, 2010). During the first training session the panel was presented with the seven Chenin blanc wine samples and asked to smell them and generate five descriptors to describe the aroma of each sample. Panellists were also required to identify the basic tastes: sweet, sour, bitter and astringent in water. Panellists were subsequently asked to taste the wines and comment on differences they observed. In the second training session, panellists were presented with 30 aroma standards, which they had to smell and identify (Addendum E). These 30 standards were aromas identified during the first training session. Most of the aromas were from the Chenin blanc aroma wheel, which was established by the Chenin Blanc Association (CBA, 2013). Thereafter the judges were required to smell the wine samples and describe them using the standards as a guide. The list of 30 general Chenin blanc aroma standards was discussed by the panel and then reduced to the most relevant 13 (Table 2).

During the third training session, panellists had to identify the basic tastes (Table 2) again and identify the 13 aroma standards. The panel was also introduced to the concept of scaling. During testing they would be required to rate each sample for each descriptor on an unstructured 10-cm linear scale, anchored “None” at the left end and “Intense” at the right end (Addendum H).

During training session 4, panellists were given two sets of standards to identify. The first set was normal aroma standards and the second was wines spiked with those same aroma standards. Lastly, panellists had to scale the wine samples for the specific attributes (Table 2).

Training sessions 5, 6 and 7 were used for reaching consensus on intensity of ratings of the attributes in the sample wines.

Table 2 Final list of aroma and taste attributes and reference standards used for descriptive analysis.

Attribute	Definition	Composition
Aroma		
Pineapple	Odour associated with fresh pineapple	¼ slice of pineapple
Banana	Odour associated with banana sweets/candy (isoamyl acetate)	1 µL isoamyl acetate + 30 mL water
Citrus	Odour associated with Lemon and grapefruit	¼ slice lemon + ¼ slice grapefruit
Yellow apple	Odour associated with yellow apple	1 cm wedge of golden delicious apple
Passion fruit	Odour associated with fresh passion fruit	1 tbs fresh passion fruit pulp
Dry grass	Odour associated dry grass/ hay	Handful finely chopped
Marmalade	Odour associated with orange marmalade	1 tsp marmalade (All gold)
Stone fruit	Odour associated with peach and apricot	15 mL peach juice + 15 mL apricot juice (Liqui Fruit)
Honey	Odour associated acacia honey	1 tsp. in 10 mL water (Woolworths)
Raisin	Odour associated raisins	5 raisins chopped (Safari)
Mint	Odour associated fresh mint	1 sprig chopped
Dried fruit	Odour associated with mixed dried fruit	1 piece apple, apricot, peach, prune, pear chopped (Safari)
Cooked vegetable	Odour associated with canned green bean and artichoke	20mL artichoke brine + 20 mL green bean brine (Goldcrest)
Taste	**Compound source?**	**Dosage**
Sweet	Sucrose (Huletts)	5 g/L in water
Sour	Tartaric acid (Sigma Aldrich)	0.5 g/L in water
Bitter	Quinine (Sigma Aldrich)	0.03 g/L in water
Astringent	Aluminium sulphate (Alpha Pharm)	1 g/L in water

2.2.3 Wine evaluation

The seven different DGB wines (Table 1) were tested in triplicate. The Riebeek wines were not included in this study, as there were a limited number of bottles, not enough for the intensive DA training and testing.

The samples were coded with randomised three-digit numbers and presented in a randomised order. All samples were kept at 15°C. Testing took place in air conditioned, light controlled rooms (ISO NORM 8589, 1988). Panellists sat in individual booths, and were supplied with tasting sheets (Addendum H), water and crackers. They were required to evaluate wines orthonasally and rate the intensity of each attribute, using an unstructured 10-cm linear scale, anchored "None" at the left end and "Intense" at the right end (Addendum H). The panel also rated the wines for taste and mouthfeel, by scoring sweetness, sourness, bitterness and astringency. The evaluation was performed in duplicate sessions on the same day, with a 15 minute break between the sessions to limit fatigue. All ratings were measured by hand and recorded in *Microsoft Excel 2010*.

2.2.4 Data analysis

For the descriptive analysis a randomised complete block design was used (Lawless & Heymann, 2010). There were seven treatments (Table 1) and three replications. The scaled values were measured by hand and captured in a spread sheet. The data was exported into NOFIMA PanelCheck V1.4.0, to check judge consistency and repeatability and to determine which attributes were significant according to the workflow proposed by Tomic *et al*., (2010). Tucker-plots showing judges consensus for attributes are shown in Addendum G. The Shapiro-Wilk test was used to test for non-normality (Shapiro & Wilk, 1965). If non-normality was significant ($p \leq 0.05$) and caused by scewness, the outliers were identified and removed until the data were normal or symmetrically distributed (Glass *et al.,* 1972). The final analysis of variance (ANOVA) was performed and the least significant difference (LSD) was calculated at the 5% significance level to compare treatment means. Statistical analysis was done using StatSoft STATISTICA 12®.

2.3 Projective mapping (PM)

PM was done as described in Chapter 3. Sorting and mapping sensory evaluation methods generally require little or no training (Valentin *et al*., 2012), but for this study where PM was being investigated as a possible alternative to DA, it was decided to include some training of the panel.

2.3.1 Samples

Nineteen Chenin blanc samples were used for the PM exercise (Chapter 3). Winemaking procedures are described in Chapter 3.

2.3.2 Panel

The trained panel employed by the Department of Viticulture and Oenology, Stellenbosch University was used. It consisted of nine trained panellists; all female, with a mean age of 44. The panel had extensive wine tasting experience and were paid for their participation.

2.3.4 Wine evaluation

All the wines described in Table 1 plus the Riebeek natural and inoculated wines were used for the projective mapping experiment. Sample presentation and testing conditions occurred as described in section 2.2.3. Panellists were supplied with a large piece of white A2 paper dimensions (420 mm X 594 mm), water and crackers. The panel was then instructed to position samples on the sheet of paper according to sensory similarity, i.e. samples with very similar aroma and/or taste close together and samples that were very different far apart. Panellists were also asked to generate descriptors (aroma and taste) for each sample or group of samples. Two repeats were done in one session, with a 15 minute break between them. Once the glasses were arranged to the panellists' liking, they were asked to mark the position on the page with a cross and write the samples' codes next to it, as shown in Addendum B.

The bottom left hand corner of the page was taken as the origin and the co-ordinates of the middle of each cross marked on the pages by the panellists, was measured in centimetres (Addendum C). The attributes generated for each sample and the X and Y co-ordinates were captured in *Microsoft Excel 2010*. When an attribute was present, it was given a score of 1 and when it was absent, it is given a 0 score (Addendum C).

2.3.5 Statistical analysis

Correspondence analysis was done on the descriptor data using StatSoft STATSTICA 12®. This was followed by multiple factor analysis (MFA) on the co-ordinates captured for all panellists. MFA was done in Addinsoft XLSTAT v.2013.5.04 as described by Abdi & Valentin (2007) and Louw *et al*. (2013).

2.4 Frequency of attribute citation (FC)

FC is a method that uses the frequency of recurrence of descriptors to describe samples. A descriptor or 'attribute' that is cited by a minimum of 15% of the group is considered significant and a minimum of 30 trained judges should be used (Campo *et al*., 2010). A list of descriptors is given to each panellist who is then asked to choose those that best describe each sample. In the case of wine, which is a complex medium, a maximum of five descriptors per sample is used (Campo *et al*., 2010).

2.4.1 Panel and training

The Department of Viticulture and Oenology, Stellenbosch University has a panel consisting of 35 trained judges, which is used for frequency based analysis. This panel was used for the FC experiment. The panel consisted of both males and females and the age of the panellists varied from 20 to 50. This panel underwent general training, as described by Campo *et al*. (2010), prior to this project. Four hour-long specific Chenin blanc training sessions were held before the wines were tested. A training session consisted of two parts. During the first part the panel was presented with between 12 and 16 aroma reference standards, which they had to smell and identify. In the second part of the training, panellists received four wine samples and they were asked to identify the five most prominent aroma descriptors for each wine. The wines were then discussed by the panel and the panel leader highlighted the terms most frequently cited to describe each wine. During the specific training session, all the descriptors on the Chenin blanc aroma wheel (Addendum A; Addendum E) were covered and a range of commercial Chenin blanc wines covering a large number of Chenin blanc aroma attributes were given to the panel. In the last training, the panel was presented with a set of four wines that contained two of the wines that were to be tested.

2.4.2 Wine evaluation

The seven different DGB wines (Table 1) were tested in triplicate. The Riebeek wines were not included in this study, as there were a limited number of bottles, which were used for the projective mapping experiment. The sample presentation and testing conditions were as described in section 2.2.3. Panellists were given an aroma descriptor sheet (Addendum H) for each sample and asked to tick the five most prominent aroma attributes for each sample evaluated.

2.4.3 Statistical analysis

The data was captured in *Microsoft Excel 2010*. The average reproducibility index (R_i) was calculated for each panellist, according to Campo *et al.* (2008) in order to access their performance. The data for judges with calculated R_i values less than 0.2 was discarded (Campo *et al*., 2008). With regards to the descriptors, only descriptors cited by 15% or more of the panel were kept. Data was organised into a contingency table and a correspondence analysis was run in Addinsoft XLSTAT v.2013.5.04. The correspondence analysis was followed by a hierarchical cluster analysis which allowed wines belonging to the same cluster to be identified.

3. Results and discussion

3.1 Descriptive analysis (DA)

A 3-way ANOVA was done on the DA data and Table 4 shows the p values obtained for all the significant attributes. The treatments differed significantly for only eight of the 17 attributes tested (Table 3).

Table 3 Sensory attributes measured during descriptive analysis and the ANOVA results.

Sensory Attribute	P value
Pineapple	0.00012
Banana	0.00000
Citrus	0.00013
Yellow apple	ns[1]
Passion fruit	0.03022
Dry grass	ns[1]
Marmalade	ns[1]
Stone fruit	ns[1]
Honey	ns[1]
Raisin	ns[1]
Mint	ns[1]
Dried fruit	ns[1]
Cooked vegetable	ns[1]
Sweet	0.01668
Sour	0.00032
Bitter	0.00019
Astringent	0.00007

[1]ns - not significant, p-value larger than 0.05

Figure 1 depicts the least squares means (LSM) for the significant attributes (Table 3), obtained using StatSoft STATSTICA 12®. As can be seen from the LSM plots, the FoS sample differed significantly from the other samples for all of the significant attributes. It was significantly lower in pineapple, citrus, banana, passion fruit and sweetness; and significantly higher in sourness, bitterness and astringency. Both the skin contact samples ScBF and FoS were significantly lower in passion fruit aroma. The naturally fermented samples were the least sour.

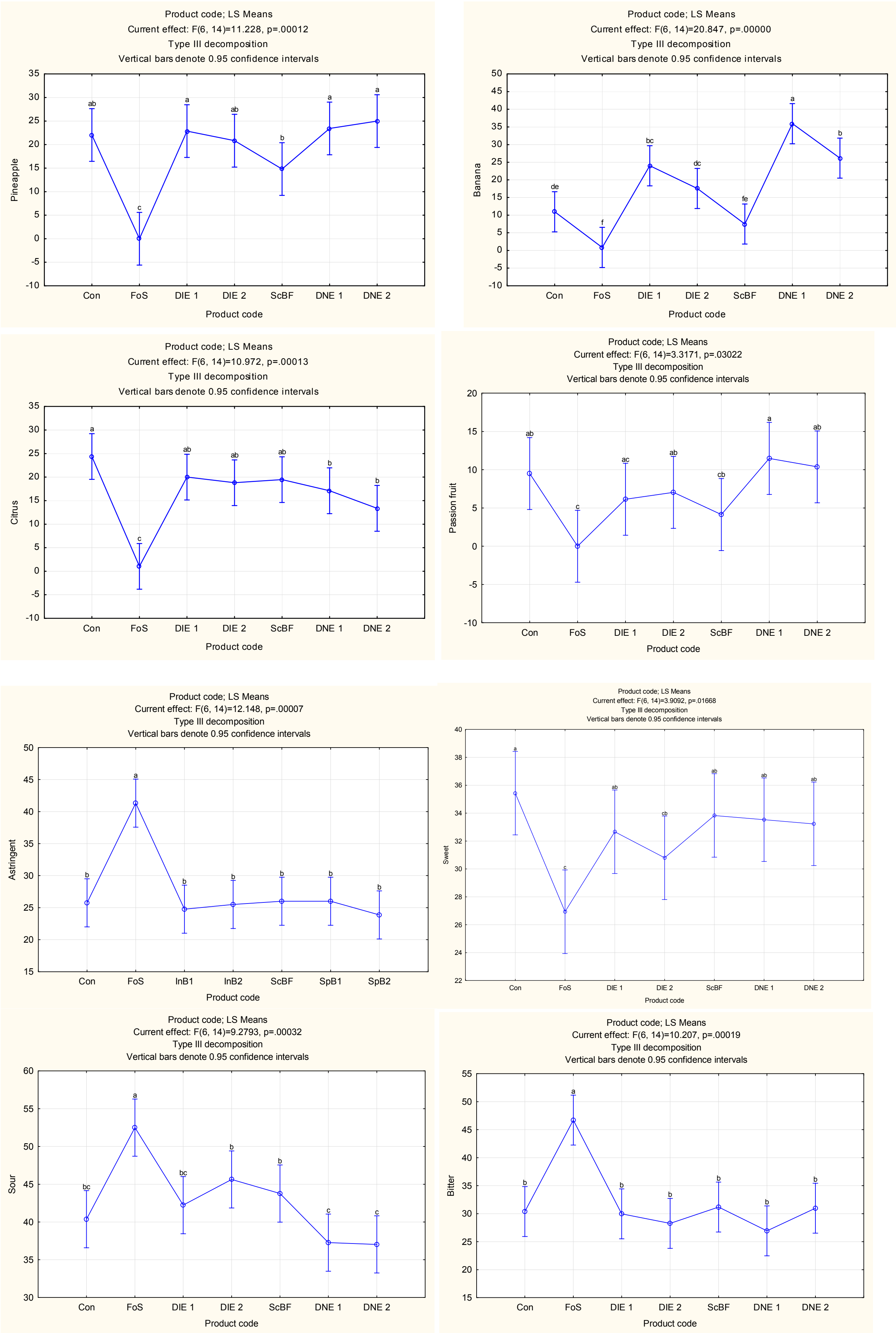

Figure 1 The LS means (LSM) plots for the significant attributes used for descriptive analysis. Different alphabetical letters in the plot indicate significant differences (p<0.05). Con: control wine, ScBF: 12 hours

skin contact, FoS: fermented on skins wine. Error bars indicate standard deviation DIE: DGB inoculated wine, DNE: DGB natural wine (obtained from StatSoft STATISTICA 12®).

Principal component analysis (PCA) (Fig. 2) was then done using the significant attributes (Table 3). PC1 and PC2 explained 79% and 17% of the variance respectively, thereby capturing 96% of the total variance observed in this set (Fig. 2). The FoS sample differed the most from the rest of the samples in the set along PC1.

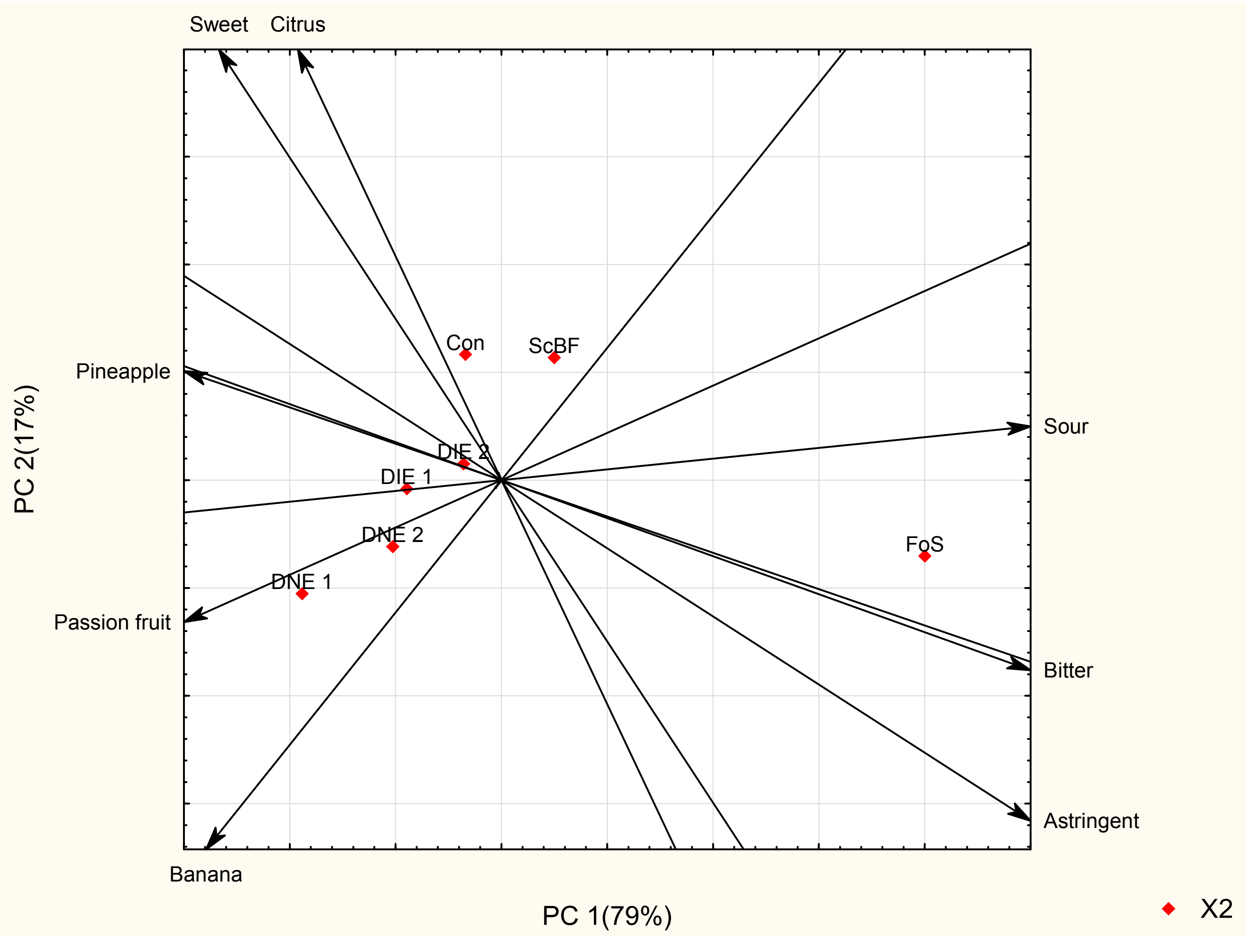

Figure 2 Principal component analysis (PCA) scatterplot of seven experimental Chenin blanc wines according to the significant aroma and taste descriptors (obtained from StatSoft STATISTICA 12®). Con: control wine, ScBF: 12 hours skin contact, FoS: fermented on skins wine, DIE 1 & 2: DGB inoculated wine, DNE 1 & 2: DGB natural wine

The FoS sample was clearly significantly different from the other samples in the set as shown by LSM analysis (Fig. 1). It was positively correlated to the bitter, astringent, sour descriptors and negatively correlated to the pineapple and passion fruit descriptors (Fig. 2). The other samples in the set were positively correlated to the tropical fruit descriptors (Fig. 2). The natural fermentations (DNE) had significantly higher intensities (as judged by LMS analysis, Fig.1) of passion fruit and banana than the inoculated fermentations (DIE). The skin contact before fermentation (ScBF) and the control samples (Con) were positively correlated to the sweet and citrus descriptors (Fig. 2)

3.2 Projective mapping (PM)

Correspondence analysis was carried out on the PM data to investigate the relationships between samples and descriptors as shown in Figure 3. Descriptors that are close to a sample are positively correlated to that sample, while descriptors far away from a sample are negatively correlated to that sample.

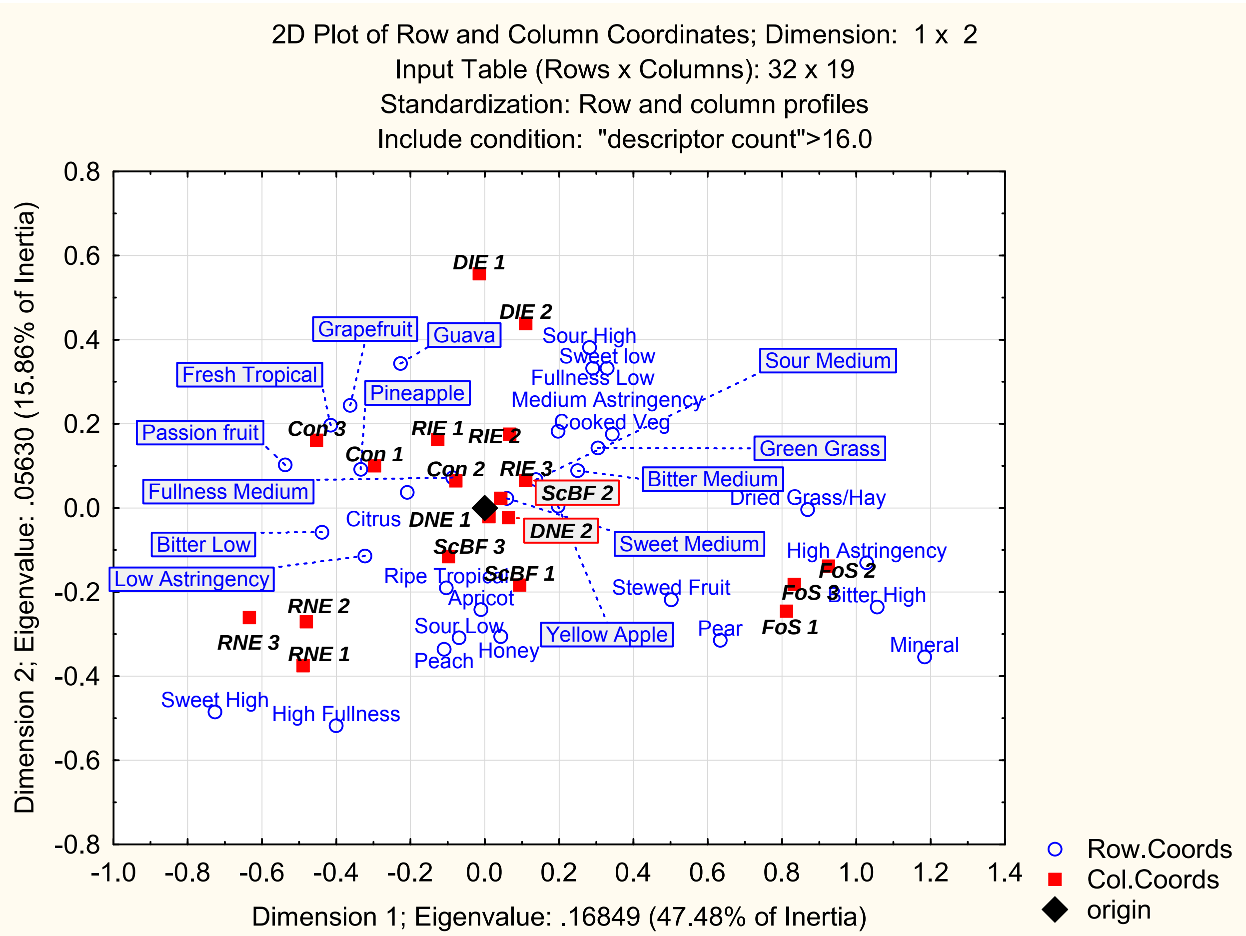

Figure 3 Correspondence analysis of the PM data. Con: control wine, ScBF: 12 hours skin contact, FoS: fermented on skins wine, DIE: DGB inoculated wine, DNE: DGB natural wine. Numbers next to sample code indicates oenological repeats. Boxed descriptors indicate those which have been moved to improve the readability of the plot (obtained from StatSoft STATISTICA 12®).

The FoS samples were clearly separated from the other samples in the set and were characterised by high astringency and a strong bitter taste, as well as a stewed fruit, dried grass and mineral aroma (Fig. 3). Samples RNE 1, 2 and 3, the Riebeek naturally fermented samples, were also grouped and characterised as high in sweetness, low in astringency and low in sourness, with a ripe tropical and stone fruit character (Fig. 3). The inoculated samples DIE 1 and 2 were grouped together and found to be high in sourness, with medium astringency, low sweetness with a tropical fruit aroma including guava and grapefruit. Samples DNE 1 and 2, and RIE 1, 2 and 3, were described as having a medium sour, bitter and sweet taste and characterised as having a melon, yellow apple, citrus and a fresh green grass aroma. Samples Con 1, 2 and 3 (the samples from DGB that had no skin contact) were located close to these samples on the plot (Fig.3), but were characterised as being more fresh-tropical, (pineapple, passion fruit and grapefruit) and less green than the others.

Multiple factor analysis of the co-ordinate data obtained from the PM experiment was performed (Fig. 4). Figure 4 shows the sample arrangements that were common among panellists.

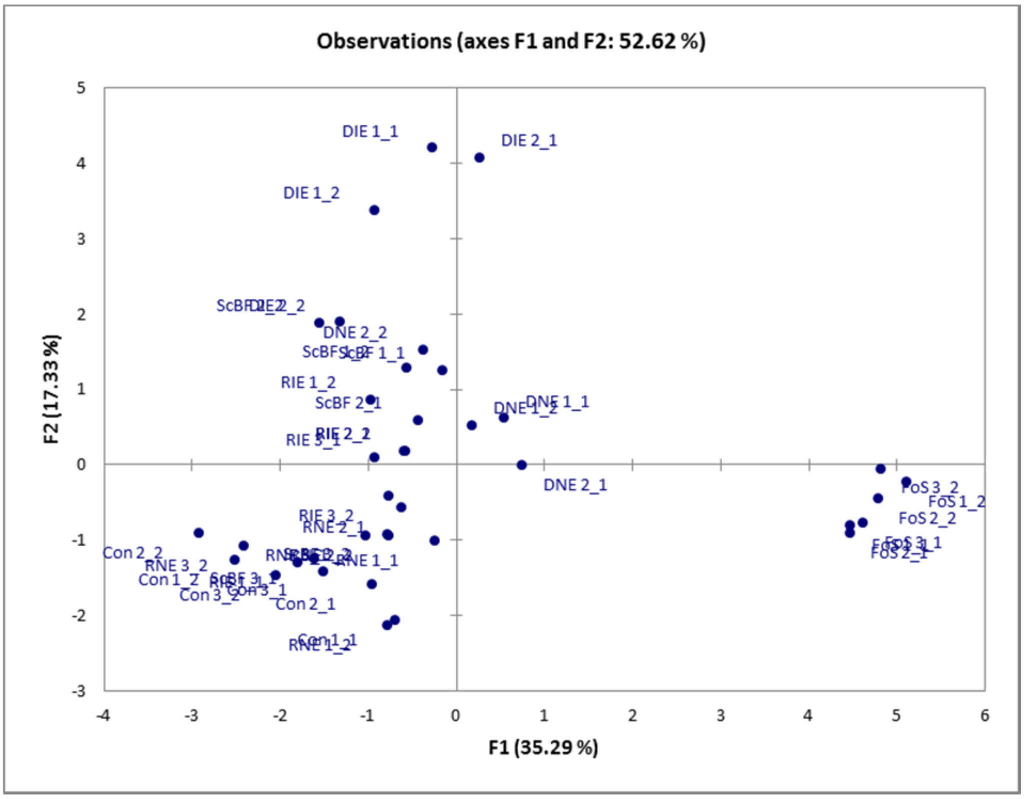

Figure 4 MFA of PM co-ordinate data. Con: control wine, ScBF: 12 hours skin contact, FoS: fermented on skins wine, DIE: DGB inoculated wine, DNE: DGB natural wine *_1 denotes the first repeat and _2, the second repeat (obtained from Addinsoft XLSTAT v.2013.5.04).

As can be seen in Figure 4, panellists' evaluations were repeatable, grouping the same samples in the same fashion for both repeats. A total of 52.62% of the variance was explained. The most variance, 35.29% was explained by F1 where the FoS samples were mapped furthest away from all the other samples, therefore indicating that they differed the most from the other samples in the set.

3.3 Frequency of attribute citation (FC)

Correspondance analysis was conducted on the FC descriptor data, to establish which descriptors were common to each sample, and results can be seen in Fig. 5.

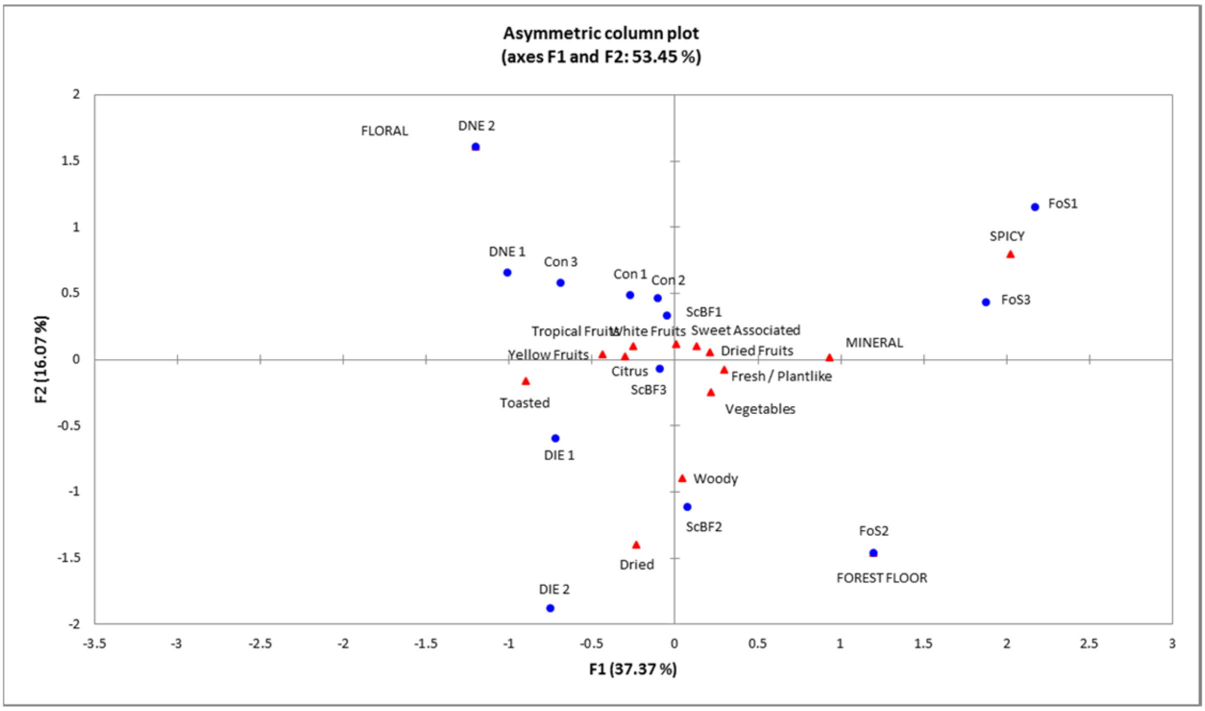

Figure 5 Bi-plot obtained from correspondence analysis of frequency of attribute of citation data (obtained from Addinsoft XLSTAT v.2013.5.04).

The bi-plot obtained from correspondence analysis of frequency of attribute of citation data showed that the FoS samples separated from the rest on F1, which explained 37% of the variation in the data (Fig 5), while the natural (DNE) and inoculated (DIE) wine samples separated on F2, which explained 16% variance. In total 53% explained variance was captured by F1 and F2. The FoS samples were positively correlated to mineral, spicy and forest floor (vegetative). DNE samples were positively correlated to tropical fruits, yellow fruits and floral descriptors. Con samples were positively correlated to tropical fruits, yellow fruits and citrus descriptors. ScBF was positively correlated to tropical fruit, yellow fruits and citrus. DIE was positively correlated to tropical fruit, citrus, toasted and dried descriptors. After the correspondence analysis, an agglomerative hierarchical cluster analysis was performed on the data to illustrate the grouping of samples more clearly (Fig. 6). Three distinct classes were identified (Fig. 6). The first class C1, contained the DBG natural and inoculated samples, class C2, contained the control (Con) and skin contact before fermentation (ScBF) samples, while class C3 contained only the fermented on skins (FoS) samples (Fig. 6).

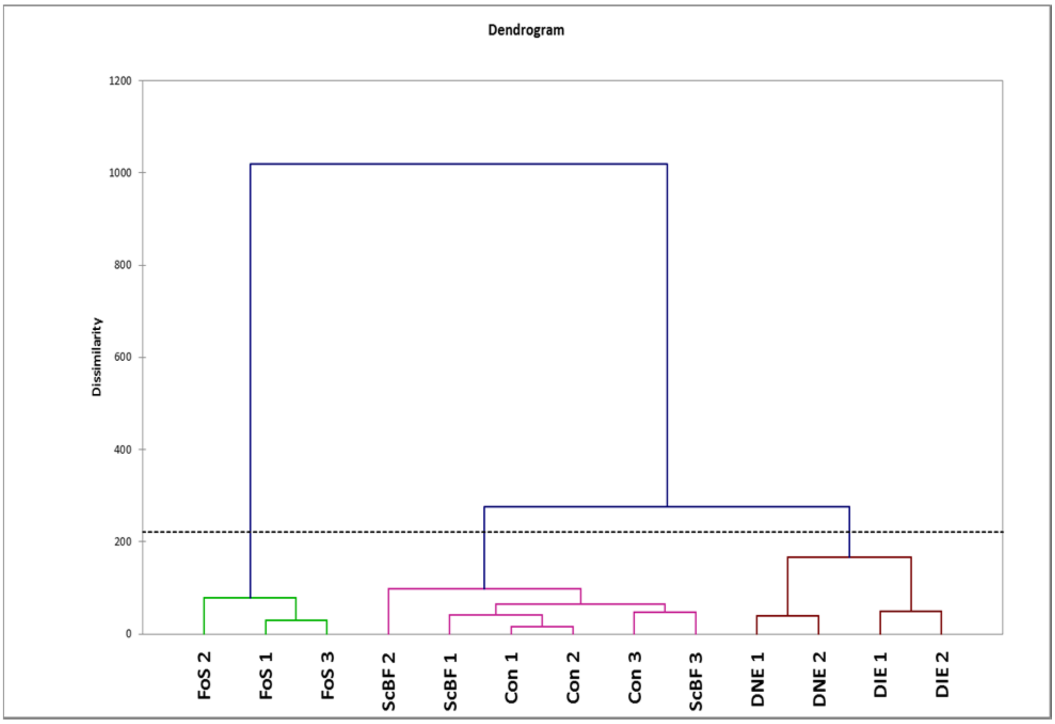

Figure 6 The three classes identified as a result of cluster analysis of frequency of citation data (obtained from Addinsoft XLSTAT v.2013.5.04).

The fermented on skins samples (FoS 1-3), clearly formed a cluster that were most different to the other samples in the set, which could be split further, by grouping the control (Con 1-3) and skin contact before fermentation (ScBF 1-2) as one group and the inoculated and naturally fermented samples (DNE1-2 and DIE 1-2) as another group (Fig. 6).

Figure 7 showed that the frequency of citation method was able to separate the samples based on differences in aroma attributes cited. The FoS samples were found to have a dried character. These samples were described as woody, dried fruit, vegetable and sweet associated (Fig. 7). The other samples had a toasted character as well as fruit driven aroma, including tropical, white and yellow fruit (Fig. 7).

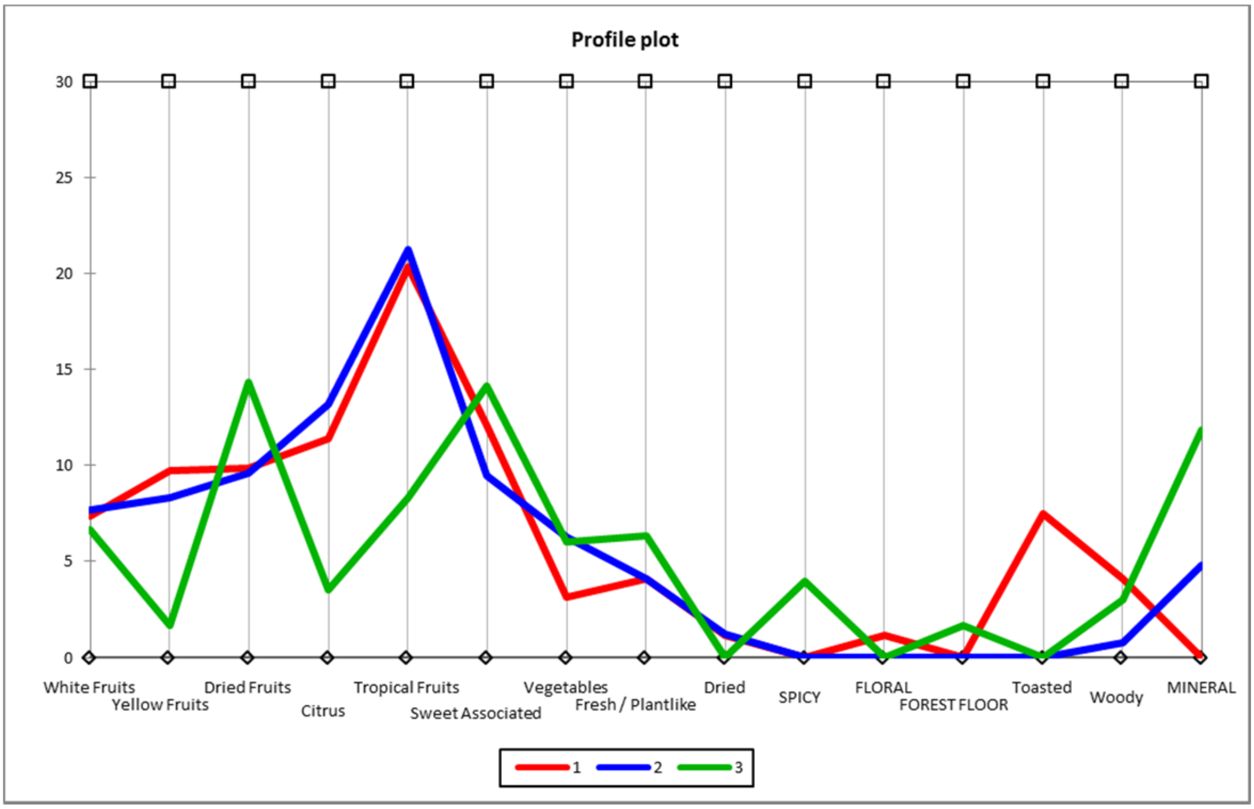

Figure 7 Profile plot of aroma sub-groups obtained with frequency of attribute citation within the sample set. Green: Fos 1-3; Blue: Con1-3, ScBF 1-3; Red: DNE 1-3, DIE 1-3 (obtained from Addinsoft XLSTAT v.2013.5.04).

A drawback of the FC method was that the data required a significant amount of clean up, as some descriptors had to be grouped at the discretion of the analyst. This method also does not given intensities, thus the data is purely qualitative. To use FC and also capture an intensity value, it could possibly be combined with an intensity rating, i.e. by performing a rate-all-that-apply (RATA) exercise, where judges first choose descriptors and then have to score each for an intensity rating (Ares *et al*., 2014).

3.4 RV coefficients: method consensus analysis

Due to the limited amount of Riebeek wine available, it was only possible to use it for one experiment (the PM) and therefore, an RV coefficient could only be calculated for the DA and FC results as the same sample set was evaluated by these two methods.

In order to compare the configurations of one method's results with another, RV coefficients were calculated. The closer the RV coefficient is to 1 the more similar the configurations are (Escoufier, 1973; Robert & Escoufier, 1976). Calculated RV values > 0.5 can be interpreted to yield sufficient consensus between methods (Louw *et al*., 2013). The RV coefficient obtained for the comparison of the DA and FC data was 0.92 (Table 4), which indicated a very good consensus between the results obtained with the different methods and two different panels.

Table 4 Comparison of the consensus between the overall product configurations obtained with descriptive analysis (DA) and frequency of attribute citation (FC) with two independent sensory panels

Methods	RV	Standard deviation	Mean	Variance	Skewness	P value
DA vs FC	0.92	2.63	0.31	0.05	1.77	0.025

The results obtained in this study with FC, confirmed the conclusion reached by Campo *et al*. (2010), that FC could be a plausible alternative to DA (Campo *et al*., 2010). DA however, provided more precise quantitative as well as qualitative data, unlike FC which just provides qualitative data.

3.5 Comparison of sensory methods

With all three sensory methods, DA, PM and FC, the same general trends were observed. The natural fermentations had a more intense riper tropical fruit aroma than the inoculated fermentations. The extended skin contact in the FoS wine, resulted in the wine having a more intense sour and bitter taste, and astringent mouth-feel. The aroma also changed from a fruity aroma to a dried grass, vegetative aroma. The wine with limited skin contact was able to retain its fruity aroma and the treatment did not seem to intensify the bitter taste.

The panel members that participated in the DA and FC sensory evaluation tasks were different people, yet still gave very similar answers. This could be interpreted that the FC method was successful in eliciting the relevant information from the sample set. A similar pattern and grouping of samples could be seen in the PCA plot obtained from the DA data (Fig. 2), the MFA from the PM task (Fig.4) and the PCA bi-plot obtained from FC data (Fig. 5). The FoS samples consistently separated from the rest of the samples and were described by the first component or factor. These samples were profiled as being more dry and mineral in character, with increased astringency and bitterness. The naturally fermented wines were in all cases described as having a strong tropical bouquet.

As was mentioned by Cartier *et al*. (2006) with sorting data and Abdi *et al*. (2007) with PM data, that DA results were more detailed than those obtained from the other methods. Taking this into account, the findings presented in this research strongly suggested that DA or similar quantitative-based methods would be the method of choice if the objective with the sensory profiling is to show in detailed quantitative terms, how similar or different two products are. For general information on the global aroma and taste differences between samples in a set of wines, the PM or FC methods could be plausible options, as less training is required and if there are readily perceivable sensory differences between wines, it could also be identified with the above mentioned rapid methods.

In terms of general evaluation of the methods, a number of general comments can be made. With regards to the PM and FC methods, the descriptor results are less specific than those obtained with DA, because the analyst has to consolidate descriptors used by the group, due to the fact that these methods use free profiling. The descriptors are therefore not homogenous like with DA (Piombino *et al*., 2004). When using FC, subtle differences between the wines may be lost, e.g. if two samples present with oaky aromas, one very intense and the other feint, the FC method will simply capture the information that the samples have an oaky aroma. PM may possibly pick up differences in intensity of aroma, as panellists may instinctively group them according to intensity, or could be instructed to do so. If the aroma components of the wines differ only in intensity, the FC method should not be used.

4. Conclusions

The most noteworthy difference between the three methods used in this study was that DA is able to quantify the differences between samples, whereas the other methods, PM and FC, cannot, although this information is not always required. Ultimately, the choice of sensory evaluation method used, will depend on the research objective, the type of data required (quantitative and/or qualitative), the intended uses thereof, the type of panel available and the financial and time implications. PM will give a general overview of the sensory space covered by the sample set, as well as the relationships between samples that are described by the distances between samples. For the screening of major differences between wines, FC will work well, but for sample sets that are fairly similar, with only small sensory differences between samples, DA would be a better option. The FC method cannot differentiate samples based on intensity of aroma, as it is purely qualitative.

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Chapter 5

Consumer preference and ranking of experimental Chenin blanc wines

Consumer preference and ranking of experimental wines

1. Introduction

There are four critical stages of new product development; these are: opportunity identification, design and development of the product, testing of prototypes and ultimately the launching of the product (Burgess, 2013). Consumer preference or acceptance studies would fall under the category of prototype testing. The prototypes in this experiment would be the experimental Chenin blanc wines. These wines were considered experimental as they were made in relatively small quantities (in the context of the scale on which industrial winemaking is done) with the purpose of experimentation with wine style modulation by the participating industrial cellar, Douglas Bellingham Green. As described in Chapter 3, the wines were made using different winemaking techniques, namely natural fermentation and extended skin contact. The naturally fermented wine and the extended skin contact wines chemical and sensory profiles were proven to be significantly different from their respective controls, as described in Chapter 3. The aim of the consumer testing was to determine whether the consumers were accepting of the product, before committing to large scale production.

When the extrinsic factors such as bottle shape, label and price of wine are deliberately taken out of consideration, such as when wines are tested blind, a direct response to the intrinsic properties, i.e. aroma and flavour of the wines, is obtained (King *et al*., 2010). However, understanding what prompts a consumer's wine choices is important for wine producers, in order for them to align themselves with the different consumer segments' preferences. The vast and increasing number of wines available in retail today, coupled with the range of styles and price brackets, makes the identification of the drivers of purchase a challenging task (Corduas *et al*., 2013). This also makes it difficult for wine producers to predict possible consumer preferences. The best route of tackling this challenge is to combine descriptive sensory analysis (DA) with consumer acceptance testing. Establishing the sensory profiles of the wines can help explain or identify those attributes of the product which the consumers like or dislike. A technique referred to as preference mapping (PREFMAP), is used to link consumer preference data and DA sensory data to aid in the identification of drivers of liking (Guinard *et al*., 2001; Ares *et al*., 2011; Varela *et al*., 2014).

Identification of the needs of a specific consumer segment is important for successful marketing of the product, marketers should take into consideration that consumers' preferences differ with regards to their age, degree of product involvement, consumption frequency, availability and place of purchase (Ginon *et al*., 2014).

Previous consumer studies conducted on commercial Chenin blanc wine focused on the Generation Y consumer segment with participants between the ages of 21 and 32 (Bester, 2011). Generation Y, also known as the ‘millenials’ are those people born between 1977 and 2000, and currently they account for more than 25% of the South African population (Goneos-Malka, 2012). These 18-35 year olds are the ‘new’ consumer group entering the wine industry. According to Bester (2012), marketing of new wine styles should be targeted at this group. Generation Y is more adventurous and willing to try new things, and their preferences can still be shaped, whereas the older consumers are generally set in their ways with regards to wine preferences (Bester, 2012).

Seven experimental Chenin blanc wines produced using different winemaking techniques were tested on a group of Generation Y consumers. The socio-demographic information of the participants was also collected and analysed. The results were then correlated with descriptive analysis data to determine possible drivers of liking for this set of wines. The aim of this study was to investigate potential preferences for the experimental Chenin blanc wines among the Generation Y consumer group.

2. Methods and materials

2.1 Consumers

The current study evaluated 86 consumers aged between 18 and 35 years, sourced from Stellenbosch and surrounding areas. It is important to have a large group of consumers, preferably between 75 and 150, to ensure more reliable results (Lawless & Heymann 2010). Similar to Bester (2011), the stratified snowball sourcing technique was used. Young working consumers, academic departments and church groups were contacted via email (Addendum I). Each confirmed participant was then asked to bring one or two other people with them, who fit the criterion of the project, which was, a consumer of wine between the ages of 18 and 35. Each consumer filled in a questionnaire regarding their demographics, wine preference and consumption habits. Samples were served blind, and the only information given to the consumers was that they were tasting experimental Chenin blanc wines made with different winemaking techniques for the purpose of experimentation of the wine style. Six tastings were held at three different venues.

2.2 Wine samples

Seven wines were used in this experiment, the winemaking procedures are described in Chapter 3. The grapes used for production of the wines originated from the same vineyard, Douglas Green Bellingham (DGB), Durbanville, Cape Town, South Africa. Two naturally fermented and two inoculated wines were made at DGB commercial cellar. These wines were fermented in barrels as they were the smallest available vessels in the cellar, and had very little effect on the wine as they were fifth fill. The control and the two extended skin contact wines (12 hours of skin contact before fermentation and fermented on skins, respectively) were made using the same grapes, but the fermentations were done at the Stellenbosch University (US) Experimental Cellar.

Table 1 The treatments of the seven different Chenin blanc wine samples used for the consumer preference test. DIE: DGB inoculated, DNE: DGB natural, Con: Control (no skin contact), ScBF: 12 hours skin contact before fermentation, FoS: fermented on skins.

Wine Code	Wine production site	Treatment	Scale
DIE 1	DGB[1]	Inoculated Barrel 1	300 L
DIE 2	DGB[1]	Inoculated Barrel 2	300 L
DNE 1	DGB[1]	Natural Barrel 1	300 L
DNE 2	DGB[1]	Natural Barrel 2	300 L
Con	SU[2]	Control	20 L
ScBF	SU[2]	12 hours of skin contact before fermentation	20 L
FoS	SU[2]	Fermented on skins	20 L

[1] Douglas Green Bellingham Cellar, Wellington, Western Cape, South Africa.

[2] Stellenbosch University Experimental Cellar, Stellenbosch, Western Cape, South Africa.

2.3 Questionnaire

Prior to the preference and ranking tests, the consumers completed a questionnaire (Addendum J). Socio-demographic information as well as information regarding the consumers' preferences, wine purchasing and consumption habits, was captured.

2.4 Tasting procedure

Consumers evaluated seven wine samples and were asked to indicate their degree of liking of each sample on a five point hedonic liking scale. The consumers were then asked to rank the samples from 1-7, one being the most preferred and 7 being the least preferred. In order to reduce the carry over effect, samples were presented in a random order. A completely randomised design was used. The tasting sheets can be seen in Addendum K.

2.5 Statistical analysis

Data was captured with *Microsoft Excel 2010* and analyses were done using StatSoft STATISTICA 12®. The data was checked for normality and a 5% significance level was used for all analyses. A number of analyses were conducted on both the demographic data and preference and ranking data. Analysis of variance (ANOVA) was used to identify significant differences between wines. An external preference map (PREFMAP) was created using the DA data from Chapter 4. The PREFMAP was used to identify drivers of liking.

3 Results and Discussion

3.1 Socio-demographic information of consumers

The consumer group used in the current study was a representative sample of the Generation Y population of the Western Cape region. The majority of participants were students. The average age of the consumers was 25. Amongst the consumers, 57% were female and 43% were male (Table 2). Interestingly 2% of the consumers indicated that they never drink wine, however, they still participated in the study, and even indicated that they liked some of the samples.

Table 2 Summary of the socio-demographic data of the Generation Y consumer group.

Gender	Female	Male	**Participation in previous sensory studies**	Yes	No
	57%	43%		38%	62%
Age	Mean Age	Median Age	Min Age	Max Age	
	25	25	19	35	
Monthly income	<R5000	R5000-R15000	>R15000	Not comfortable disclosing this information	
	36%	24%	18%	22%	
Highest qualification	Matric	Diploma	Degree	Post Graduate	
	23%	12%	34%	31%	
Residence	Stellenbosch	Cape Town	Paarl	Wellington	Other
	67%	8%	21%	1%	3%
Frequency of wine consumption	Never	Once a month	1-2 times per week	Almost every day	Every day
	2%	21 %	63%	12%	2%
Usual purchase	Red wine	White wine	Rosé wine	Both red and white wine	
	43%	13%	10%	34%	
Prefer to drink	Red wine	White wine	Rosé wine	I like both red and white wine	
	15%	44%	10%	30%	

The consumers' knowledge ranged from novice to above average (Fig. 1). The majority of the consumers (45%) considered themselves to have a moderate knowledge of wine, while 15% considered themselves to be complete novices and 36% indicated an above average knowledge of wine. Only 3% of consumers referred to themselves as wine connoisseurs. Looking at the consumer segment as a whole, they have some knowledge about wine, but would not be considered experts. This information was the consumers' personal opinion of their knowledge and the results obtained in this study might have differed if they underwent a wine knowledge evaluation, as was pointed out by Faye *et al*. (2013)

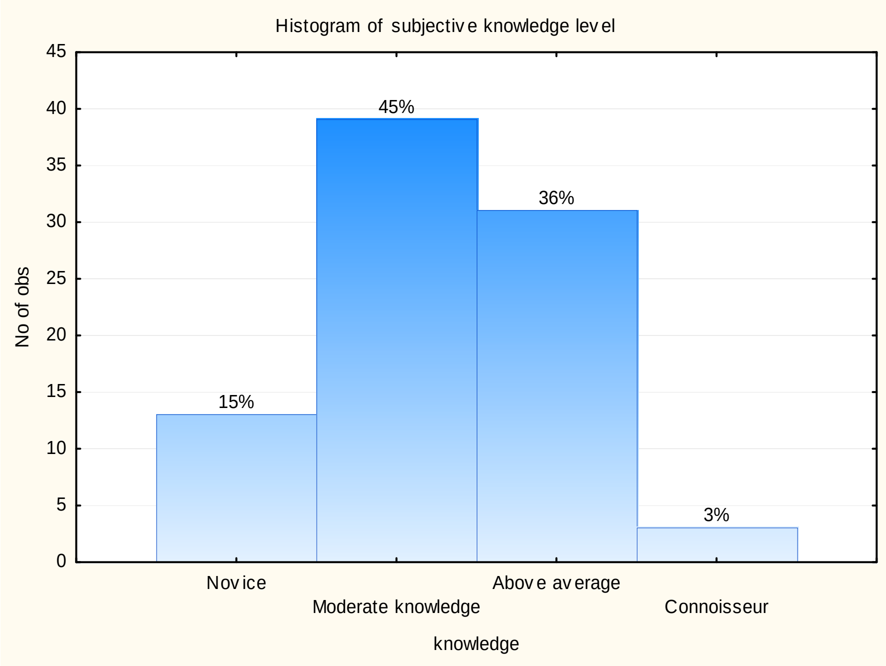


Figure 1 Histogram of consumers' subjective wine knowledge levels (obtained from StatSoft STATISTICA 12®).

Although the age interval for consumers was slightly larger for this study, 18-35 years of age, as opposed to 21-32 years of age (Bester, 2011), the subjective wine knowledge of the consumer segment tested in this study seemed to mirror what was found by Bester (2011). The consumers' subjective wine knowledge evaluations seemed to follow the same general trend (Table 3).

Table 3 Comparison of the subjective wine knowledge of consumers in 2011 and 2013.

Wine knowledge	**2011(Bester, 2011)**	**2013 (this study)**
Novice	13%	15%
Moderate knowledge	59%	45%
Above average	28%	36%
Connoisseur	1%	3%

As can be seen in Figure 2, the majority of participants (63%) consumed wine at least once a week, classifying them as regular wine consumers; 10 participants indicated that they consumed wine nearly every day and 18 indicated that they only occasionally drank wine.

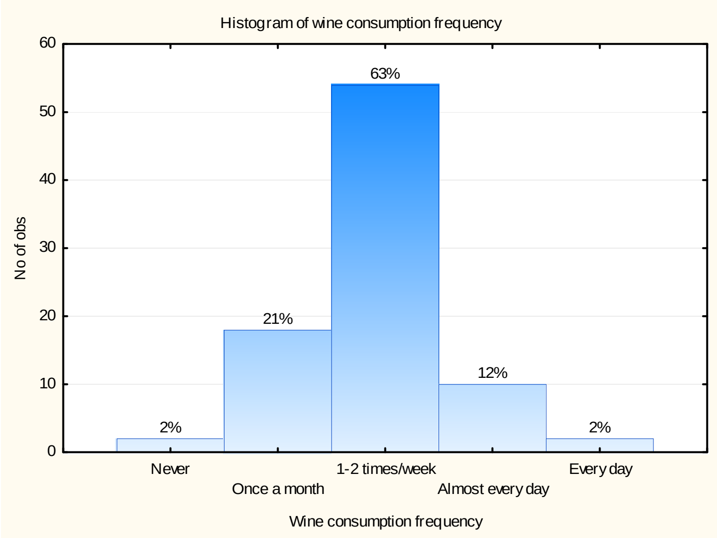
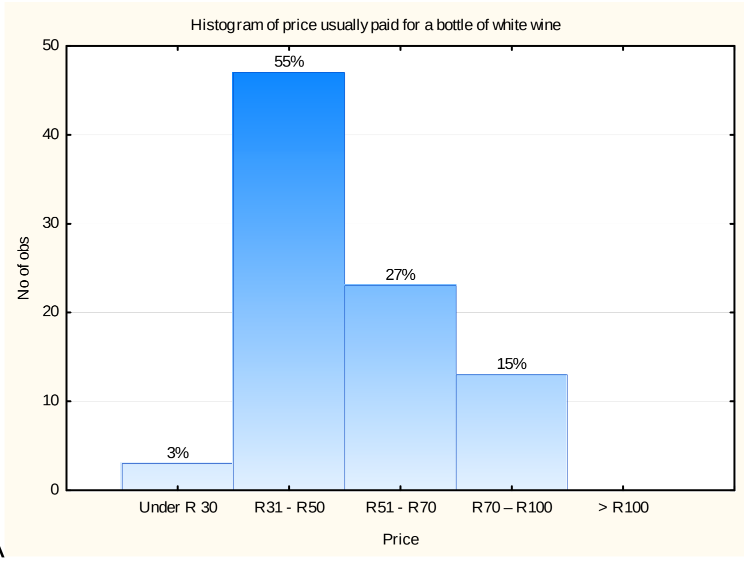


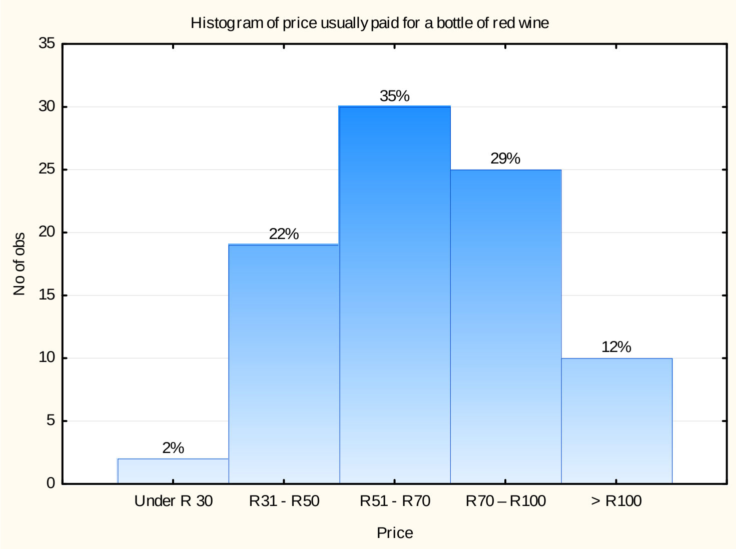
Figure 2 Consumer wine consumption frequency (obtained from StatSoft STATISTICA 12®).

3.2 Consumer opinions

The current data showed that, on average, the Generation Y segment was willing to spend more money on red wine than white wine. Fifty five percent would spend between R31 and R50 on a bottle of white wine (Fig. 3A), whilst more than 70% would spend R50 or more on a bottle of red wine (Fig. 3B). No participants were willing to pay more than R100 for a bottle of white wine (Fig. 3A), but 12%, indicated they would spend that amount on a bottle of red wine (Fig.3B).



A



B

Figure 3 The price intervals consumers would consider paying for a bottle of wine, (A) White wine (B) Red wine (obtained from StatSoft STATISTICA 12®).

Eighty four percent of consumers said that they usually consumed wine in social situations and that their purchase decisions were usually based on previous experience and word of mouth. Fifty two percent of consumers started drinking wine with friends and 31% said their interest was piqued after participating in wine tours. The level of interest that the consumers had in wine varied between 'moderately interested' to 'very interested'. Fifty seven percent of consumers responded that they were very interested in wine and 43% only had a moderate interest in wine.

When consumers were asked what attracted them to a specific bottle of wine in a store, the majority responded either the label design or the brand/cellar name (Fig. 4).

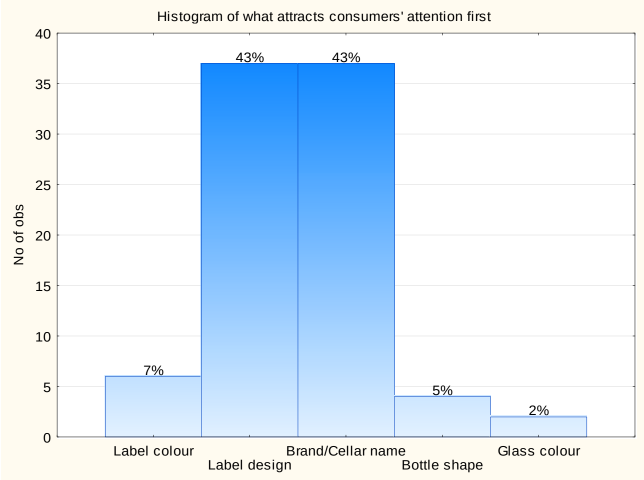


Figure 4 Histogram of wine bottle attributes that attracted consumers' attention in a store first (obtained from StatSoft STATISTICA 12®).

Forty three percent of consumers responded that label design was the first aspect that attracted their attention. Another 43% mentioned brand/cellar name. Interestingly, only 7% said bottle colour, 5% said bottle shape and 2% said glass colour attracted their attention first. These findings contradicted what was found in an Italian wine consumer study, where results showed that label or brand did not strongly influence consumer purchases (Corduas *et al*., 2013). This difference could be attributed to the different wine drinking cultures in Europe and should be verified in future wine consumer perception studies, by using larger numbers and demographically diverse consumers.

3.3 Consumer liking of experimental Chenin blanc wines

Two tests were performed with the consumers. In the first one, they were presented with the samples and asked to indicate their degree of liking on a five point hedonic scale (Addendum K). The second task was a ranking exercise where participants had to rank the samples from the least preferred to most preferred.

3.3.1 Degree of liking

It is evident from the data, that the fermented on skins sample (FoS) was not liked by the majority of the consumers (Fig. 5). There was a significant difference between liking of the FoS wine and the other wines. Most consumers gave the FoS wine either a 1 (dislike very much) or a 2 (dislike slightly) on the 5-point scale.

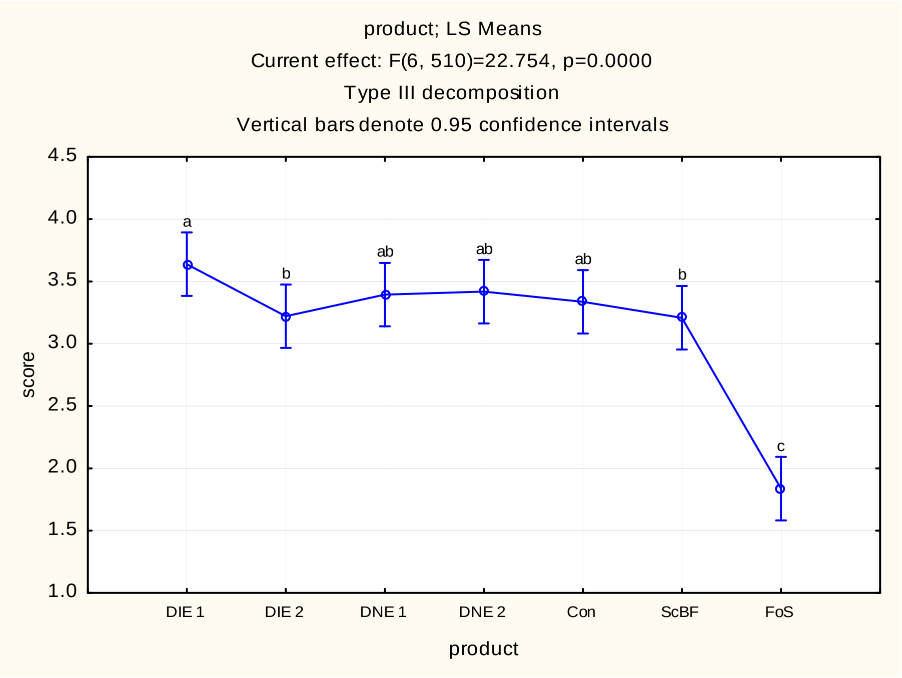


Figure 5 The LS means plot for degree of liking of each sample by the consumer group. Different alphabetical letters indicate significant differences (p<0.05), error bars indicated standard deviation. DIE: DBG inoculated wine, DNE: DGB natural wine, (1 and 2 denote barrel number), Con: control no skin contact wine, ScBF: 12 hours skin contact before fermentation wine, FoS: fermented on skins wine. (obtained from StatSoft STATISTICA 12®).

3.3.2 Preference ranking

Consumers were asked to rank the samples from 1 to 7, 1 being their most preferred sample and 7 their least preferred. The lowest ranked sample was the FoS wine, as the majority of the consumers ranked it as 7 (Fig. 6). Inoculated sample 1 (DIE 1) and the naturally fermented samples (DNE 1 & 2) were the most preferred wines. The majority of consumers ranked these samples as 1 (Fig. 6). Ranked below that was the inoculated barrel 2, the control, the skin contact before fermentation and lastly the fermented on skin sample. Although, according to the chemistry and sensory profiles (Chapter 3) the two inoculated wines were not significantly different, there was a significant difference between their rankings. DIE 1 was preferred over DIE 2. There was no significant difference between the ranking of DNE 1 and the ranking of the naturally fermented samples (Fig. 6).

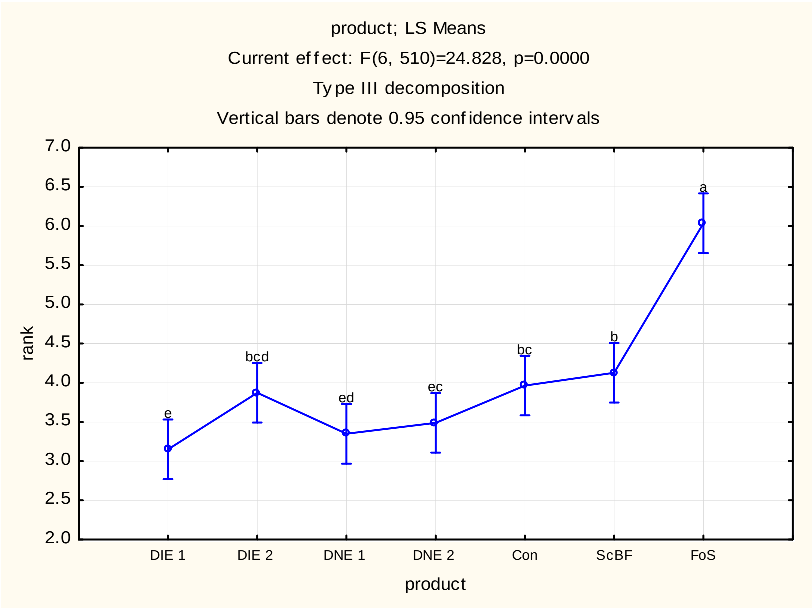


Figure 6 The LS means plot for the most preferred and least preferred sample. Different alphabetical letters indicate significant differences ($p<0.05$), error bars indicated standard deviation. DIE: DBG inoculated wine, DNE: DGB natural wine, (1 and 2 denote barrel number), Con: control (no skin contact) wine, ScBF: 12 hours skin contact before fermentation wine, FoS: fermented on skins wine. (obtained from StatSoft STATISTICA 12®).

3.4 Drivers of liking

The DA results from Chapter 4 were combined with the preference ranking results and a preference map was obtained (Fig. 7), so that the possible drivers of liking could be established. The majority of the consumers' most preferred wine samples fell on the right hand side of the plot. These samples can be positively correlated to the attributes: banana, pineapple, citrus, passion fruit and sweet (Fig. 7). The samples on the right hand side were negatively correlated with the attributes bitter, astringent and sour. Notably, the majority of consumers preferred the fruitier and sweeter wines (Fig. 7). A possible explanation for the dislike of the fermented on skin sample is the over extraction of tannins from the skins during fermentation, resulting in a more bitter and astringent wine which consumers did not enjoy.

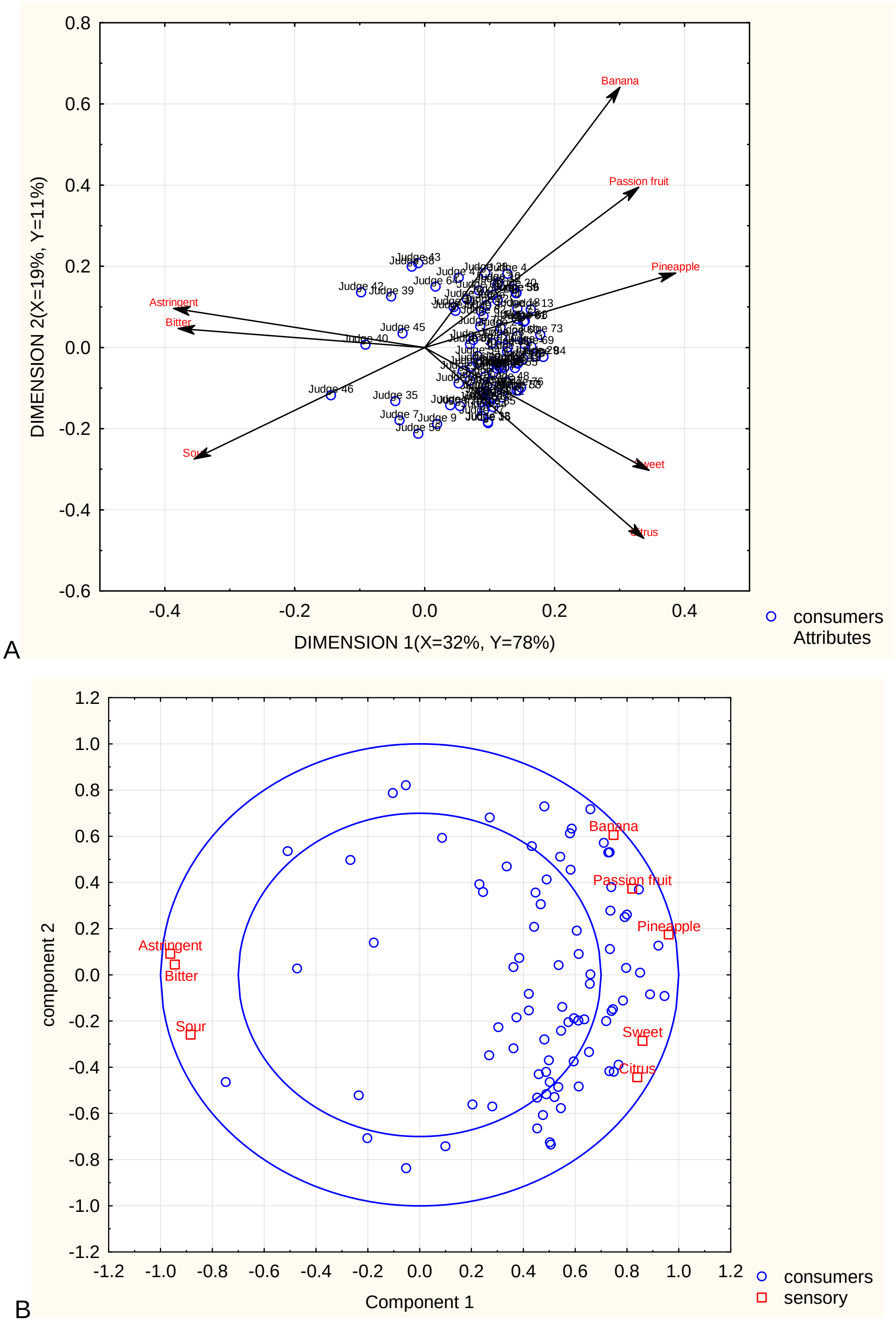


Figure 7 (A) Preference analyses of 86 Generation Y consumers for the seven Chenin blanc wines via an external preference map (PREFMAP). The arrows indicate intensity increase of relevant wine sensory attributes and the dots indicate the 86 consumers distributions in relation to the wine sensory attributes (B) Scatterplot of consumers' preferred sample plotted against the aroma and taste attributes (obtained from StatSoft STATISTICA 12®).

When the consumers' preferred samples were projected against the descriptors used during DA, no gender specific trends could be observed (Fig. 8).

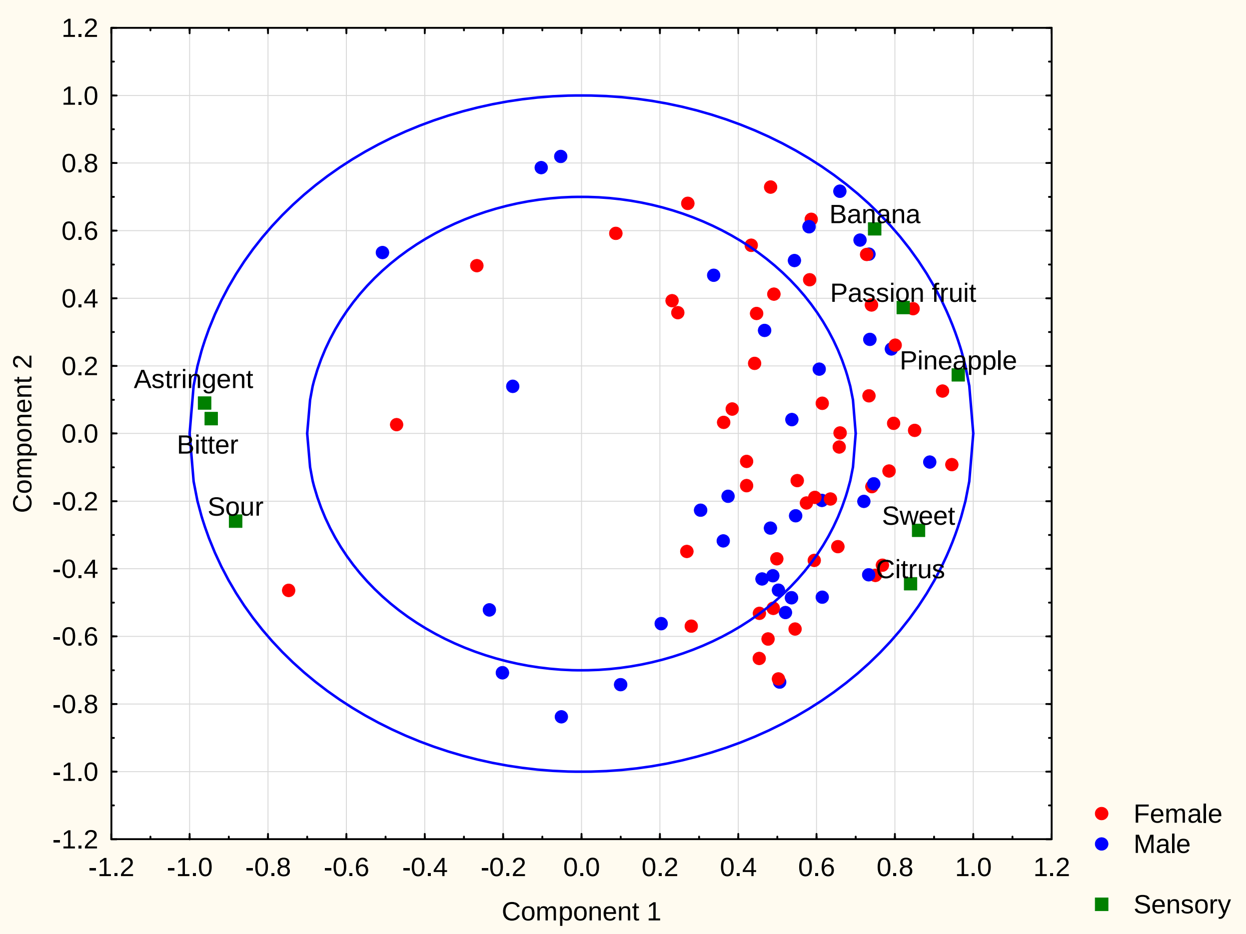


Figure 8 Scatterplot of most preferred sample and projected against sensory descriptor data. Red dots indicate female and blue dots male (obtained from StatSoft STATISTICA 12®).

Figure 9 is a modified version of Fig. 8, where the consumer markers were coloured by wine preference. The data showed that the consumers' who indicated that they preferred red wine, liked the wine samples that were described as bitter and astringent more and samples described as tropical and fruity, less; there was also a preference trend towards the limited skin contact sample and the control (Fig. 9). The consumers, who indicated that they preferred white wines, had no specific preferences as they were equally spread throughout the plot. Consumers who indicated that they liked both red and white wine equally, preferred the wines with descriptors on the right hand side of the plot, which excluded the FoS sample.

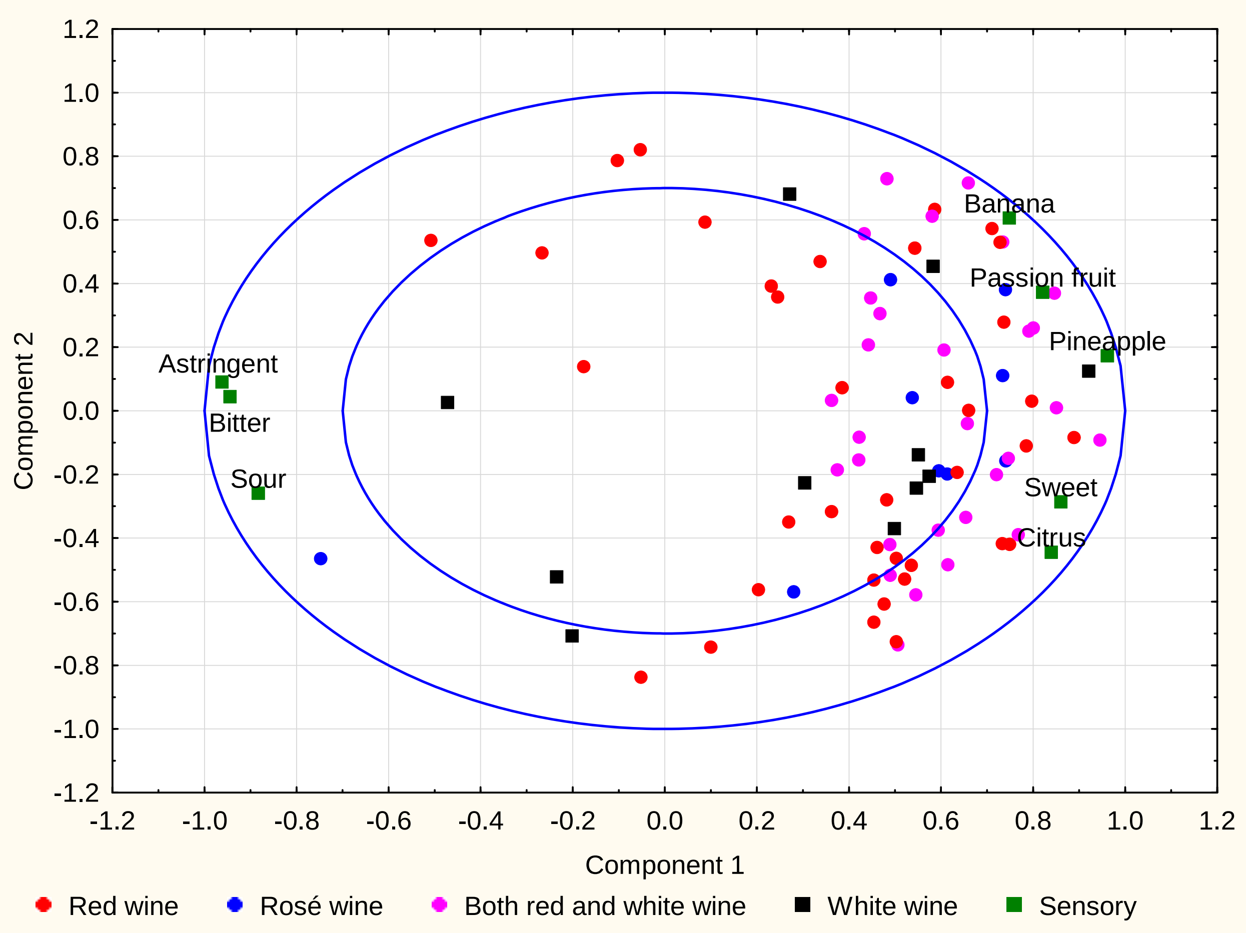


Figure 3 Scatter plot of consumers' most preferred sample projected with the DA sensory descriptors, coloured by wine preference. Dots coloured in red indicate consumers who prefer red wine, blue dots indicate consumers who prefer rose wine, pink dots consumers who like both red and white wine equally and the black squares indicates consumers who preferred white wine (obtained from StatSoft STATISTICA 12®).

From these preliminary tests, it can be concluded that in general, the consumer group had a preference for the naturally fermented wines and disliked the fermented on skins wine, while the other wine samples were ranked by the group in varying orders. Consumers had an increased preference for the naturally fermented wines, as in the preference ranking they tended to be marked as the most preferred sample (Fig. 6). A reason for this could be the strong tropical fruit character and sweeter taste of these wines (established during sensory profiling in Chapters 3 and 4). As for the fermented on skins wine, in the preference ranking it tended to be marked as the least preferred sample (Fig. 6). The sensory profile established in Chapters 3 and 4, and the subsequent identification of drivers of liking, characterised this wine as bitter, sour and astringent and lower in fruit character (Fig. 7), which collectively, could be the reason why consumers rated it so low. Selli and co-workers did an experiment using *cv.* Muscat, with varying degrees of skin contact; a control, six hours of skin contact and twelve hours of skin contact (2006). Results of that consumer study showed that the six hours of skin contact wine was the most preferred, followed by the control and then the twelve hours of skin contact sample. Gawel *et al*. (2014) also found that white wines with pre-fermentative skin contact tended to be less bitter. It could therefore be concluded that a decrease in bitterness intensity can be achieved by not fermenting on skins and decreasing the duration of pre-fermentative skin contact. Clearly, a fine balance in the duration of skin contact is necessary, since the results presented here, also highlighted some positive aspects of limited skin contact. The effects of skin contact on consumer product liking should also be tested on a larger group of consumers, possibly from a different geographic area, or even as part of a different product set, since different conclusions may be reached.

4. Conclusion

The results presented here suggested that consumers of red wine may possibly prefer the more astringent, bitter and less tropical taste obtained through skin contact. This aspect can be further explored by including another wine with a different length of skin contact into the set and testing again on perhaps a larger group of consumers, possibly including multi-cultural segments.

The natural and inoculated wines were enjoyed by the consumers and the naturally fermented wines seemed to be the favourite among consumers, most likely due to their strong fruity character and sweeter taste. The preference for the majority of this consumer group was for a more fruity wine.

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Chapter 6

General discussion and conclusions

GENERAL DISCUSSION AND CONCLUSIONS

Based on the increased recognition that South African Chenin blanc wine has received in the last few years, winemakers are experimenting with the development of new styles with modulated flavour profiles, by using different winemaking techniques. In this context and due to the current research focus on sensory methodologies for testing of food and beverages, the prime goal of this study was not only to look at the sensory profiles of wines made using different winemaking techniques, but also to evaluate the sensory methodology and their potential use both in industry and a research capacity. The following sections evaluate the pros and cons of the sensory methods used in the course of this study, highlight the contributions made by the work presented here and make suggestions for optimisation and future research. Based on the importance of transferring the developed technology to the wine industry, practical recommendations are also made for environments where there are severe limitations on availability of panels, repeats, and training, as well as time that can be allocated to the evaluation tasks.

1. Scientific Outcomes

1.1 Optimisation of Rapid Sensory Profiling Methods

Chapter 4 explored the use of rapid sensory methods, specifically projective mapping (PM) and frequency of attribute citation (FC), as alternatives to descriptive analysis (DA). Results showed that DA can potentially be substituted by both PM and FC, indicated by the similar results achieved by using the three methods with three independent panels. These rapid methods do however have limitations. Looking at the descriptive data captured for all three methods, DA provides more precise and easily interpretable descriptions than those obtained from both PM and FC, and can be easily correlated with chemical data. The FC and PM generally only picked up large differences between wines, and identified the most dominant characteristics. These methods are also limited in their ability to differentiate between samples where differences are intensity based. A possible solution to this problem could be to use PM and instruct panellists to arrange samples based on aroma intensity as well. This modification should be tested in future work in order to optimise the outputs of the rapid methods.

FC and DA profile samples individually, whereas PM is a holistic approach where all the samples are compared to one another in order to be arranged on the tasting sheet (Louw *et al.*, 2013); therefore, if another sample was added to the set, for DA and FC (where samples are described individually) the results would stay the same, but for PM (where samples are described relative to each other), the results may change.

FC and PM are not as easy to use, to explain consumer preferences, as they do not scale data like is done in DA.

With a large set of wines and the objective to get an idea of the sensory space that they occupy, projective mapping with descriptions is an option. The main draw-back of projective mapping is that samples' positions are captured with a co-ordinate system, which might not be used in the same fashion by the assessors, which ultimately makes the statistical analysis more complicated and more time consuming, and the method less rapid. Likewise, because free description is used, not every panel member describes the wine in the same way, or even uses the same descriptors. The data capturing is therefore slow as it takes time to group descriptors appropriately. If, however, the panel is trained, the descriptors used, may be more similar and ultimately easier to combine for analysis. This aspect was also discussed by other researchers (Barcenas *et al*., 2004). Mapping is mostly done manually, but if it could be done electronically, this could speed up the data capturing stage. This would unfortunately not speed up the descriptor analysis, as the analysts would still have to use their discretion when combining descriptors.

Consistency between FC and DA was shown to be good; the calculated RV coefficient was 0.92. Although the RV coefficient for PM and DA could not be calculated (due to sample constraints), the descriptions generated and the product maps (PCA and MFA) produced by both methods were similar (Chapter 4).

Overall, the advantages of the rapid methods are that they require less panel training as the panel does not have to come to consensus on scaling of descriptors, as is the case with DA.

The rapid methods are definitely more rapid for the panel, but not for the panel leader / analyst and more research needs to be done on speeding up the data capturing and subsequent data analysis stages.

1.2 Winemaking techniques

In Chapter 3 two winemaking techniques, respectively natural fermentation and skin contact, and their effects on Chenin blanc wines, were investigated.

1.2.1 Natural fermentation

There was a definite treatment effect in the wines produced experimentally, as observed by the different sensory profiles, as well as the volatile compound chemistry. The yeast populations on the grapes from the two vineyards differed. It was not possible to identify clear trends in the chemical profilesof natural fermentations, but preliminary conclusions point to a significant effect by the yeast populations. However, more research is needed to fully characterise this complex aspect and variability from one season to the next can be anticipated.

Although the sensory and chemical profiles of the wines were different, there are other factors which could have influenced the results, including the scale of fermentation, different cellars, different yeast used in the inoculated fermentations, and the barrel vs. tank fermentations. Therefore, the comparisons in this work was only made between the control and treatment per cellar, and not collectively. Future studies focussed on the investigation of the effects of winemaking techniques should aim to keep as many variables as possible constant. All fermentations should be (if possible) conducted at one site, in containers of the same volume and material (i.e. steel tank or wooden barrel) and the commercial starter culture in the inoculated fermentation should be kept constant for all the inoculated fermentations.

1.2.2 Skin contact

Results in Chapter 3 and Chapter 4 showed that the skin contact treatments had a notable effect on the sensory and volatile chemical profiles of the Chenin blanc wines produced. The fermentation on the skins (full contact for the duration of the fermentation) significantly affected both the aroma and the taste of the wines. The increase in bitter taste and astringency testified to a too long a period of skin contact.

Future studies should look into intermediate periods of skin contact, for example 24 and 35 hours which have been shown to be beneficial in other white wine cultivars (Sokolowsky *et al*., 2015). Analysis of phenolic compounds that are known to affect mouth-feel and colour differences could also be included.

For both methods, natural fermentation and skin contact, future research should be done on two consecutive harvests to test for treatment vs. vintage effects. Other studies have found that volatile chemical profiles of control samples have varied across vintages (Rodriguez-Bencomo *et al*., 2008).

2. Industrial outcomes

2.1 Rapid methods

Of the two rapid methods tested, FC seems to have the most potential to be adapted for use in industry. This is based on the important practical considerations that the training for FC required is far less than that for descriptive analysis. In addition, once the panel is trained with this procedure testing can be done as required. The statistical analysis is easy (in comparison to PM) to perform and interpret, once the data has been captured. If it could be designed that the panellists could complete their tasting sheet electronically and the data automatically collected in a spread sheet, it would make the statistical analysis much faster. There are a couple of drawbacks for FC; at present the recommendation is to use 30 trained judges, since it is frequency-based. Another drawback is that this method may miss subtle differences between wines, as only the most dominant attributes are profiled. More work needs to be done to optimise the method for industry use, especially when number of available assessors is small, but this method shows promise.

2.2 Winemaking techniques

2.2.1 Natural fermentation

Natural fermentation is very yeast dependant and because of this it is unpredictable. The natural fermentation had positive effects on the aroma profile of the wine, and no unpleasant aromas were detected. The use of co-inoculation with non-*Saccharomyces* yeasts (Jolly et al., 2003) could be beneficial and make the fermentation more predictable.

2.2.2 Skin contact

The fermentation on skins treatment was too harsh; the wine lost its fruity character and had an increased bitter taste and astringent mouth-feel. Sensory profiles of the 12 hours of skin contact was not found to be significantly different from those of the control wine which had no skin contact. There were however chemical differences present that were not perceived, but perhaps by extending the skin contact to 24 or 35 hours the sensory impact will become more easily perceived. . This was a preliminary study, and further research needs to be done on this technique.

2.3 Generation Y consumers' blind preferences for the experimental wine

In Chapter 5 the preference for seven experimental Chenin blanc wine samples was investigated using consumers belonging to Generation Y (18-35 years in this study). The most preferred sample of this set was the naturally fermented wine and the least preferred was the fermented on skins wine. Possible reasons for this include the increased tropical fruit character of the naturally fermented wine and the fact that the fermented on skins sample was bitter tasting and had an astringent mouth-feel. It should be kept in mind that these wines were all experimental and did not go through fining/barrel maturation like they possibly would do in a commercial product. The results may change when tested on a larger group of consumers, or different consumer segments.

For this study the consumer preference testing was conducted blind, but it would be of interest to do an informed test where the consumers are told exactly how each wine was made and compare the results achieved to those achieved during the blind tasting. Previous studies have shown that consumer preference tends to change when they are given more information about the products (Hanekom, 2012; Guinard *et al*., 2001).

Sourcing panels is the most difficult task involved in consumer studies. More than 150 consumers were approached to participate in this study and only 86 actually showed an interest. Sourcing consumers is a difficult task and building a database of willing participants would be helpful for future consumer studies.

3. Conclusion

FC and PM can successfully be used as alternatives to DA for some sensory evaluation tasks. FC has the potential to be used by industry for rapid profiling of wine, as it requires minimal aroma training. It should be noted that the rapid methods will never give the complete accurate quantitative and qualitative results that DA does (Chollet *et al*., 2010), but confirming what was found by Dehlholm *et al*. (2012), it can be stated that the rapid methods are definitely capable of describing differences among samples.

Chenin blanc, although the most cultivated wine grape in South Africa, is the least researched, judged by the lack of published data. From the results of this research extended skin contact as a treatment for Chenin blanc needs to be researched further. The fermentation on the skins was too harsh a treatment, the wine lost its fruity aroma and the perceived astringency and bitterness was notably increased. With regards to natural fermentation, Chenin blanc seems to respond well, and the indigenous yeasts seem to increase the fruity profile of the wine and by doing so increase the perceived sweetness of the wine, but this is not guaranteed as vineyard populations change from season to season and so consistency may be an issue.

The preference for the tested Generation Y consumer group seems to be for the more fruity Chenin blanc wines, in particular the naturally fermented wines. This was however a preliminary test and would have to be tested on a larger group of consumers to be confirmed.

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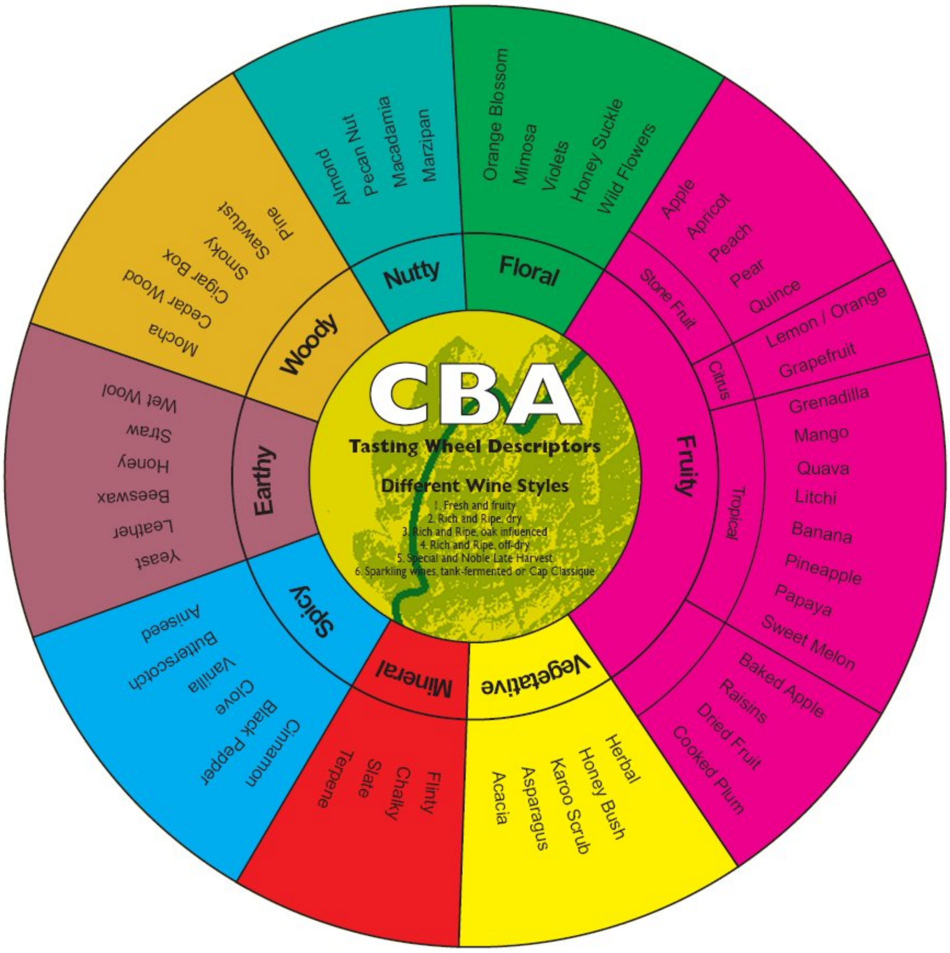
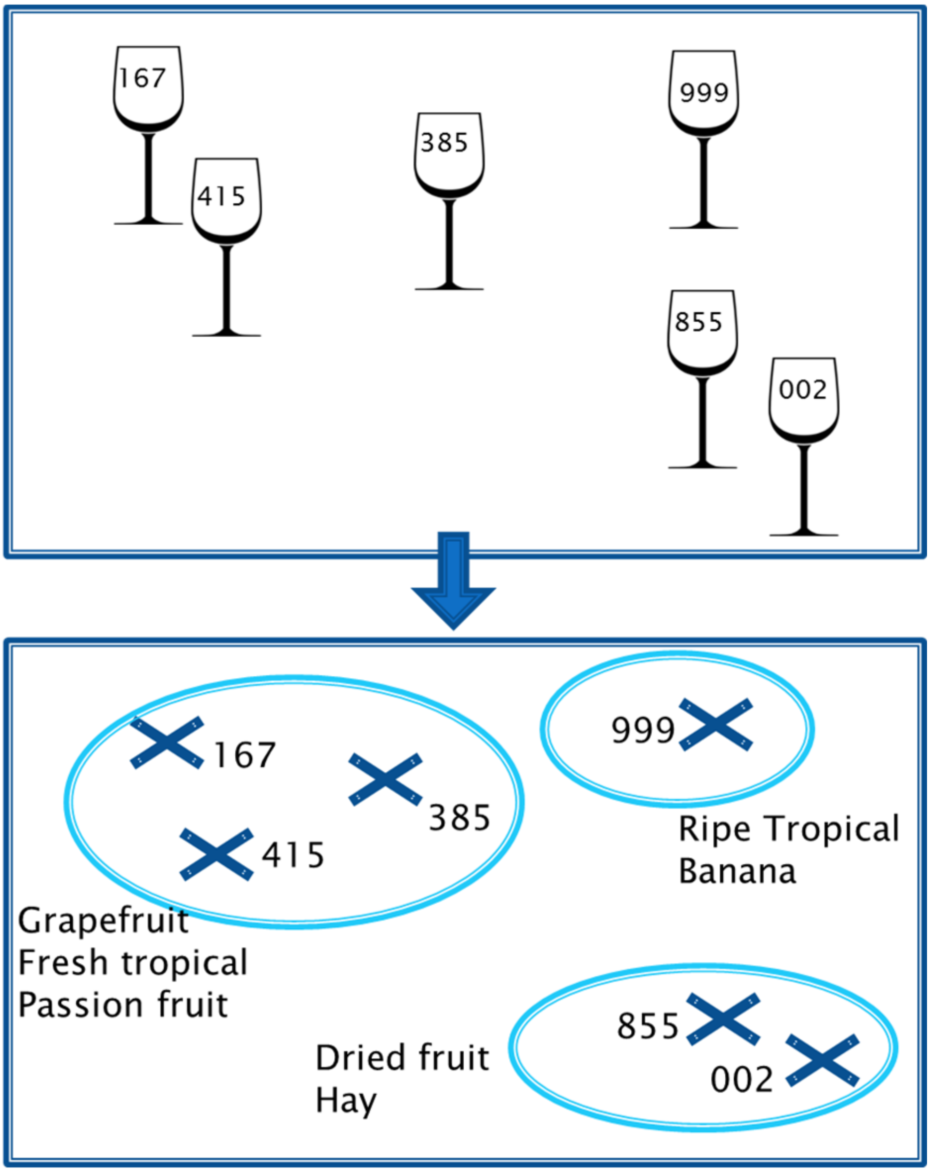
Addendums

Addendum A

Chenin blanc aroma wheel developed by the Chenin blanc association.

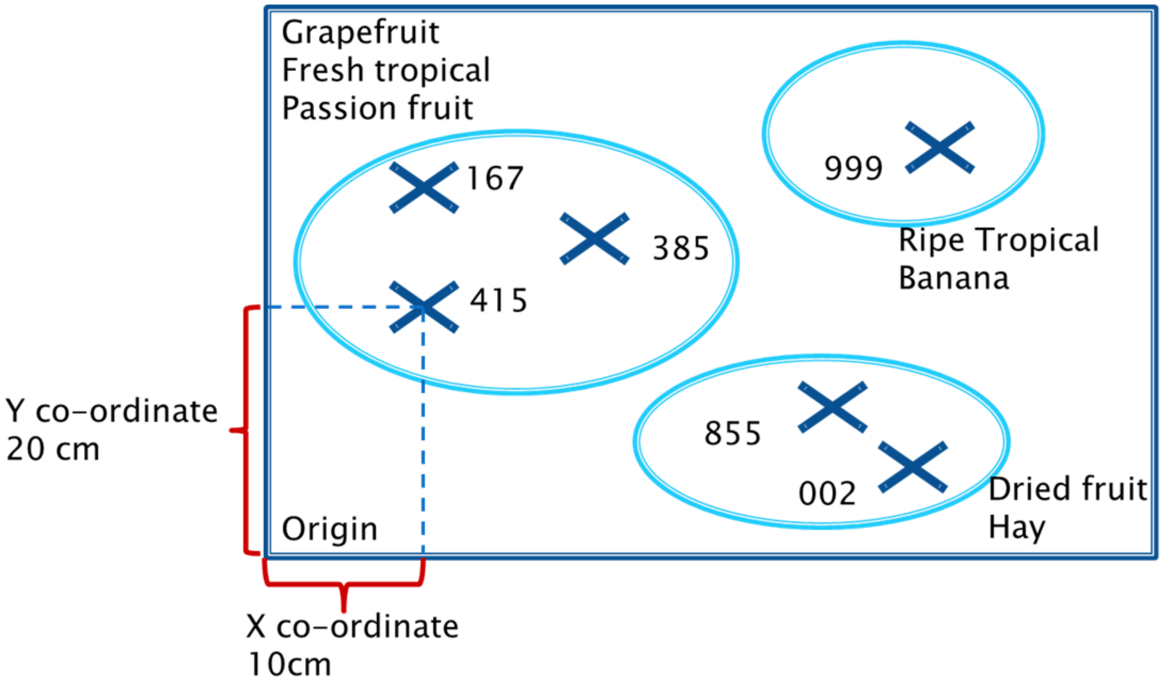


Addendum B


167
415
385
999
855
002
167
385
415
999
Ripe Tropical
Banana
Grapefruit
Fresh tropical
Passion fruit
855
002
Dried fruit
Hay

Addendum C

Example of projective mapping testing sheet and how X and Y co-ordinates are measured and recorded.



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Sample code	**X**	**Y**	**Grapefruit**	**Fresh tropical**	**Ripe tropical**	**Passion fruit**	**Banana**	**Dried fruit**	**Hay**
167			1	1	0	1	0	0	0
385			1	1	0	1	0	0	0
415	10	20	1	1	0	1	0	0	0
999			0	0	1	0	1	0	0
855			0	0	0	0	0	1	1
002			0	0	0	0	0	1	1

Addendum D

Abbreviations for chemical compound names used in Chapter 3 in Fig. 5B, 6B, 7B and 8B, in the order in which they appear on the graph.

Abbreviation	Chemical Compound
3MHA	3-mercaptohexylacetate
3MH	3-mercaptohexanol
Eth Ac	Ethyl Acetate
Meth	Methanol
Eth Bu	Ethyl Butyrate
Prop	Propanol
Isobu	Isobutanol
Iso Ac	Isoamyl Acetate
But	Butanol
Iso Al	Isoamyl Alcohol
Eth Hex	Ethyl Hexanoate
Pent	Pentanol
Hex Ac	Hexyl Acetate
Acetoin	Acetoin
3-Meth-1-pen	3-Methyl-1-pentanol
Eth Lac	Ethyl Lactate
Hex	Hexanol
3-eth-1-pro	3-ethoxy-1-propanol
Eth Capr	Ethyl Caprylate
Acet A	Acetic Acid
Eth-3-hybu	Ethyl-3-hydroxybutanoate
Propi A	Propionic Acid
Isob A	Isobutyric Acid
Bu A	Butyric Acid
Eth cap	Ethyl Caprate
Isov A	Isovaleric Acid
Dieth suc	Diethyl Succinate
Val A	Valeric Acid
Eth pheAc	Ethyl Phenylacetate
2-Phe Ac	2-Phenylethyl Acetate
Hex A	Hexanoic Acid
2-PheEth	2-Phenylethanol
Oct A	Octanoic Acid
Dec A	Decanoic Acid

Addendum E

Original comprehensive list of attributes and aroma reference standards used for descriptive analysis and frequency of citation training.

Family/Subfamily	Attribute	Composition
Citrus	Lemon	¼ slice lemon
	Orange	¼ slice orange
	Grapefruit	¼ slice grapefruit
	Mandarin	1 segment and 2x3cm piece of skin
White/Yellow fruit	Peach	20 mL Liquifruit Peach
	Apricot	20 mL Liquifruit Apricot
	Pear	2x3cm piece canned pear
	Yellow apple	1cm wedge fresh yellow apple
Tropical	Banana	1 µL Isoamyl acetate + 30mL water
	Litchi	5ml canned litchi juice
	Passion fruit	1/3 pulp fresh passion fruit
	Pineapple	¼ slice of pineapple
	Guava	2x3cm piece fresh (ripe) guava
	Mango	2cm block dried mango roll
Vegetative	Fresh cut grass	Handful fresh cut grass
	Fresh green beans	2 green beans chopped
	Green pepper	2x3cm piece chopped
	Mint	1 sprig chopped
	Oregano	1 tsp. dried oregano
	Eucalyptus	3 leaves chopped
	Celery	1 stick chopped
	Dry grass/Hay	Handful dry grass
	Canned Green beans	10 mL brine + 3 pieces of green bean
	Cooked vegetable	Dimethyl sulfide
Sweet Associated	Honey	Acacia honey
	Caramel	1 tsp. caramel sauce + 5 mL water
	Toffee	1 toffee chopped + 5 ml Hot water
	Vanilla	½ tsp. vanilla essence
	Marmalade	1 tsp. orange marmalade
	Dried fruit	I piece apple, apricot, peach, prune, pear chopped
	Raisin	5 raisins chopped
Nutty	Nutty	2 drops walnut flavour + 10 mL water
Floral	Orange blossom	2 drops orange blossom flavor on cotton wool
	Rose	1 mL rose water + 10 mL water
	Violet	2ml Violet flavor + 4mL water

Addendum F

Testing Sheet

Judge number:__________ Date:______________________

Sample code: [ ]

Pineapple	None	├──────┤	Intense
Banana	None	├──────┤	Intense
Citrus	None	├──────┤	Intense
Yellow apple	None	├──────┤	Intense
Passion fruit	None	├──────┤	Intense
Dry grass	None	├──────┤	Intense
Marmalade	None	├──────┤	Intense
Stone fruit	None	├──────┤	Intense
Honey	None	├──────┤	Intense
Raisin	None	├──────┤	Intense
Mint	None	├──────┤	Intense
Cooked veg	None	├──────┤	Intense
Dried fruit	None	├──────┤	Intense
Sweetness	None	├──────┤	Intense
Sourness	None	├──────┤	Intense
Bitterness	None	├──────┤	Intense
Astringency	None	├──────┤	Intense

Addendum G

Tuckerplot evaluations of DA data

PanelCheck software was used to evauate panel concensus. The tuckerplots for each attribute were looked at to see if the panel was consistent in terms of their intensity scaling of the attributes.

Fig. G.1 shows good consensus for the attribute bitterness, as the majority of panel scaled the attribute similarly, and thus lie in the outer circle of the plot.

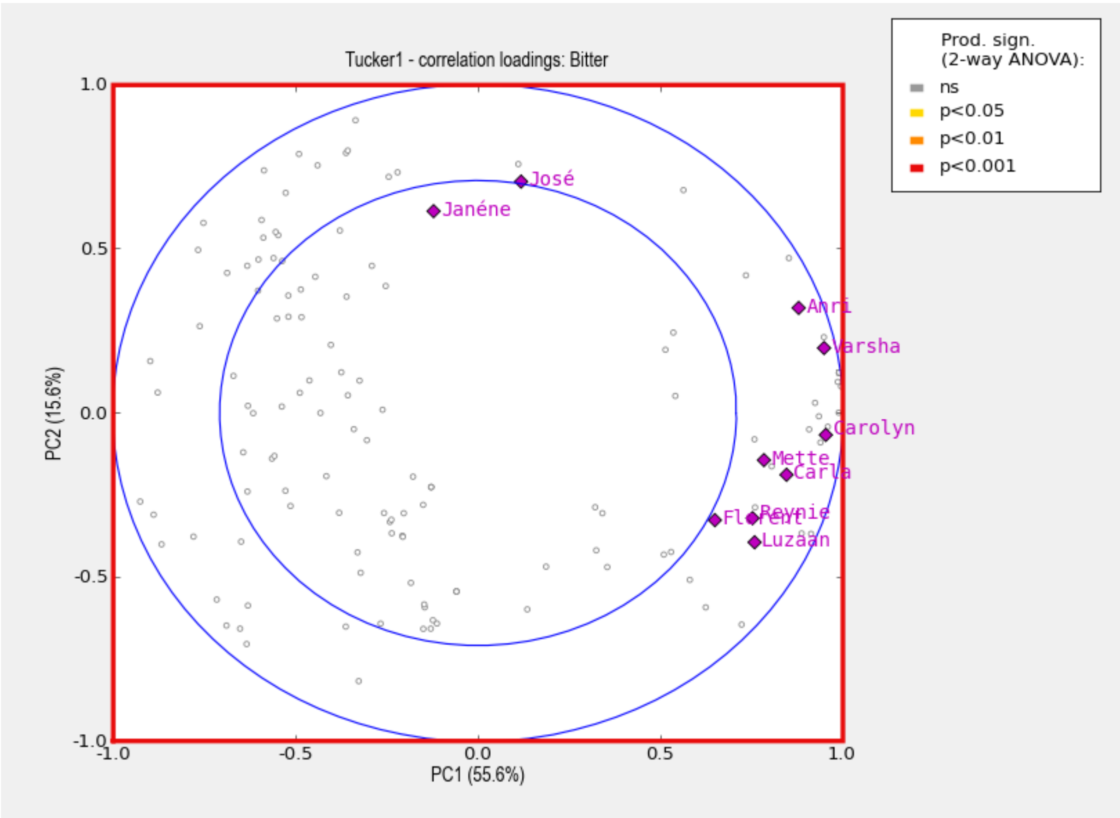

Figure G.1: Tuckerplot of the correlation between bitterness intensity ratings by panellists for 7 wine samples ($p<0.001$).

As is evident from Fig. G.2, there was no consensus of the panel for the attribute stonefruit, as most of the judges lay in the middle of the plot.

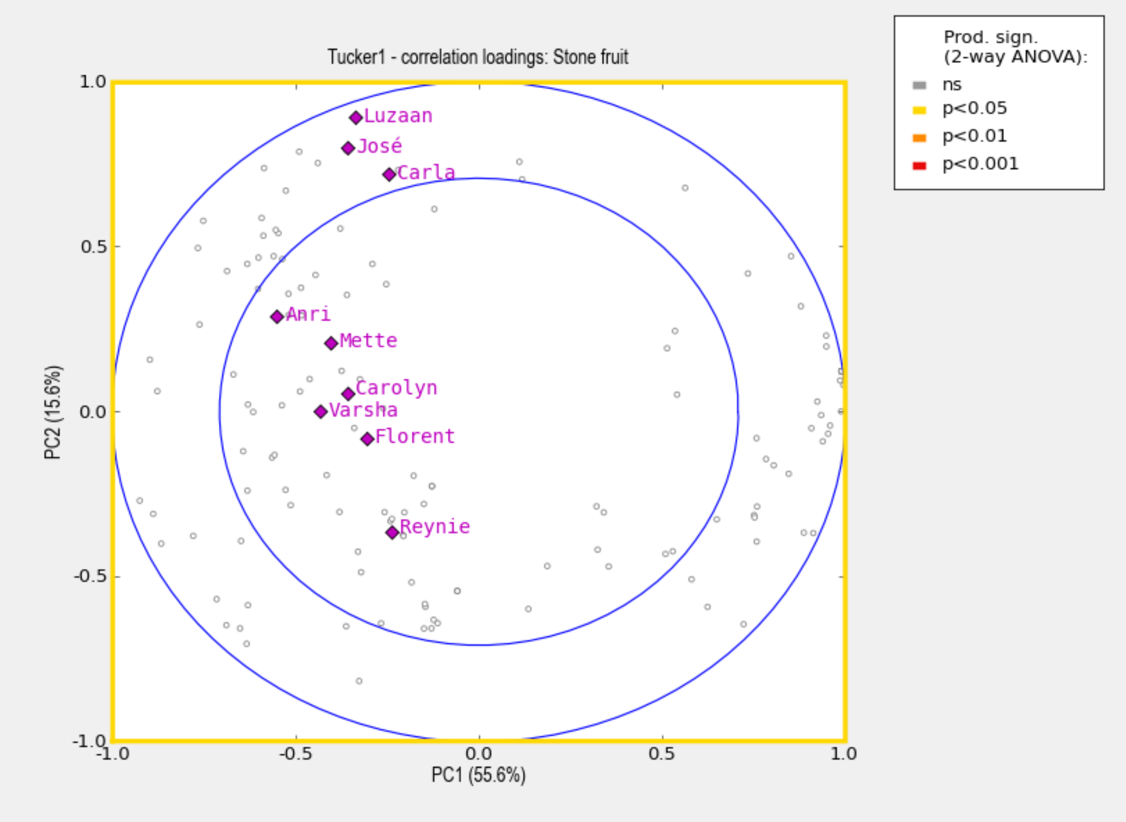

Figure G.2 Tuckerplot of the correlation between Stonefruit intensity ratings by panellists for 7 wine samples (p<0.05).

Addendum H

Aromatic descriptor list for frequency of attribute citation

Judge:…………. **Wine Code:**……… Date:………….

Odour Descriptors: Choose the most relevant descriptors on the list below by ticking the corresponding box **(Maximum 5 descriptors)**

AROMATIC DESCRIPTORS LIST

☐ FRUITY

☐ WHITE FRUITS
- ☐ Quince
- ☐ Pear
- ☐ Yellow Apple

☐ YELLOW FRUITS
- ☐ Apricot
- ☐ Peach
- ☐ Melon

☐ RED FRUITS

☐ BLACK FRUITS

☐ DRIED FRUITS
- ☐ Dried Apple
- ☐ Dried Peach
- ☐ Dried Apricot
- ☐ Dried Fig
- ☐ Date
- ☐ Prune
- ☐ Raisin

☐ CITRUS
- ☐ Grapefruit
- ☐ Lemon
- ☐ Orange

☐ TROPICAL FRUITS
- ☐ Pineapple
- ☐ Banana
- ☐ Guava
- ☐ Passion Fruit
- ☐ Litchi
- ☐ Mango
- ☐ Gooseberry
- ☐ Papaya (Paw-paw)
- ☐ Coconut

☐ SWEET ASSOCIATED
- ☐ Ripe Fruit
- ☐ Mamelade
- ☐ Honey
- ☐ Fruit Jam
- ☐ Glazed / Crystallized Fruit
- ☐ Muscat
- ☐ Baked Apple

☐ VEGETATIVE / GREEN

☐ VEGETABLES
- ☐ Artichoke
- ☐ Asparagus
- ☐ Cabbage
- ☐ Green Beans
- ☐ Green Pepper
- ☐ Green Olive
- ☐ Celery

☐ FRESH/ PLANTLIKE
- ☐ Eucalyptus
- ☐ Herbaceous
- ☐ Tomato leaf
- ☐ Green / Cut Grass
- ☐ Lemon Grass
- ☐ Mint

☐ DRIED
- ☐ Hay / Dried Grass
- ☐ Tobacco

☐ SPICY
- ☐ Bay Leaf / Laurel
- ☐ Thyme
- ☐ Juniper
- ☐ Nutmeg
- ☐ Cinnamon
- ☐ Ginger
- ☐ Clove
- ☐ Anise / Fennel
- ☐ Liquorice
- ☐ Curry
- ☐ Black Pepper
- ☐ White Pepper

☐ FLORAL
- ☐ Camomile
- ☐ Linden Tree Flower
- ☐ Honeysuckle
- ☐ Orange Blossom

☐ FOREST FLOOR
- ☐ Humus/Earthy
- ☐ Mouldy
- ☐ Mushroom

☐ TOASTED / WOOD

☐ TOASTED
- ☐ Caramel / Burnt Sugar
- ☐ Toffee
- ☐ Vanilla
- ☐ Roasted Coffee
- ☐ Toasted Bread

☐ WOODY
- ☐ Planky / Pine Shavings
- ☐ Oaky
- ☐ Burnt / Smoked Wood

☐ NUTS
- ☐ Almond
- ☐ Hazelnut
- ☐ Walnut

☐ ANIMAL
- ☐ Leather

☐ MINERAL
- ☐ Chalky
- ☐ Iodine / Salty
- ☐ Mineral / Flinty
- ☐ Solvent / Chemical

☐ OTHER
- ☐ Butter
- ☐ Lactic
- ☐ Sulphur
- ☐ Stuffy
- ☐ Dusty
- ☐ Wet mop
- ☐ Yeast

Addendum I

Consumer contact email

WHITE WINE TASTING

The Institute for Wine Biotechnology (IWBT) at Stellenbosch University would like to invite you to participate in a consumer white wine tasting. This study will form part of an on-going research project involving different vinification techniques of Chenin blanc wine. This particular study is focused on generation Y consumers' preferences.

- This is an opportunity to try some different wines and give us your much needed opinions on them
- You will receive a small gift for your participation

PLEASE NOTE: **All personal information will be kept strictly confidential** and all references to consumers will be **kept anonymous**.

You will only be contacted again if you indicate to us that you would like to participate.

The study will take place on ***Wednesday the 20th*** and ***Thursday the 21st of November*** at the following times: ***10:00, 13:00, 16:00 and 18:00***. You are only required to attend **one session** on either of the days.

If you are interested in participating in this study **please complete the attached screening test and send it back to: hhn@sun.ac.za**

Addendum J

Screening Questionnaire – Consumer Demographics

Your details are important to provide us with a snap shot of the profiles of young wine consumers; Consumer Y. Please complete the following screening questionnaire as accurately as possible. We are interested in **average responses** and no individual personal details will be disclosed. All information regarding demographic information is kept confidential.

1. Name:____

2. Age:____________

3. Job description:__________________________________

Please select the answer that applies to you and mark the appropriate box with an 'X'

4. Gender:

Male	
Female	

5. Please indicate your main recent area of residence?

Stellenbosch	
Cape Town	
Paarl	
Robertson	
Rawsonville	
Wellington	
Malmesbury	
Worcester	
Other (Specify): …………………………..	

6. Please indicate your monthly income level:

This question is not compulsory and should only be completed if you are perfectly comfortable with providing a response.

<R5 000/month	
R5 000- R15 000/month	
>R15 000/month	

7. Please indicate your highest education level:

High School/Grade 12 certificate	
Secondary Diploma	
Have a University Degree	
Have a postgraduate qualification (e.g. Masters/Doctors degree)	

8. I usually drink (only choose 1)

Cider	
Beer	
Wine	
Spirits (Brandy, Whisky etc)	
Coolers (Brutal fruit etc)	

9. Have you participated in a wine-sensory evaluation study before?

Yes	
No	

10. How frequently do you purchase wine?

<1 times/month	
1-3 times/month	
4-6 times/month	
7-9 times/month	
>10 times/month	

11. How often do you drink wine?

Never	
Once a month	
1-2 times/week	
Almost every day	
Every day	

12. I usually buy

Red wine	
White wine	
Rosé wine	
Both red and white wine	

13. I prefer to drink:

White wine	
Red wine	
Rosé wine	
I like both **white** AND **red** wine equally	
I do not like to drink wine at all	

14. Please indicate your degree of liking of red and white wine

	Dislike strongly	Don't like it so much	Like it sometimes	Like it	Like it very much
White wine					
Red wine					
Rosé wine					

15. Which occasion are you more likely to buy wine for?

To enjoy on my own	
No specific occasion	
For informal social gatherings e.g a “braai”	
For special occasions eg. Birthday or Celebration	
For sports events	
All of the above	

16. With whom do you like to drink wine?

On my own	
With friends	
With boyfriend/girlfriend	
With work partners/associates	
With family members	
Other (Specify):	

17. What sparked your interest in wine?

Friends	
Participated in wine tours	
Studied a course in wine	
Other (Specify):	

18. When drinking wine, how important is aroma (smell)?

Not at all important	
Sometimes important	
Always important	

19. When drinking wine, how important is taste?

Not at all important	
Sometimes important	
Always important	

20. Please indicate how interested you are in wine:

Uninterested	
Moderate interest	
Very interested	

21. How would you rate your knowledge of wine?

Novice (Do not know anything about wine)	
Moderate knowledge	
Above average	
Connoisseur (Expert)	

22. Indicate how much you agree/disagree with the statements

Please select one answer per statement

	Statement:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	I like drinking wine					
2.	Food and wine pairing is important					
3.	I would like to know more about wine					
4.	Price of wine is important to me					
5.	Drinking wine is part of my lifestyle					
6.	I belong to a wine club					
7.	I like visiting wine farms					
8.	I like to participate in wine tastings					
9.	I like to try *new* wines					
10.	I like buying wine packaged in a plastic bottle					
11.	I like buying wine packaged in a box					
12.	I support organic production of wine					
13.	The serving suggestions/food pairings on the wine label are important to me					

23. How important are the following factors when purchasing wine?

Please select one answer per statement

		Unimportant	Fairly important	Very Important	Extremely Important
1.	Price				
2.	Wine cultivar identity				
3.	Back label description/ aroma description				
4.	Wine region				
5.	Vintage				
6.	Label design				
7.	Brand/ Cellar name				
8.	Closure type				
9.	Bottle shape				
10.	I have tasted it before				
11.	Serving information				

24. My purchase decision is based on:

Previous experience	
Word of mouth of family/friends	
Opinions of top wine critics	
Wine awards on the bottle	
Shelf /label information	

25. What aspect of a wine bottle attracts your attention first?

Label colour	
Label design	
Brand/Cellar name	
Bottle shape	
Glass colour	

26. How much do you usually spend on a bottle of *white* wine?

Under R 30	
R31 - R50	
R51 - R70	
R70 – R100	
> R100	

27. How much do you usually spend on a bottle of *red* wine?

Under R 30	
R31 - R50	
R51 - R70	
R70 – R100	
> R100	

Thank you for taking the time to complete this questionnaire

Addendum K

Consumer Testing Sheets

Consumer Acceptance Test **Name:___________________** **Date:_______________**

Instructions

- Please taste the 7 samples in the order presented (from left to right)
- Take a generous sip from each sample and rinse your mouth with water between samples
- For each sample **circle the number next to the preferred degree of liking**

Sample		**Sample**		**Sample**		**Sample**	
5	Like very much	5	Like very much	5	Like very much	5	Like very much
4	Like slightly	4	Like slightly	4	Like slightly	4	Like slightly
3	Neither like nor dislike	3	Neither like nor dislike	3	Neither like nor dislike	3	Neither like nor dislike
2	Dislike slightly	2	Dislike slightly	2	Dislike slightly	2	Dislike slightly
1	Dislike very much	1	Dislike very much	1	Dislike very much	1	Dislike very much

Sample		**Sample**		**Sample**	
5	Like very much	5	Like very much	5	Like very much
4	Like slightly	4	Like slightly	4	Like slightly
3	Neither like nor dislike	3	Neither like nor dislike	3	Neither like nor dislike
2	Dislike slightly	2	Dislike slightly	2	Dislike slightly
1	Dislike very much	1	Dislike very much	1	Dislike very much

Preference Ranking

Instructions

- Re-Taste the samples and rank them from most preferred to least preferred
- **1 = most preferred**
- **7= least preferred**

*** Two samples may not receive the same number i.e. no ties**

Sample code	Rank (1 to 7)
________	☐
________	☐
________	☐
________	☐
________	☐
________	☐
________	☐