Consumer acceptance of a selection of South African red wines: Intrinsic, extrinsic and socio-demographic influences

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DECLARATION

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ABSTRACT

In this study an industry-selected and diverse range of South African red wines were analysed for sensory and chemical attributes, as well as degree of liking using a target group of black South African consumers. Segments of consumers that differed in degree of liking were then tested for their response to intrinsic (sensory) and extrinsic (non-sensory) cues.

The selection of wines included eighteen *dry* and *natural sweet red wines*, representing *low-end inexpensive wines* together with *high-end, top quality wines*. Sensory profiles for all samples were established using Quantitative descriptive analysis (QDA). The results revealed that cultivar specific dry red wines associated with a wide range of sensory descriptors such as *woody*, *vegetative* and *fruity,* while the sweet red wines associated with the *fruity* and *sweet-associated* attributes.

Chemically there was a significant variation between wines regarding the alcohol and sugar content. Gas chromatography with flame ionisation detection (GC-FID) indicated the major volatile constituents present in the wine, i.e. esters, alcohols and fatty acids.

When investigating the association between the chemical and sensory data, it was revealed that the red blends were driven by the presence of alcohols and esters, and sensory descriptors such as *high roast oak, coffee* and *mixed spice*, whereas the red cultivar wines were mostly driven by fatty acids and esters and the sensory descriptors, *green bean* and *asparagus*. The sweet red blends were closely associated with acids and the sensory descriptors *sweet-associated* and *floral*.

Degree of liking of a subset of 18 wines was investigated based on the preferences of black consumers from the Western Cape area, South Africa. These consumers predominantly preferred the sweet red wines with high sugar content, in a blind tasting session. Purchase intent was also evaluated by viewing actual photographs of packaging formats of the respective wines and the results indicated that the consumers preferred the well-known cultivar wines with a perception of value and style.

Cluster analysis was furthermore performed to ascertain whether these consumers differed in their degree of liking of the intrinsic character of the respective wines. Four different clusters of consumers were identified: 1) Consumers preferring both *dry* and *sweet red wines* equally, 2) Consumers who *strongly favoured sweet red wines* and *moderately liked dry red wines*, 3) Consumers who *strongly favoured sweet red wines* with little preference for *dry red wines;* and 4) Consumers preferring *dry red wines.*

Consumers were also probed on their general opinions or perceptions on the extrinsic character of the wines, and thus factors that influence the purchasing process. It was found that black consumers who don’t consume wine often, preferred wines that they are familiar with, while consumers that drink wine more frequently enjoy to broaden their horizons by experimenting with more expensive wine brands.

Extrinsic or non-sensory cues such as *alcohol content*, *label*, *vintage*, *price* and *cultivar* were found to be the most important considered factors when purchasing red wines, while *awards* and *type of closure* were regarded as the least important. It was also found that the discerning consumers, who purchase high-end wines, took more of the latter aspects into consideration, whereas consumers who purchase low-end wines considered a limited number of the non-sensory cues.

UITTREKSEL

In hierdie studie is ‘n diverse reeks industrie-geselekteerde, Suid-Afrikaanse rooiwyne geanaliseer vir hul sensoriese en chemiese eienskappe. Verbruikersvoorkeur van die wyne is getoets, asook tot watter mate verbruikersvoorkeure beïnvloed word deur intrinsieke (sensoriese) en ekstrinsieke (nie-sensoriese) faktore.

Die reeks van agtien wyne het bestaan uit *droë* en *soet rooi wyne*, wat op hul beurt verder verdeel kan word in *goedkoper, kwaliteit* wyne en *duurder, ultra-premium* wyne. Die sensoriese profiel van al die wyne is bepaal deur beskrywende sensoriese analise. Resultate het getoon dat die kultivar-spesifieke droë rooiwyne geassosieer word met ‘n wye reeks sensoriese eienskappe soos *houtagtig*, *kruidagtig* en *vrugtig*, terwyl die soet rooiwyne beskryf is as *vrugtige* en *soet-geassosieerd*.

In terme van die chemiese analises was daar betekenisvolle verskille betreffende die alkohol- en suikerinhoud van die wyne. Gas chromatografie gekoppel met vlam-ioniserende deteksie (GC-FID) het die mees vlugtige verbindings teenwoordig in die wyn aangedui, naamlik esters, alkohole en vetsure.

Met die korrelasie van die chemiese en sensoriese data is gevind dat die droë versnitwyne gedryf word deur die teenwoordigheid van alkohole en esters, asook sensoriese eienskappe soos *gehout, koffie*, en *gemengde spesery*, terwyl die kultivar-spesieke wyne weer meestal gedryf word deur vetsure en esters en sensoriese eienskappe soos *groenboontjie* en *aspersie*. Die soet rooiwyne het chemies geassosieer met sure en sensoriese terme soos *soet-geassosieerd* en *blomagtig*.

Die aanvaarbaarheid van ‘n kleiner groepering wyne is bepaal deur gebruik te maak van swart verbruikers in die Wes-Kaap area, Suid-Afrika. Die verbruikers het in ‘n blinde proesessie onderskeie wyne se wynverpakking besigtig en aangedui of hulle die wyne sou koop. Hierdie resultate het getoon dat die verbruikers bekende kultivarwyne verkies wat ‘n persepsie van waarde en styl geïllustreer het.

Segmentasie tegnieke is op die data uitgevoer ten einde te bepaal of verbruikers in groepe verdeel kan word, wat betref hul voorkeur van die sensoriese of intrinsieke eienskappe van die wyne. Vier verskillende groepe is geïdentifiseer, nl. verbruikers wat 1) droë en soet rooiwyne ewe veel verkies; 2) soet rooiwyne en tot ‘n mate ook droë rooiwyne verkies; 3) soet rooiwyne en tot ‘n mindere mate droë rooiwyne verkies; en laastens 4) slegs droë rooiwyne verkies.

Verbruikers se algemene opinies en persepsies betreffende die ekstrinsieke eienskappe van die wyne is ook ondersoek, met ander woorde faktore wat die aankoop van wyne beïnvloed. Daar is gevind dat swart verbruikers wat nie gereeld wyn drink, bekende handelsmerke verkies, terwyl verbruikers wat gereeld wyn drink, daarvan hou om hul horisonne te verbreed en te eksperimenteer met ‘n verskeidenheid handelsmerke.

Ekstrinsieke of nie-sensoriese aspekte soos, *alkohol-inhoud, etiket, oesjaar, prys en kultivar* is die belangrikste faktore wat in ag geneem word wanneer rooiwyne gekoop word, terwyl *wyntoekennings* en die feit dat die wyn met *kurke* gebotteleer word, nie as belangrik beskou word nie. Daar is ook gevind dat die meer ingeligte verbruiker, wat hoë kwaliteit wyne koop, meer van die bogenoemde aspekte in ag neem tydens die aankoopproses, terwyl die verbruiker wat meer geneig is om goedkoper wyne te koop, slegs 'n paar ekstrinsieke faktore in ag neem.

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‘Trust in the Lord with all your heart, and do not lean on your own understanding, in all your ways acknowledge Him and He will make straight your paths”

[Proverbs 2:4-5]

TABLE OF CONTENTS

CHAPTER 1

General introduction

With the current global oversupply of wine, as well as the rapid emergence of new brands, wine marketing continues to be highly competitive and challenging. Due to this situation, Tach and Olsen (2006), recommend that the focus of wine marketing should be on identifying new consumer segments, rather than merely trying to expand existing consumer segments. According to Gil and Sanchez (1997), undifferentiated wine marketing currently appears to be an unrealistic approach. The wine industry thus needs to broaden its market to reach beyond the traditional core consumers and turn its focus towards newly emerging consumer segments. At present, the wine industry is also in competition with other major producers of alcoholic beverages. According to Troncoso-Valverde (2004) there has recently been a strong tendency to substitute wine for other alcoholic beverages, mainly beer. Similarly, the spirits industry offers new flavoured products to the younger consumer coupled with innovative and highly successful marketing approaches (Mosher & Johnsson, 2005). The latter tendencies are topped with the challenge that both the beer and spirits industries have high-priced, focused marketing strategies. *Wine Business Monthly* (2007) of the United States of America (USA) claims that to be successful, it is vitally important for the wine industry to broaden its market and to reach consumers who are not traditionally perceived as regular wine drinkers, for example; the Spanish and Portuguese consumer living in the USA. This is also the case for the South African wine industry, considered as one of the world's significant wine-producing areas (Giuliani *et al*., 2010). Wine sales in the black townships such as Soweto, South Africa with 3.5 million residents, are far below the average sold nationally (Personal communication: D. Schmidt, Distell, Stellenbosch, South Africa, 2009). To stimulate economic growth and broaden market share, the South African wine industry is currently attempting to stimulate wine sales among the so-called *black diamonds*, i.e. the emerging black middle class (Ndanga *et al.,* 2009). One such example is the annual *Soweto Wine Festival*. The primary aim of this festival is to market South African wines among black consumers and to shift the black market's perceptions of wine to that of a lifestyle commodity (Anon. 2010).

Market researchers usually only look at sales volumes to track market trends for a given product, and such data can reveal leaders in terms of market share (Lesschaeve, 2007). However, to understand why products sell, or do not sell, requires a more comprehensive strategy. According to Lesschaeve (2007), wine preference is influenced by many interrelated factors, which include sensory, psychological, sociological and economic aspects. The current challenge is to understand the motivation behind consumer preference and to develop and produce wines of enhanced quality that will satisfy what different segments of consumers anticipate. This challenge requires an understanding of the role of both the *intrinsic*, as well as *extrinsic* factors that underlie wine preferences and perceptions.

Intrinsic factors refer to the inherent sensory and chemical attributes of wines, such as wine aroma, flavour and mouthfeel. These attributes are derived from a wide range of volatile and non-volatile compounds originating from the grapes, fermentation and wine making processes, as well as ageing (Swiegers *et al*., 2005).

Extrinsic factors, on the other hand, refer to aspects such as brand, pricing, packaging and promotion and they can also play a major role in consumer purchase behaviour (Mueller & Szolnoki, 2010).

Knowledge of both the *intrinsic* and *extrinsic* should thus be researched in combination, to ultimately sustain and develop a successful industry within a fiercely competitive wine market (Bertucciolo, 2010). In other words, it is important for researchers to understand the interplay of intrinsic (sensory) and extrinsic (non-sensory) factors, as both dimensions have to be optimised for a product to be successful in the marketplace.

Until recently, wine consumer research has focussed to a large extent on assessment of the effect of intrinsic factors on consumer wine preference. Examples include Sauvignon blanc (Lund *et al*., 2009), Godello (Vilanova, 2006), Cabernet Sauvignon and Shiraz (Lattey *et al*., 2010) and Merlot (Lesschaeve, 2003). These studies used an array of analytical chemical methodologies in combination with sensory panels to qualify and quantify the chemical and/or sensory attributes of the products in question. Most frequently consumer liking is measured to indicate the sensory drivers of consumer liking.

However, of equal importance is knowledge of the role of extrinsic cues on consumer liking and purchase intent. It is well-documented that consumers are heterogeneous in their responses to extrinsic cues (Mueller *et al*., 2010a, 2010b), yet the extent to which wine consumers differ in their responses to extrinsic cues, is still to be explored. Insight into how distinct consumer segments perceive wine could provide a basis for specific production practices, as well as marketing strategies. In a study concerning Australian wine consumers, Mueller and Szolnoki (2010) identified three consumer segments that differed in their response to extrinsic cues: younger inexperienced wine consumers utilised a mix of various cues; experienced wine consumers based their choice of wines mainly on grape variety and hedonic liking; whilst the older, frequent wine consumers, were influenced significantly by brand and packaging. Ndanga *et al*. (2009) also investigated the extrinsic cues of wine choice among South African black wine consumers. This study indicated that well-established brands play a major role in the black consumer's choice. They concluded that there is scope for an integrated approach in wine research within the South African black consumer segment, where the effect of both intrinsic and extrinsic factors should be analysed concurrently, as well as the interplay between them.

In order to analyse the effect of both intrinsic (sensory) and extrinsic (non-sensory) factors on the consumption and purchasing of wines, a variety of multivariate techniques such as principal component analysis, preference mapping and partial least squares regression can be used. In addition these techniques are able to indicate the drivers of liking, as well as the role of extrinsic factors influencing the consumption and purchasing of wines. These statistical techniques can also be applied to indicate segments of consumers within a wider wine population (Næs *et al.,* 2010).

The wine industry should use the extensive range of intrinsic and extrinsic cues to translate consumer expectations into product specifications, and by doing this it would be possible to develop wines that will be accepted by the consumer (Verdú Jover *et al*., 2003).

In the context of the above, the aim of this study was to analyse an industry-selected range of South African red wines for sensory and chemical attributes. Consumer degree of liking was also tested using a target group of black consumers who consume wine regularly. Based on the findings obtained from these analyses a further aim was to determine whether there were sub-segments of consumers within this segment that differed in their degree of liking and response to specific extrinsic cues.

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CHAPTER 2

Literature review: Wine quality and consumer preference

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1. INTRODUCTION

Human perception of wine flavour can be measured using formal sensory analysis methodologies, designed to quantify sensory quality differences between wines, as well as to test the preference or consumer liking of wines (Lawless & Heymann, 2010). However, other factors apart from sensory quality also play an important role in consumer purchase behavior. These include aspects such as brand, price, and packaging (Verdú Jover *et al., 2004*). To date, wine consumer research has mainly focused on correlating consumer liking to wine quality in order to determine the drivers of liking (Næs *et al*., 2010). There is, however, a need to determine the role of non-sensory factors in the consumer's decision to purchase wines. This literature review will thus focus on *wine quality* and *consumer preferences*, therefore *understanding the wine consumer*.

2. DIMENSIONS OF WINE QUALITY

The consumer has become one of the main driving forces behind wine research (Mueller & Szolnoki, 2010, Lattey *et al*., 2010, Parpinello *et al*., 2009). Wine demand is changing continuously and therefore the assessment of purchase behaviour is becoming more and more important. Even in European countries such as Italy and France, where per-capita consumption is considered of the highest in the world, it was found that an increasing percentage of consumers use both sensory and non-sensory cues when purchasing wines (Rocchi & Stefani, 2005). In countries where wine is marketed through the modern retail sector, consumers often have to make a choice between large ranges of locally produced, as well as imported wines, in a relatively short period of time (Vrontis & Papasolomou, 2007). It is therefore important to understand what drives consumers' purchasing decisions.

A number of studies have proposed models to illustrate the dimensions of wine quality. Charters and Pettigrew (2007) stated that the "'*nature of product quality is difficult to understand, and the nature of wine quality with its quasi-aesthetic character and relation to personal taste is particularly hard to pinpoint"*. Their model for the different dimensions of wine quality, i.e. intrinsic and extrinsic, is illustrated in Figure 1. Verdú Jover *et al.* (2004) also classified the quality dimensions of red wine as being intrinsic and extrinsic (Table 1). Both these classifications are derived from the *Quality Model* as proposed by Grunert (1996). In following sections the two main dimensions associated with wine quality will be discussed briefly, as well as how they are applied in wine research.

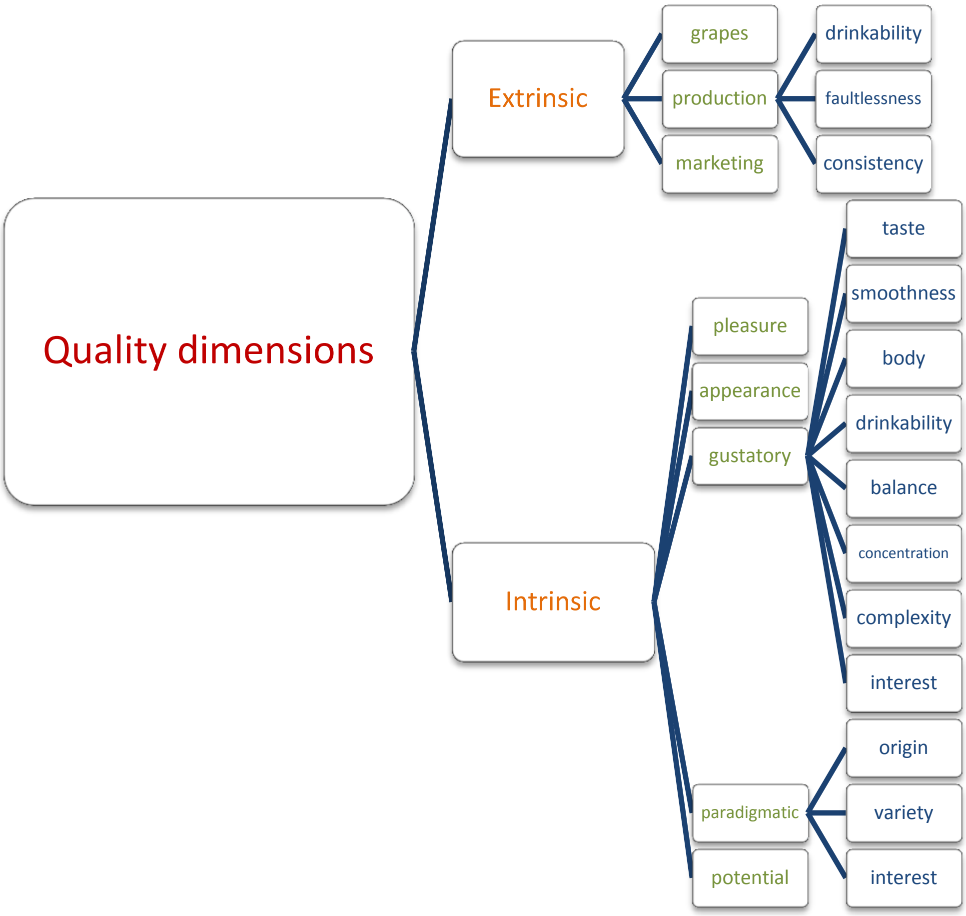

Figure 1 Dimensions of wine quality (Charter & Pettigrew, 2007).

Table 1 Red wine quality dimensions (Verdú Jover *et al*., 2004).

Extrinsic factors	Intrinsic factors
1. Reputation	1. Age
2. Growth region	2. Harvest
3. Appellation d'Origine	3. Alcohol content
4. Advertising and propaganda	4. Varieties
5. Distribution channels	5. Taste
6. Bottling and labelling	6. Aroma
7. Brand	7. Colour
8. Price	

2.1 Intrinsic dimension

Intrinsic attributes refer to inherent qualities of a product and include aspects such as appearance, aroma, flavour and mouthfeel (Geel *et al*., 2005). Intrinsic attributes cannot be altered without changing the nature of the product and according to Verdú Jover *et al.* (2004) the intrinsic attributes of red wines can be classified as appearance, sensory attributes, grape variety, alcohol content, harvest date and ageing of the wine (Table 1).

Charters and Pettigrew (2007) indicated a different classification of the intrinsic quality dimension (Figure 1), which is more extensive than the extrinsic attributes. This dimension includes the hedonic (pleasure and enjoyment), the visual (appearance), the gustatory (aroma, flavour, taste and mouthfeel, body, balance, complexity), the paradigmatic (origin, varietal purity and typicality), and potential (wine's potential to improve with age).

Egan *et al.* (2009) indicated that intrinsic attributes can be divided into those that can be searched for (*intrinsic cues, e.g. origin*) and those which can be experienced (*intrinsic attributes, e.g. mouthfeel*). Sensory attributes form an important part of intrinsic cues and are usually evaluated during consumption or tasting of samples (Verdú Jover *et al*., 2004). It can be argued that while extrinsic cues play an important role in the purchasing decision, intrinsic cues may influence the possibility of future purchasing behavior or re-purchase. Once these intrinsic elements have been defined, these attributes can be tested by using visual mechanisms to test re-purchase behavior (Egan *et al*., 2009).

2.2 Extrinsic dimension

The extrinsic quality dimension can be defined as the "'*characteristics that are related to the product, but are not physically part of it"* (Oude Ophuis & van Trijp, 1995). Thus if extrinsic purchase cues are changed experimentally, the physical characteristics of the product do not per definition change (Verdú Jover *et al*., 2004). According to Charters and Pettigrew (2007) the following can be classified under extrinsic attributes: grapes, production (drinkability, faultlessness, consistency) and marketing. Verdú Jover *et al*. (2004), once agian, has a slightly different approach and includes a broader range of extrinsic attributes which includes reputation, growth region, *appellation d'origin* (wine of origin) (Angulo *et al*., 2000), advertising and propaganda, distribution channels, bottling and labelling, brand and price.

It seems that there is some disagreement with regards to classifying the various dimensions, as either an intrinsic or extrinsic attribute. Charters and Pettigrew (2007) classified grapes and production under extrinsic attributes while Verdú Jover *et al*. (2004) classified factors such as harvest, varieties and age under intrinsic attributes.

Whenever consumers do not have intrinsic-related knowledge of wines, they usually use extrinsic cues (Lockshin *et al*., 2006). Extrinsic attributes are important to form perceptions of quality and are the main drivers to the public (Verdú Jover *et al*., 2004). Non-sensory variables can thus influence the sensory acceptability of products (Guinard *et al*., 2001). It has also been argued that extrinsic cues provide a stronger competitive advantage as it incorporates visual elements as well. This then aids in differentiating the product from other products on the shelf.

Extrinsic cues therefore add an additional dimension to the product, allowing associations to be established within consumers, and thus acting as a guide. Associations and proxies are therefore developed and can have an effect on the evaluation of the intrinsic components of a product. For example, a higher price could lead consumers to believe that the product has a superior level of intrinsic quality (Egan *et al*., 2009).

Packaging, for example, could influence the sensory perception when tasting the wine (Mueller & Lockshin, 2008). The appearance and visual attributes of wine packaging are regarded as important and powerful influences on acceptability of wines. The packaging attributes of products include aspects of shape, colour, design, symbols, logos and brand names (Mueller & Szolnoki, 2010). The influence of marketing elements on consumption trends is well documented. In this context packaging becomes a fundamental marketing tool for a winery as it distinguishes a specific wine from its competitors. The label is a crucial part of the packaging and communicates the relevant and appropriate information about the quality of the wine to consumers, thus indicating important intrinsic attributes (Tootelian & Ross, 2000).

In their research study on internal and external preference mapping for commercial larger beer Guinard *et al*., (2001) compared consumer hedonic ratings of blind versus informed conditions. They found that there was a significant change in consumers' preference ratings in terms of blind and informed conditions. Informed conditions include extrinsic aspects like packaging and price and these aspects enable consumers to create expectations even before the product is consumed. Extrinsic cues are therefore able to indirectly increase the degree of liking of a certain product.

3. RESEARCH ON WINE QUALITY, CONSUMER LIKING AND CONSUMER PERCEPTIONS OF WINES

As already indicated, consumer wine research usually entails the analysis of the sensory and/or chemical quality of wines, the determination of the degree of liking or preference for wines, and establishing the role that non-sensory attributes or cues play when consumers purchase wines (Lund *et al*., 2009). Consumer wine research previously focused mainly on assessing the effect of sensory attributes on degree of liking, i.e. to determine the sensory drivers of consumer preference (Lattey *et al*., 2010). In many instances instrumental analyses are also conducted to indicate how the sensory attributes correlate with specific instrumental attributes (Kotseridis *et al*., 2000). It is important to understand the relationship between the chemical nature and sensory properties of wines, but also how enological and viticulture practices influence the chemical and sensory attributes of wine, and ultimately consumer preference (Lund *et al.,* 2009; Parpinello *et al*., 2009). Preference data (i.e. for example whether consumers prefer wines with more or less acidity, riper or less ripe flavours, increased oak flavour) will assist winemakers to create a wine style that is acceptable to a group or segments of consumers, and that will not fail commercially upon launching of the wine (Lattey *et al*., 2007; Raz *et al.,* 2008). Preference studies can provide an understanding of the market preference, but do not always give insight into how the results interplay with extrinsic factors (Egan *et al*., 2009).

Although the effect of non-sensory cues on the purchasing of wines is reasonably well investigated (Mueller *et al.,* 2009; Thomas & Pickering, 2003), there is a need for research where both the role of degree of liking (an intrinsic cue), as well as the role of extrinsic cue(s) (e.g. the role of packaging in the purchasing process) are determined simultaneously (Mueller & Szolnoki, 2010). When both preference and perception data are available, wine marketers acquire an indication of which sensory attributes consumers like, as well as to what extent the specific extrinsic attributes influence the purchasing behavior. The latter information will allow wine marketers to make informed decisions during product development, assist them in aligning an existing brand or style of wine to consumer preference and to provide companies with the understanding needed to enhance the profitability of existing wines (Westad *et al*., 2004).

The methodology required to research the interaction between sensory and chemical attributes of red wines, to determine consumer preference of wines, as well as to determine the role of non-sensory attributes in the purchasing of wines will be discussed subsequently.

3.1 Determination of the quality of red wines

The quality of wine can be measured using a wide range of strategies, i.e. sensory quality, chemical composition, microbial stability, physical attributes, etc. (Jackson & Lombard, 1993).

3.1.1 Sensory profile of wines

Sensory analysis involves the measurement, interpretation and understanding of human responses to the properties of food as perceived by the senses, such as sight, smell and taste. It is a quantitative method for analysing the sensory attributes of a product such as wine (Lawless & Heymann, 2010; Stone & Sidel, 1993). Several standardised methodologies for sensory analysis exist (Murray *et al*., 2001). Generic descriptive sensory analysis, or quantitative descriptive analysis (QDA), is regarded as one of the most comprehensive and informative tools for analysing sensory attributes. This technique can provide complete sensory descriptions of a product such as wine and is considered as one of the cornerstone methodologies when profiling the sensory attributes of a product such as wine (Lesschaeve, 2007; Næs *et al.,* 2010). This method has been widely studied, has been shown to give reliable results in terms of sensory analysis; and is one of the primary sensory tools when analysing the large range of complex wine aromas, flavours and mouthfeel attributes (Lesschaeve, 2007). A panel of 10 to 15 well-trained judges is the foundation of descriptive sensory analysis. The task of the panellists is to identify and provide an intensity rating for each of the perceived sensory attributes. As a result of this method the sensory perception can be analysed and reported using a set of independent and previously defined descriptors (Murray *et al*., 2001).

QDA usually involves training of the judges to score the respective samples according to the specific sensory attributes on a line scale; the determination of judge reproducibility; and the analysis of the samples (Lawless & Heymann, 2010). Many authors recommend the use of reference standards during the training phase of QDA, mainly to allow concept alignment in sensory panels (Murray *et al.,* 2001). As starting point an appropriate wine aroma reference wheel is usually used or developed. Figure 2 indicates the wine aroma wheel of Noble *et al.* (1987) illustrating first tier, second tier and third tier wine aroma attributes. Once the spectrum of attributes is determined, reference standards should be formulated using a lexicon of aromas, flavours and mouthfeel attributes.

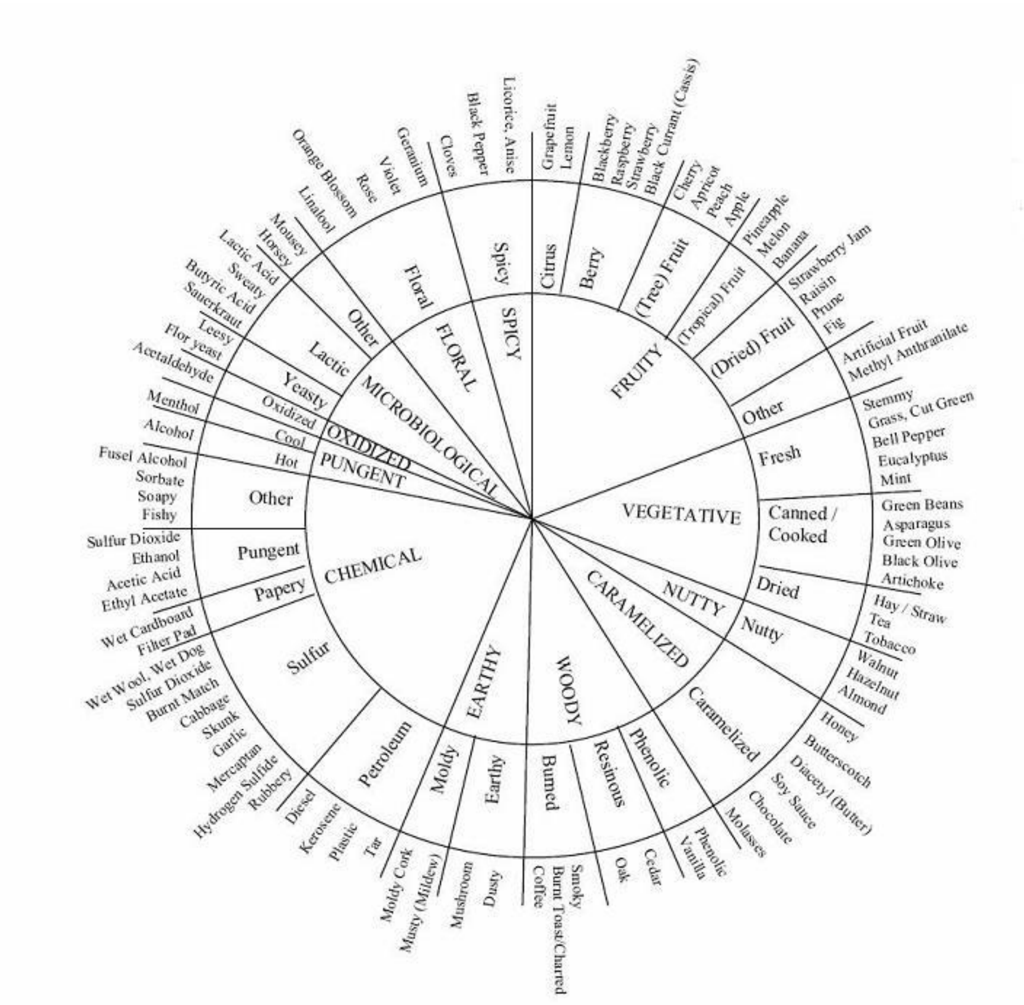

Figure 2 Wine aroma wheel illustrating 1st tier, 2nd tier and 3rd tier sensory attributes (Noble *et al.,* 1987).

3.1.2 Chemical attributes of red wine

Wine is a complex mixture of various chemical compounds including alcohols, phenolic compounds, organic acids, volatile aroma compounds and residual sugar, all of which can contribute to the sensory attributes of wine as perceived by humans (Vilanova *et al*., 2010). The formation of these compounds depend on many factors, including the geographical origin of the grapes, grape varieties and ripeness, soil and climate, yeasts used during fermentation and winemaking practices such as, juice production, fermentation, maturation and ageing (Kotseridis & Baumes, 2000; Spranger *et al*., 2004). While hundreds of different volatile compounds are present in a given wine, only a subset is likely to contribute specifically to certain aroma and flavour attribute. In flavour research, the relationship between sensory and instrumental analysis can be explored, mainly to establish the drivers of wine quality (Vilanova *et al.,* 2010). According to Gil *et al*. (2006) the volatile fraction of wine includes three main chemical groups, namely; alcohols, esters and fatty acids. Table 3 contains a range of sensory descriptors associated with specific chemical compounds in red wines.

3.2 Consumer liking, relating consumer liking to wine quality and the determination of non-sensory cues

When consumer liking is measured, a selected group of consumers will usually taste the respective samples blind and then indicate how much they like the flavour, taste and/or mouthfeel of the wine. However, the role of non-sensory cues should also be measured, as consumer perceptions can play a vital role in understanding how consumers make purchasing decisions. The correlation of quality attributes with liking data, as well as perception data will be discussed briefly in terms of the selected examples illustrated in Table 4.

Table 3 Flavour descriptions as found in literature for the measured chemical compounds.

Analyte	Aroma descriptor
Alcohols	
Propanol	Ripe fruit, alcohol[2, 4]
Butanol	Medicinal, phenolic, alcohol, fusel[4, 6]
Isobutanol	Oily, bitter, green, fresh, fusel, alcohol[2, 3, 4, 5]
Isoamyl alcohol	Sweet, fusel, bitter, harsh[1, 3]
Hexanol	Flowers, green, cut grass, dry, toasted, vegetable[3]
2-Phenylethanol	Roses, sweetish[2, 6]
Esters	
Ethyl acetate	Fruity, solvent[2, 4, 5]
Ethyl butyrate	Fruity, papaya, butter, sweetish, acid fruit, strawberry[1, 2, 4, 5, 6]
Isoamyl acetate	Banana[2, 4, 5]
Ethyl hexanoate	Green apple, fruity, sweetish, anise, strawberry[1, 2, 3, 5, 6]
Ethyl lactate	Acid, medicine, milky, lactic, strawberry, raspberry [2,4, 5, 6]
2-Phenylethyl acetate	Floral, rose, honey, tobacco[3, 4, 6]
Ethyl decanoate	Fruity, pleasant, soapy[2, 5]
Ethyl octanoate	Sweet, fruity, fresh, soapy[1, 2, 5]
Fatty Acids	
Acetic acid	Sour, pungent, vinegar, spicy[1, 3, 4]
Propionic acid	Pungent, rancid, soy[4]
Isobutyric acid	Rancid, butter, cheese, fatty, acid, phenolic [1, 2, 4, 5]
Butyric acid	Rancid, cheese, sweat, spicy[1, 2, 3, 4, 5, 6]
Isovaleric acid	Sweet, acid, rancid, fatty, blue cheese, spicy[1, 2, 3, 4, 5]
Hexanoic acid	Green, sweat, cheese, geranium, vegetable[2, 4, 5, 6]
Octanoic acid	Sweat, cheese, fatty, unpleasant, rancid, harsh[1, 2, 4, 5, 6]
Decanoic acid	Rancid, fat, soap[2, 4, 5, 6]

[1](Aznar *et al*., 2001), [2](Gil *et al*., 2006), [3](Gómez-Míguez *et al*., 2007), [4](Sánchez-Palomo *et al*., 2010), [5](Santos *et al*., 2004), [6](Vilanova *et al*., 2010)

Table 4 Selection of studies illustrating the role of intrinsic and extrinsic dimensions in wine analysis.

Measured	**Title**	**References**
Wine quality (sensory, chemical) & consumer preference	Relationship among sensory descriptors, consumer preference and color parameters of Italian Novelle red wines	Parpinello *et al.,* 2009
	Consumer acceptability, sensory properties and expert quality judgements of Australian Cabernet Sauvignon and Shiraz wines	Lattey *et al*., 2010
Alcohol content	Impact of partial alcohol reduction in Syrah wine on perceived complexity and temporality of sensation and link with preference	Meillon *et al*., 2010
Body	A latent look at emerging Asian wine consumers and their intrinsic – extrinsic preferences	Egan *et al*., 2009
Packaging	How important is wine packaging for consumers	Mueller & Lockshin, 2008
Label design	Effects of wine label design on purchase intent and brand personality	Boudreaux & Palmer, 2007
Label information	The importance of wine label information	Thomas & Pickering, 2003
Location on shelf	How does shelf information influence consumers' wine choice?	Mueller *et al*., 2009
Price	A latent look at emerging Asian wine consumers and their intrinsic – extrinsic preferences	Egan *et al*., 2009
Country of origin	A latent look at emerging Asian wine consumers and their intrinsic – extrinsic preferences	Egan *et al*., 2009
Geographic origin	The impact of geographic origin, vintage and wine estate on sensory properties of *Vitis vinifera* cv. Riesling wines	Fischer *et al*., 1999
Wine estate	The impact of geographic origin, vintage and wine estate on sensory properties of *Vitis vinifera* cv. Riesling wines	Fischer *et al*., 1999
Vintage	The impact of geographic origin, vintage and wine estate on sensory properties of *Vitis vinifera* cv. Riesling wines	Fischer *et al*., 1999

3.2.1 Relating consumer liking to chemical and/or sensory attributes

In preference testing consumers usually taste the products under investigation and give an indication of their degree of liking on a hedonic scale ranging from 1=*Like extremely* to 9=*Dislike extremely*. This test uses unbranded products and gives an indication of preference, as well as acceptance (Lawless & Heymann, 2010). However, purchase intent can also be measured after tasting unbranded wines using a 5-point category scale ranging from 1=*Will definitely not purchase* to 5=*Will definitely purchase (*Lawless & Heymann*,* 2010; Guinard *et al.,* 2001). For both these types of analyses, it is common practice to use between 100 and 150 target consumers (Næs *et al*., 2010).

As mentioned earlier, relating *wine quality* to *consumer liking* has been the focus of many studies in recent years. Table 4 illustrates a number of studies where chemical and/or sensory data were used to indicate the drivers of liking for specific groups of consumers.

Consumer data coupled with trained panel data can give highly valuable information regarding the consumer drivers of liking. In a study on Cabernet Sauvignon and Shiraz wines, Lattey *et al*. (2010) found that for different groups of consumers there were different liking patterns. Therefore grape variety was found not to be the only factor driving consumer preference. Acidity was found to have a negative influence on consumer liking, while green or vegetal flavours seemed to have a positive influence. Similarly Meillon *et al*. (2010) conducted a study where the impact of partial alcohol reduction in Syrah wines was investigated. The study involved the perception of complexity and temporality of sensations, both which were linked to preference. Wines with higher alcohol content were perceived as less astringent, aromatically more complex with a lingering finish on the palate. The results, however, also confirmed that liking of partially dealcoholised wines, was not uniform.

Egan *et al*. (2009) found that consumers from Chinese descent typically prefer sweeter wines. The study divided the consumers into five groups. Three of the groups (80% of the sample), illustrated a preference for the sweeter wines, while the other two groups (20%) indicated that they prefer a drier style with a fuller body.

Wine packaging is receiving increased research attention in the last few years (Rocchi & Stefani, 2005). Appearance and packaging of food products and wine play an important role in influencing consumer perceptions and acceptance (Imram, 1999). Mueller and Lockshin (2008) found that Australian wine consumers regarded the visual extrinsic wine attributes as more important than the intrinsic sensory attributes. Label style and label colour were found to be important attributes, while bottle form was found not to be an important choice driver. In terms of label design, Boudreaux and Palmer (2007) confirmed that there are tangible benefits to designing packaging with a *brand personality*. When analysing consumers on the colour of labels for a wine such as Cabernet Sauvignon, the warmer palettes (burgundy, red-orange) were perceived as successful, desirable, and expensive. The brighter palettes (wasabi green and red-orange) were seen as exciting and imaginative, while pink was seen as a poor choice of colour for Cabernet

Sauvignon. It is important to note that these results will vary according to cultures, context and current fashion, therefore the use of colour in packaging cannot necessarily be generalised across cultures.

Thomas and Pickering (2003) surveyed New Zealand wine consumers regarding the importance of information displayed on the wine labels. They found that when consumers viewed wine labels to make purchase decisions, they first considered *winery,* then *brand name*, and then *opinions of wine experts* and lastly *awards and medals*. In contrast, Rocchi and Stefani (2005), found that consumers considered two aspects when purchasing wines, firstly the shape, size and colour of the bottle and, secondly, the label on the wine bottle.

In terms of vintage and wine estate, Fischer *et al*. (1999) utilised descriptive analysis of commercial wines from two vintages, five wine estates and six vineyard designations. The study found that vintage, wine estate and vineyard designation correlated significantly to the sensory properties of Riesling wines from Rheingau.

3.2.2 Analysis of non-sensory cues in wine research

As indicated in Table 2 the role of non-sensory attributes in the purchasing of red wines can be analysed by using 5-point or 7-point attitude scales to measure the importance of the respective non-sensory attributes (Mueller *et al.,* 2009). In most cases the respective non-sensory cues are tested conceptually, i.e. without introducing actual wine samples (Angulo *et al*., 2000), however, when testing the role of packaging cues a number of studies have investigated the role of non-sensory cues by simulating a retail shelf-scenario. An example of this is illustrated in Figure 3, where Mueller *et al.* (2009) tested the importance of label style, label colour, type of closure and medals by using graphically simulated wine bottles. This type of analysis can be done at a central test location, but also via the internet (Mueller *et al.,* 2009).

Figure 3 Example of a simulated retail shelf-scenario (Mueller *et al,.* 2009).

4. CROSS-CULTURAL RESEARCH

South Africa is currently not considered as a major wine drinking nation. In comparison to other wine producing countries such as Italy, Australia and USA, South Africa's consumption per capita is considered reasonably low (Anderson *et al*., 2003). Since 1994, the South African economy, as well as its wine industry, has undergone deep structural reforms, as a result of this, there has been a substantial growth in South Africa's wine export (Giuliani *et al*., 2010). Unfortunately local wine marketing has not been optimal when compared to the marketing of other alcoholic beverages, such as beer (Personal communication: D. Schmidt, Distell, Stellenbosch, South Africa, 2009).

When considering the South African consumers' improved socio-economic status, due to the steadily growing Gross domestic product (GDP), as well as the middle class, one could argue that the black South African consumer is ready to associate with wine as a lifestyle choice (Ndanga *et al*., 2009). It is, however, important to note that the majority of South Africans choose *not to drink wine,* partly as a result of minimal exposure to wine in comparison to beer, ready-to-drink categories, and other alcoholic products such as entry-level brandy. A concerted effort should therefore be put into the marketing of wine at all price points, across all cultural groupings. To research the possibility of the latter, Ndanga *et al*. (2009) used a choice-based conjoint analysis, in an attempt to develop a consumer profile for the new market of black South African consumers. In so doing the study also wanted to focus on changing the attitude of these consumers toward wine. Data were collected in a consumer behavioural study, using a mall survey, at the 2007 Soweto Wine Festival, Gauteng, South Africa. The target consumer was selected according to their age, gender, income, race and wine drinking history. Age, income and frequency of consumption were found to be statistically significant determinants of this group of consumers' choice of sparkling, red and white wines. The study showed that older consumers were more likely to choose sparkling wines, while younger consumers were more likely to choose red and white wines. It was also found that consumers with a higher income, as well as those that consume wine more frequently, were more likely to choose red and white wines. In conclusion the study found that age, gender and the choice of favourite red wine were significant determinants of wine choice and could therefore be used to segment the market.

5. SUMMARY

Wine companies have realised the need for a better understanding of consumer preferences, mainly to sustain and develop their business in a competitive global market. Such an understanding will allow companies to produce wine styles that effectively respond to consumer needs and expectations. From literature it is clear that in consumer wine research, companies should not only have an advanced knowledge of the intrinsic, as well as extrinsic wine quality cues influencing consumer behavior, but also have experience of how consumers perceive and evaluate these cues. This will enable winemakers and marketers alike to understand the consumer and produce products that are in line with consumers' needs.

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CHAPTER 3

Chemical and sensory attributes and consumer perception of a selection of South African red wines

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1. INTRODUCTION

Wine preference is invariably influenced by numerous interrelated factors. Whenever wine is presented for consumption, the consumer usually has certain preconceived expectations about what the inherent wine quality *should* be. When studying preferences, attitudes towards the type of product, as well as information about consumers' age, gender, socio-demographics and habits may be extremely relevant for product development, marketing endeavours and ultimately for increasing sales (Thybo *et al.,* 2004).

Challenges facing wine producers are daunting and producers need to sell wine at a price that satisfies the consumer and at the same time generate a fair profit. In the global economy wine producers need to understand the motivation behind consumers' choices and then produce wines of enhanced attractiveness while simultaneously developing and implementing sustainable production practices in viticulture and winemaking (Bertuccioli, 2010). It is important that the wine industry is familiar with the chemical qualities and related sensory attributes, as well as the external factors that drive consumers' choices towards a specific brand or product (Geel *et al*., 2005). This is especially true for developing countries where there are emerging markets and the possibility for the wine industry to increase its market share (Egan *et al.,* 2009).

Evaluation of wine quality is usually done by wine experts as their experience and training enable them to evaluate whether the wine being assessed represents the variety, region or style (Gawel & Godden, 2008). However, there is no apparent evidence that wine experts can predict consumer liking (Lesschaeve, 2003; Melo *et al.,* 2010; Mueller *et al.,* 2010). It is well known that among wine consumers there are often different segments, each with their own sensory preferences. In the production of wine it has become increasingly important to identify these segments, as well as the attributes driving consumer liking. This may evidently lead to different approaches of wine style design (Lattey *et al.,* 2007; Bertuccioli, 2010).

The focus of our study was to attempt to understand a specific wine consumer's preference for red wines. To study this phenomenon, two closely related aspects had to be investigated, firstly, the inherent or intrinsic characteristics (sensory attributes) driving preference, and secondly, the external or extrinsic influences connected to consumers' perceptions such as label and price (Geel *et al*., 2005; Grunert, 2007).

Wine aroma is produced by a large number of volatile compounds (Vilanova *et al*., 2010) and the volatile composition plays an extremely important role in wine quality. It is evident from literature that the major volatiles consist of three main chemical groups of compounds, namely; alcohols, esters and fatty acids (Lambrechts & Pretorius, 2000; Gil *et al.,* 2006; Gomez-Miguez *et al.,* 2007; Biasoto *et al.,* 2010). Methodologies such as gas chromatography are employed for determining the basic volatile composition of wines (Ortega *et al*., 2001; Callejon *et al.,* 2010). On the other hand, sensory analysis is an equally important tool when studying wine aroma. Quantitative descriptive analysis is considered as one of the most comprehensive tools in sensory testing (Lawless & Heymann, 2010) and provides sensory descriptors for complex products such as wine (Vilanova *et al*., 2010; Biasoto *et al.,* 2010, Callejon *et al.,* 2010; Weldegergis *et al.,* 2011). Futhermore, the relationship between chemical and sensory variables has been explored by a number of researchers (Biasoto *et al.,* 2010; Callejon *et al.,* 2010; Chira *et al.,* 2010; King *et al.,* 2010; Vilanova *et al.,* 2010). According to Vilanova *et al.* (2010) hundreds of different volatile compounds are present wine, however, only a subset is likely to contribute to the aroma as perceived by the human nose.

There have been numerous research projects focusing on assessing the drivers of wine liking. Lund *et al.* (2009) attempted to establish the drivers of liking of Sauvignon blanc wines by determining differences among a spectrum of Sauvignon blanc wines from different geographical areas in terms of chemical composition, sensory profile, and also consumers' preferences. The study indicated that Sauvignon blanc wines exhibiting significant amounts of vegetal characteristics (*capsicum, fresh asparagus*) and fruity notes (*tropical, passion fruit, stone fruit*) were preferred by most consumers, the latter being the younger consumer (<34 years) who was willing to spend more than $15 for a bottle of white wine. Parpinello *et al*. (2009) mentioned that the understanding of consumer expectations and the factors that drive wine liking is critical for winemakers. In a study by Ndanga *et al.* (2009) on the determinants of wine choice among black South African consumers, it was concluded that age and gender, as well as the *favourite brand* of red wine can be used as determinants to segment consumer preference.

Several multivariate statistical techniques have been employed to investigate the possible relationships between instrumental, sensory observations and drivers of consumer liking, e.g. principal component analysis (PCA) and partial least squares regression (PLS) (Bro *et al.,* 2008; Kjelhahl & Bro, 2010; Weldegergis *et al.,* 2011). PCA is a projection method that aims to explain the maximum variation between samples and assists to visualise data by indicating which samples are similar or dissimilar, as well as indicating which variables contribute most to this similarity or dissimilarity. This methodology also enables one to detect patterns within sample sets (Anon., 2010a). PLS regression, on the other hand, is frequently used to understand relationships between two data sets by mathematically predicting the properties of one data set based on that observed in the other set. In wine studies PLS can be applied to investigate the relationship between instrumental (*X*) and sensory (*Y*) data. PLS not only tries to provide solutions for both *X* and *Y* variables, but also simultaneously attempts to find the best solution of *X* that will explain the variation of the *Y*-variable set (Cozzolino *et al*., 2009). PLS can also be used where sensory, chemical, and preference data are available. In the latter case hedonic consumer responses are regressed onto the first two principal components of the descriptive and analytical data (Tenenhaus, 2005; Parpinello *et al.,* 2009; King *et al.,* 2010) to indicate drivers of consumer liking.

In view of the above, the aim of this study was to characterise industry-selected South African red wines, according to their sensory and chemical attributes. A subset of wines with the greatest statistical variance was then chosen to be analysed further by a group of black consumers for degree of liking and purchase intent. The consumers were also tested for perceptions on the purchasing and consumption of wines *per se*. Correlations between the sensory, chemical and consumer data were made in order to determine the drivers of liking, as well as understand consumer expectations.

2. MATERIALS AND METHODS

2.1 Wine samples

In accordance with industry, eighteen South African sweet and dry red wines were selected for this study. The wines were divided into four groups (Table 1) according to fact sheet data obtained from industry (See Addendum A for fact sheet data). As indicated in Table 1, the cultivar specific wines were grouped together, while red blends and natural sweet wines were also divided into further separate groups. A young, unwooded red blend with an alcohol content of 12.5%, with the brand name *Tassenberg*, was added to the list of wines and was used as a *control sample* or reference standard.

2.2 Chemical analyses

2.2.1 Spectroscopic determination of principal wine parameters

A WineScan FT 120 spectrometer equipped with a Michelson interferometer (Foss Analytical, Denmark; http://www.foss.dk) was used to generate spectra in the wavenumber region 5011-929 cm^{-1}. Quantification of the principal wine parameters was done using in house developed calibration models developed for these compounds (Nieuwoudt *et al*., 2004). These parameters were: ethanol, volatile acids, malic acid, lactic acid, pH, titratable acidity (TA), glucose, fructose and glycerol.

2.2.2 Gas chromatographic determination of major volatiles in wine

The analytical protocol described by Louw *et al.* (2009) was followed for determination of major volatiles. Briefly, for sample pre-treatment, 5 mL of wine was extracted by 1 mL diethyl ether by Liquid-liquid extraction (LLE) and dried on Na_2SO_4. 3 μL of this extract was subjected to Gas Chromatography with Flame Ionisation Detection (GC-FID) (Agilent). Concentrations reported were determined by using calibration graphs constructed with authentic standards and correlated to the internal standard (4-methyl-2-pentanol).

2.3 Descriptive sensory analysis

2.3.1 Panel members

For sensory analysis, panellists experienced in descriptive analysis were chosen for their ability to assess aroma, mouthfeel and taste attributes. All of the panellists had prior experience in wine assessment. Their collective experience included *Brettanomyces* taints, cork taint and the detection of diacetyl in red and white wines. The panel consisted of 9 females, ranging in age from 24 to 60 years.

2.3.2 Calibration and training of panel using reference standards

The panel of nine judges was trained extensively to analyse specific aroma (orthonasal and retronasal), taste and mouthfeel attributes of the selected wines (Lawless & Heymann, 2010). In order to achieve this, the wine aroma wheel of Noble *et al.* (1987) was used as a starting point in this study (Figure 1) for indicating the most applicable descriptive terms. This wheel divides descriptors into three tiers. Judges were firstly encouraged to evaluate the first tier and to then move on to the second and third tiers. As the training progressed, an adapted wheel with appropriate tiers and descriptors was drawn up for the specific wine samples used in this study (Figure 2). For illustrating the respective aroma attributes, reference standards were prepared and used during training, mainly to calibrate the judges with a the full spectrum of red wine aroma attributes (Biasoto *et al.,* 2010). See Table 2 for the list of reference standards, as well as the dosage instructions.

As already indicated, a control sample was used as point of reference in the analysis of all 18 wines to enable the sensory panel to conduct all the sensory analyses reliably over an extended period of time.

Generic descriptive analysis, also known as Quantitative Descriptive Analysis (QDA), was used as a research tool for analysing the full spectrum of sensory attributes of the respective wines (Lawless & Heymann, 2010; Lattey *et al.,* 2007). For each sub-set or group of wines (Table 1) the judges were trained for ten consecutive sessions of approximately 1.5 h per session. During each training session the panel members were exposed to 4 or 5 red wine samples, as well as the control sample.

Descriptors were generated for the respective wine samples and discussed by the panel members until consensus was reached on the range of sensory attributes necessary to profile the respective wines; as well as on the minimum and maximum intensity value of each aroma (retro- and orthonasal), taste and mouthfeel attribute (See Figure 2). See Addendum B for example of questionnaire.

Table 1 Grouping of 18 wines into four sub-groups.

Group 1 (Cultivar wines & Dry blends)	Group 2 (Cultivar wines & Dry blends)
A Nederburg Cabernet Sauvignon	F Obikwa Merlot
B Nederburg Merlot	G Obikwa Shiraz
C Nederburg Pinotage	H Roodeberg
D Nederburg Shiraz	I Nederburg Ingenuity Red
E Nederburg Baronne	
Group 3 (Dry blends)	**Group 4 (Natural sweet blends)**
J Chateau Libertas	N Four Cousins Natural Sweet Red
K Namaqua Dry Red	O Cellar Cask Johannisberger Red
L Two Oceans Cabernet Sauvignon-Merlot	P Robertson Winery Natural Sweet Red
M Alto Rouge	Q Drostdy Hof Natural Sweet Red
	R Namaqua Johannesberger Red

Control wine (Ctr) = Tassenberg, a dry red blend (12.5% alcohol v/v_1).

Table 2 List of reference standards used during training of QDA panel and dosage instructions.

First Tier	Second Tier	Third Tier	Reference	Dosage per 150 mL red wine (Tassenberg)
Fruity	Berry	Blackberry	Hillcrest Frozen Blackberries	45 g
		Raspberry	Hillcrest Frozen Raspberries	48 g
		Strawberry	Hillcrest Frozen Strawberries	50 g
		Blackcurrant	Hillcrest Frozen Blackcurrant	50 g
		Berry jam	Pick 'n Pay Mixed Fruit Jam	75 g
		Cherry	Moir's Cherry Essence	1%
		Plum	Hillcrest Plum Jam	100 g
		Prune	Safari Dried Prunes	100 g
Vegetative	Fresh	Cut green grass	IFF Grassy 00022010	0.08%
		Green pepper	Fresh Green Pepper	4.5 g
	Canned	Green bean	Koo Canned Green Beans, Brine	50 mL
		Asparagus	Koo Canned Asparagus, Brine	18 mL
		Olive	Black olive in brine	1 black olive
Spicy	Spicy	Liquorice/Aniseed	Expressions Star Anise LA 01322	0.05%
		Black pepper	Robertson's	0.2 g
		Cloves	Robertson's	3 cloves
		Cinnamon	Robertson's	0.15 g
		Nutmeg	Robertson's	0.1 g
		Mixed spice	Robertson's	0.15 g
Nutty	Nutty	Hazelnut	IFF Hazelnut 13642200	0.1%
Sweet Associated	Sweet Associated	Vanilla	Moir's Vanilla	1%
Woody	Resinous	Oak/Planky	Oak shavings	1.5 g
		Pencil shavings	Pencil shavings	1.5 g
		Coffee	Diemersfontein Pinotage	
		Woody	Oak chips (High roast)	2 g

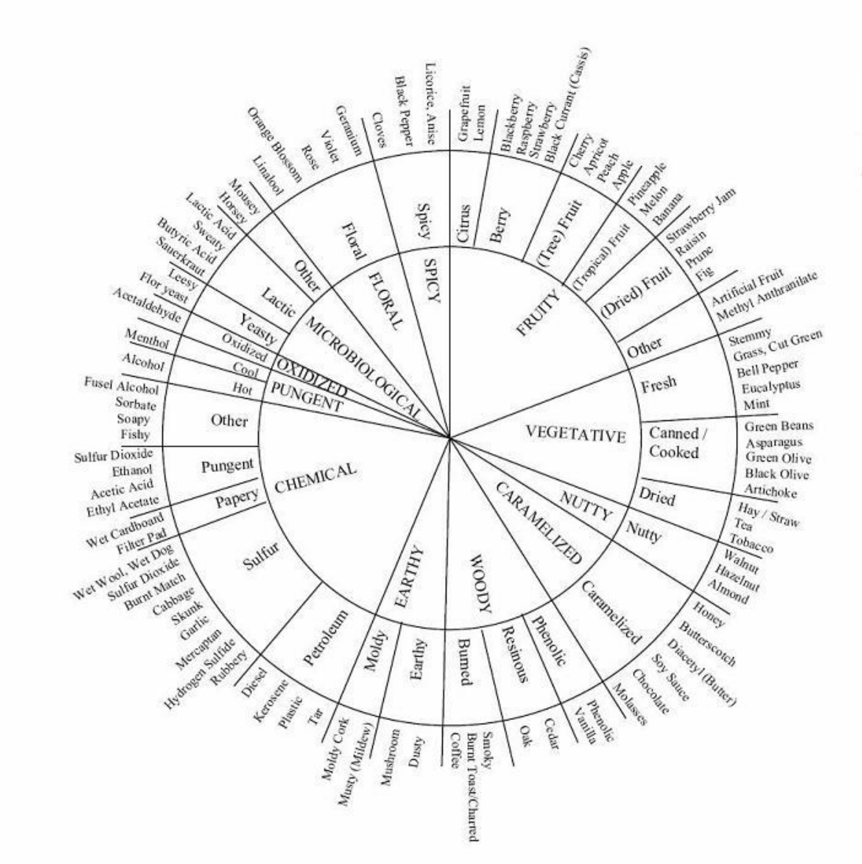

Figure 1 Wine aroma wheel, indicating 1st, 2nd and 3rd tiers (Noble *et al*., 1987).

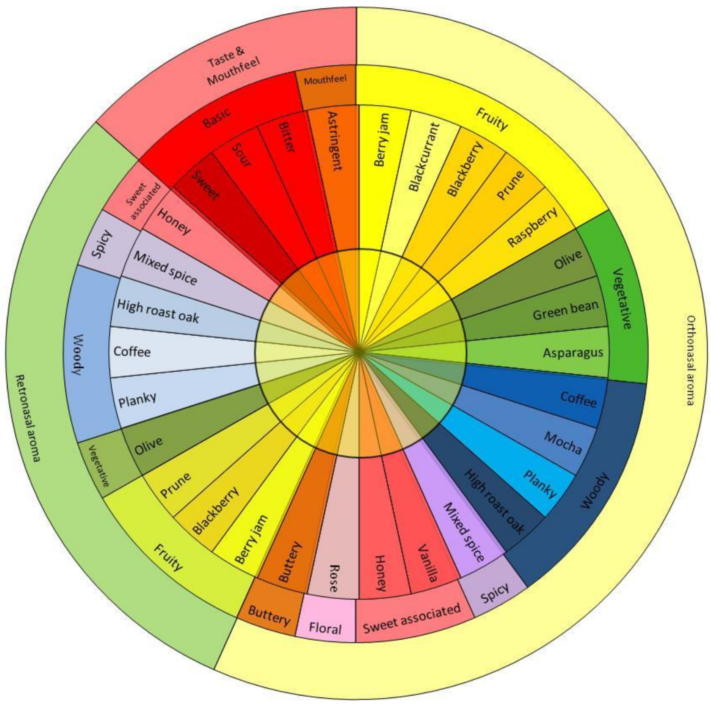

Figure 2 Red wine flavour wheel adapted from Noble *et al*. (1987) for the purpose of this study.

2.3.3 Testing of sensory profile

The sensory attributes were profiled on unstructured line scales with 0 = *No intensity* and 100 = *Prominent intensity*. The profiling was conducted in tasting booths fitted with Compusense software (Compusense® *five*, Compusense, Canada) and artificial daylight lighting. The room temperature was controlled at 20ºC ± 1ºC (ISO, 1988). The wines were analysed in standard ISO wine tasting glasses at 20ºC ± 1ºC and the sample size was 20 mL (ISO, 1977). Each sample was coded with a three-digit code and the judges received treatments in a complete randomised order; however the control sample was always served in the first position. Each glass was covered by a lid (Kimix, South Africa) and prior to the aroma analysis the judges were instructed to remove the lid from the glass, swirl the wine and analyse the specific aroma concentrated in the headspace area. After all aroma (orthonasal) attributes were analysed, the panel members were instructed to analyse the flavour or palate aroma (retronasal), taste and mouthfeel attributes. The analysis was replicated in six identical sessions on three consecutive days.

2.5 Testing of consumer liking and perceptions

As a consumer panel can only analyse a limited number of samples, a subset was chosen based on sensory results. Seven red wines illustrating the largest degree of statistical variance according to their sensory profile were thus chosen. This decision was also taken in co-operation with a major wine producer as they supplied relevant sales data (data not shown). The wines were divided into two groups, four dry red wine samples, followed by three sweet red blends.

Hundred and fifty (N=150) black male and female red wine consumers, aged between 18 and 40, were sourced in the Western Cape, South Africa. This group of consumers were asked to complete a questionnaire determining the overall degree of liking, as well as the purchase intent of the subset of wine samples. Degree of liking was tested using the 9-point hedonic scale and purchase intent by means of the 5-point scale (Lawless & Heymann, 2010; Guinard *et al*., 2001).

The two sets of samples were presented in a complete randomised order. The sample size was 50 mL and each treatment was served in an ISO wine tasting glass coded with a three digit random code. All the analyses were conducted in a light- and temperature-controlled room (21±1°C). After tasting the samples, a *simulated wine shelf scenario*, similar to what one will see in a wine store, was tested by giving each consumer a set of photographs consisting of seven wines. Photographs were evaluated using the 5-point purchase intent scale (Guinard *et al*., 2001; Mueller *et al.,* 2010).

Questions relating to the socio-demographics of the consumers were also incorporated in the questionnaire and included gender, age (Geel *et al*., 2005), income, education (Mueller *et al*., 2010), knowledge of wine and frequency of consuming wines (Verdú Jover *et al*., 2004).

The consumers were also probed on their general opinion on the *consumption* and *purchasing* of an array of wines and other alcoholic beverages, as well as the factors driving these opinions. For the latter; consumers had to rate their response on a 9-point scale (Guinard *et al*., 2001). See Addendum C for consumer test questionnaire.

2.6 Statistical analysis of data

All univariate analyses were conducted using using SAS® software (Version 9; SAS Institute Inc, Cary, USA). For the QDA a randomised complete block design was used where each judge received a control sample, as well as four to five red wine samples. The latter was replicated six times. Using the SAS® software the data were subjected to a test-retest analysis of variance (ANOVA) to test for reliability, i.e. temporal stability (Judge*Replication interaction) and internal consistency (Judge*Level interaction). The Shapiro-Wilk test was used to test for non-normality of the residuals (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 after the above-mentioned procedures have taken place. Student's t-test was performed and least significant difference (LSD) was calculated at the 5% significance level to compare the means. For consumer analysis a complete block design was also used, with each consumer tasting all seven wines. After normalising the consumer data, ANOVA was performed. Chemical analysis data were not subjected to these procedures as samples were not analysed in duplicate, i.e. for both GD-FID and FTMIR analyses.

Multivariate statistical techniques were performed using the XLSTAT software (Version 7.5.2, Addinsoft, New York, USA). Principal component analysis (PCA) using the correlation matrix and partial least squares regression (PLS) was conducted in order to investigate the associations and patterns within the sensory, chemical and consumer data sets (Guchu *et al*., 2006). For the chemical data the concentration levels of the chemical compounds were considered as the response variables for each sample. The chemical data were then assigned as the *X*-variables and the sensory data set was designated as the *Y*-variables in the PLS analysis with the assumption that the chemical stimuli mainly cause the sensory perception. For the combination of the sensory and consumer data the same procedure was used, in this case the sensory data were assigned as the *X*-variable and the consumer responses as the *Y*-variable. Discriminant analysis (DA) was also performed to determine possible clustering of liking scores, note that for the application of segmentation techniques it is important to use complete block designs (Mueller *et al.,* 2010). Correlations were investigated using the Pearson correlation coefficient (Cozzolino *et al*., 2009).

3. RESULTS AND DISCUSSION

The wines selected for this study varied significantly in terms of style. The selection included *dry* and *natural sweet red wines*, as well as *low-end*, inexpensive wines together with *high-end*, top quality wines. As a subset of these wines had to be analysed by the consumer, it was important to include a wide variety of wines at the start of the study. The results of the consumer study could be used to give an indication to the South African wine industry on how to re-direct the research and development and/or marketing strategies, especially with regard to the black consumer. According to *Statistics South Africa's* mid-year estimates for 2010, the black consumer constitutes approximately 79.4% of the South African population (Anon., 2010b). Currently they do not form a major part of the South African wine consumer, there is thus a potential for growth in this direction (Personal communication: D. Schmidt, Distell, Stellenbosch, South Africa, 2009).

A substantial degree of variation was found between the wines, brands, cultivars and styles, as well as price and quality. As would be expected, there was a significant variation in alcohol and sugar content, ranging from dry red wines with high alcohol content to natural sweet red blends with low alcohol content.

The chemical and sensory attributes of the full spectrum of wines will be discussed, where after the results of a subset of wines will be discussed with regard to their sensory and chemical attributes, as well as how a specific group of black consumers residing from the Western Cape, South Africa liked and perceived a selection of red wines.

3.1 Chemical attributes of the full set of wines

3.1.1 Principal wine parameters

When investigating the principal wine parameters as presented in Table 3, percentage alcohol was found to range from 7.60 – 14.91%. Variation can thus be seen between the sweet samples, N, O, P, Q and R, and the rest of the samples which consisted of all the dry red wines. Similar results were found with regard to the glycerol content of the wines, with the sweeter samples having half the glycerol content of the dry samples, the glycerol content ranged from 5.50 – 11.96 g/L. The glucose and fructose concentrations showed similar patterns, with the sweeter red wine samples showing values of up to 30 times higher values than the dry samples. The glucose and fructose concentration ranged from 0.04 – 36.33 g/L and 1.92 – 40.99 g/L, respectively. The other wine constituents showed little variation across the samples. It was observed that the malic acid concentration levels were low and the lactic acid concentrations high, indicating that malolactic fermentation took place, to a certain extent, in all the samples (Davis *et al.*, 1985).

3.1.2 Volatile compounds

For the identification and quantification of 25 of the major volatile constituents in the wines, GC-FID was used. Three main groups, consisting of the dominant esters, alcohols and fatty acids, were analysed in all wines, of those the higher alcohols and esters, produced during alcoholic fermentation, play an important role in the base aroma of wines, depending on the type of compound and concentration in which they are present (Biasoto *et al.,* 2010). Tables 4 to 6 indicate the means of all the samples, as well as the total concentration, range, average and standard deviation (SD) obtained for each compound in the selected wine samples.

The concentrations of the ester compounds are indicated in Table 4. Ethyl esters are usually formed through esterification in the presence of ethanol and fatty acids and contribute to the *fruity* aromas in wine. Sample H had the highest total ester concentration of 491.33 mg/L, while Sample Q had the lowest concentration of 247.11 mg/L

Higher alcohols are indicated in Table 5. Sample N had the highest total alcohol concentration of 882.91 mg/L and Sample Q had the lowest concentration of 449.78 mg/L.

Fatty acids are principally produced during the first phases of alcoholic fermentation, however, they can even be found at low concentrations in the must prior to fermentation (Gil *et al.,* 2006). Table 6 indicates the concentrations for different fatty acids measured. It was found that Sample P had the highest total concentration of 1691.55 mg/L, while Sample F had the lowest concentration of 567.44 mg/L.

3.1.3 Relationship between the wine samples and chemical attributes

In Figure 3, a PCA loadings and scores plot, the chemical compounds are indicated as the loadings and the wine samples as the scores. A clear division can be seen in the first principal component (Factor 1), with all the dry cultivars and blends on the left side and all the natural sweet wines on the right side of the plot. When the chemical composition is investigated further, it can be seen that compounds such as fructose and glucose are the main reason for the sweeter samples clustering on the right, as the sweet samples clearly have a higher concentration of these compounds. This can further be justified by the results in Table 3, where it is clear that the sweet red wines N, O, P, Q and R have high concentrations of fructose (26-40 g/L) and glucose (19-36 g/L).

It makes sense that the dry samples are more closely associated with ethanol, as these samples have a higher total alcohol content (>13.6%), because they were fermented to dryness. It would also be expected that the dry samples would have higher concentrations of volatile esters. This can be seen from Figure 3 where esters are found closely associated with the dry red samples. Esters add to the complexity experienced in these dry red wine samples. The ester ethyl lactate is also more closely associated with the dry samples; this is most likely because of the presence of ethanol and lactic acid, also found closely associated with the dry red wine samples. Acid and alcohols produce esters through the process of esterification (Bardi *et al*., 1998). Thus a higher percentage of alcohol could lead to a higher percentage of esters in wine samples, which would in turn lead to a more complex wine.

The presence of malic and lactic acid should also be noted, as the presence of lactic acid indicates that malolactic fermentation has occurred. The presence of malic acid on the right side of the plot also indicates that malolactic fermentation occurred to a lesser extent in the sweet red wine samples. Malic acid closely associated with natural sweet wines, where sugars are still present in high concentrations and this indicates that fermentation is not complete. Glycerol and lactic acid are found closely associated with the dry red wines, both these compounds contribute positively to the mouthfeel attributes of the dry red wines (Vidal *et al*., 2004).

It is also interesting to note that the dry red wines can be divided into two groups, as indicated by the second principal component. The top cluster of samples contains dry blends, except for Sample A which is a Cabernet Sauvignon, while the bottom cluster contains mainly cultivar samples, except for Samples, K and E, both dry blends, and the control sample. One could speculate that the chemical composition of dry red blends and dry red cultivar wines do in fact differ to a large extent with regard to certain chemical compounds. The main reason for this division may be due to the concentration of certain fatty acids, further investigation is required to substantiate this tendency.

Table 3 Concentration ranges in g/L for some commonly measured fermentation parameters. The range, average and standard deviation (SD) are indicated for each compound.

Analyte	Ethanol (%v/v)	Volatile acid	Malic acid	Lactic acid	pH	TA	Glucose	Fructose	Glycerol
Dry red wine samples									
A	14.64	0.45	<0.10	1.16	3.62	6.70	0.33	1.92	11.73
B	14.87	0.47	< 0.10	0.91	3.43	7.17	2.21	2.73	11.83
C	14.06	0.66	< 0.10	1.49	3.54	6.36	1.01	2.30	11.22
D	14.47	0.58	< 0.10	0.91	3.46	6.85	1.37	1.98	11.95
E	14.28	0.49	< 0.10	1.03	3.57	6.58	0.75	1.93	11.53
F	13.99	0.40	< 0.10	0.68	3.51	6.27	2.37	3.13	11.38
G	13.98	0.51	< 0.10	0.89	3.58	6.21	2.57	3.34	11.59
H	14.36	0.48	< 0.10	0.65	3.43	7.29	0.04	1.07	11.59
I	14.91	0.57	< 0.10	0.50	3.35	6.95	0.94	1.25	11.48
J	13.99	0.50	< 0.10	0.87	3.52	6.65	0.27	1.04	10.94
K	13.78	0.40	1.55	0.745	3.53	7.13	0.720	1.78	9.74
L	13.6	0.44	< 0.10	0.735	3.52	6.41	1.63	2.96	11.06
M	14.58	0.46	< 0.10	0.61	3.42	7.09	0.39	0.915	11.38
Sweet red wine samples									
N	8.70	0.41	< 0.10	<0.39	3.76	6.80	36.33	40.99	6.70
O	12.10	0.43	< 0.10	0.70	3.67	6.48	22.84	26.65	9.80
P	7.60	0.55	< 0.10	0.68	3.53	6.35	32.07	36.07	5.50
Q	7.80	0.52	1.30	0.50	3.79	6.77	34.64	36.98	5.60
R	12.60	0.60	< 0.10	0.94	3.75	6.77	19.49	32.10	9.50
Control	13.19	0.52	< 0.10	0.75	3.52	6.50	0.86	2.78	9.79
Range	7.60 - 14.91	0.40 - 0.66	<0.10 - 1.55	0.39 - 1.49	3.35 - 3.79	6.21 - 7.29	0.04 - 36.33	1.92- 40.99	5.50 - 11.95
Average	13.03	0.50	ND	0.80	3.55	6.70	8.47	10.63	10.22
SD	2.34	0.07	ND	0.26	0.12	0.32	13.15	14.93	2.07

TA: Titratable Acidity

ND: Not Determined

SD: Standard Deviation

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

Table 4 Concentration ranges in mg/L for analysed esters. The range, average and standard deviation (SD) are indicated for each compound.

Analyte	Ethyl acetate	Isoamyl-acetate	Ethyl butyrate	Ethyl hexanoate	Ethyl lactate	Diethyl succinate	2-Phenyl-ethyl acetate	Ethyl decanoate	Ethyl octanoate	Total Esters
Dry red wine samples										
A	100.80	0.74	0.47	0.68	274.35	17.16	0.57	0.12	<.LOD	**394.89**
B	112.72	0.54	0.55	0.72	297.34	27.67	<LOQ	0.13	0.07	**439.74**
C	115.86	0.92	0.62	0.84	287.03	14.41	<LOQ	0.13	0.10	**419.91**
D	111.07	0.62	0.53	0.66	241.48	19.74	0.54	0.11	0.06	**374.81**
E	90.35	0.76	0.54	0.67	218.59	16.05	0.31	0.17	0.06	**327.50**
F	74.51	1.12	0.55	0.72	158.51	10.75	0.58	0.13	<LOQ	**245.87**
G	81.85	1.10	0.49	0.71	202.41	11.85	0.59	0.13	0.09	**298.22**
H	135.68	0.59	0.49	0.69	331.94	21.21	0.56	0.12	0.05	**491.33**
I	137.34	0.43	0.47	0.63	269.24	20.63	0.56	<LOQ	0.08	**429.38**
J	109.30	0.60	<LOD	0.57	285.57	13.03	0.57	<LOQ	0.11	**409.75**
K	80.95	1.16	0.55	0.67	199.49	8.87	0.61	<LOQ	<LOD	**332.39**
L	95.30	0.86	0.60	0.67	223.69	11.13	0.57	0.17	<LOD	**332.99**
M	122.04	0.56	0.50	0.68	314.26	17.82	0.57	0.12	0.15	**456.70**
Sweet red wine samples										
N	63.81	0.55	<LOD	<LOD	220.55	5.40	<LOQ	<LOQ	<LOD	**290.31**
O	73.40	0.74	0.51	0.58	345.52	10.83	0.59	<LOQ	0.12	**432.29**
P	76.84	0.57	0.68	<LOQ	329.44	3.66	<LOQ	<LOQ	<LOQ	**411.19**
Q	78.50	0.50	0.50	0.52	161.92	5.17	<LOQ	<LOQ	<LOQ	**247.11**
R	115.04	0.91	<LOD	0.52	274.05	7.83	<LOQ	<LOD	<LOQ	**398.35**
Control	97.43	0.98	0.52	0.63	219.42	7.04	0.61	<LOD	0.11	**326.74**
Range	63.81 - 137.35	0.43- 1.17	0.47- 0.68	0.52- 0.84	158.52- 345.52	3.66- 21.22	0.31- 0.61	0.11 - 0.17	0.05 - 0.15	**414.20 - 845.21**
Average	63.81	0.75	0.54	0.66	255.52	13.18	0.57	0.13	0.09	**640 .74**
SD	21.66	0.23	0.21	0.22	56.08	6.40	0.27	0.07	0.05	**70.77**

SD: Standard Deviation

Average and Standard Deviation (SD) calculated without <LOD (Limit of detection) and <LOQ (Limit of quantification) values

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg**;** **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

Table 5 Concentration ranges in mg/L for analysed alcohols. The range, average and standard deviation (SD) are indicated for each compound.

Analyte	2-Phenyl Ethanol	Methanol	Propanol	Butanol	Isobutanol	Isoamyl Alcohol	Hexanol	Total Alcohols
Dry red wine samples								
A	1.27	249.67	40.31	2.49	69.56	403.08	2.19	**768.57**
B	1.25	201.12	54.54	2.42	46.38	327.03	1.54	**634.28**
C	1.09	162.62	70.05	2.12	40.98	193.30	1.54	**471.70**
D	1.19	212.60	54.60	2.34	51.27	276.44	2.12	**600.56**
E	1.22	179.88	46.03	2.18	49.31	320.01	2.09	**600.72**
F	1.17	264.46	47.49	2.06	55.28	303.80	1.70	**675.96**
G	1.15	262.65	53.86	2.28	64.73	286.21	1.96	**672.84**
H	1.22	315.42	69.24	2.64	65.79	353.97	1.94	**810.22**
I	1.11	287.31	66.24	2.44	56.80	242.04	1.60	**657.54**
J	1.13	283.01	31.52	2.53	66.29	310.69	1.94	**697.11**
K	1.08	253.35	58.77	2.13	68.73	323.03	2.72	**709.81**
L	1.15	265.44	54.44	2.17	69.20	340.62	1.81	**734.83**
M	1.16	353.18	78.64	2.44	60.22	302.15	1.81	**799.60**
Sweet red wine samples								
N	7.98	507.09	77.32	1.94	62.17	224.01	2.40	**882.91**
O	5.78	318.29	77.58	2.51	63.86	305.30	1.9	**775.22**
P	8.45	585.03	72.25	1.72	40.94	142.02	2.42	**852.83**
Q	5.59	194.56	57.60	1.62	36.68	152.24	2.03	**449.78**
R	5.43	469.51	50.75	2.11	72.49	271.92	2.00	**874.21**
Control	4.90	291.14	83.24	2.15	62.67	271.42	1.93	**716.64**
Range	1.08 - 8.45	162.62 - 585.03	31.52 - 78.64	1.62 - 2.53	36.68 - 72.49	142.02 - 403.08	1.54 - 2.72	**449.78 - 882.91**
Average	2.81	297.70	60.24	2.23	58.07	281.54	1.98	**704.49**
SD	2.60	112.32	14.22	0.27	10.90	66.75	0.31	**120.81**

SD: Standard Deviation

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

Table 6 Concentration ranges in mg/L for acids. The range, average and standard deviation (SD) are indicated for each compound.

Analyte	Propionic acid	Butyric acid	Isobutyric acid	Isovaleric acid	Hexanoic acid	Octanoic acid	Decanoic acid	Acetic Acid	Valeric acid	Total Acids
Dry red wine samples										
A	11.48	1.70	2.19	4.52	2.09	2.68	1.30	781.99	0.99	**808.94**
B	12.58	1.63	1.79	3.07	2.07	2.98	1.19	707.71	1.20	**734.22**
C	15.83	1.01	1.48	2.35	2.61	3.73	1.23	692.82	0.66	**721.72**
D	16.13	1.46	1.91	2.93	1.97	2.58	1.29	676.90	0.86	**705.22**
E	10.71	1.29	1.79	3.37	1.96	2.73	1.16	568.54	1.13	**592.68**
F	16.85	1.70	1.85	3.50	2.19	3.14	1.21	535.95	1.05	**567.44**
G	21.93	1.68	2.07	3.36	2.19	3.16	1.36	744.21	0.92	**780.88**
H	19.45	1.76	2.00	3.12	2.08	3.03	1.67	893.76	1.26	**928.13**
I	29.75	1.65	1.48	1.93	1.77	2.66	1.11	883.19	0.88	**924.42**
J	22.98	1.57	2.29	4.02	1.69	2.26	1.87	926.14	1.33	**964.15**
K	16.94	2.12	2.44	2.88	2.50	3.10	0.91	604.77	1.16	**636.82**
L	16.90	1.69	2.01	4.07	2.21	2.95	1.20	708.43	1.27	**740.73**
M	27.03	1.73	2.21	3.23	1.91	3.12	1.15	880.90	1.17	**922.45**
Sweet red wine samples										
N	23.11	1.42	2.54	2.43	1.66	2.16	1.40	1327.62	1.41	**1363.75**
O	29.70	1.82	2.33	3.32	1.79	2.58	1.07	1254.57	1.45	**1298.63**
P	17.66	1.62	1.61	1.64	1.54	2.03	2.00	1662.46	0.99	**1691.55**
Q	14.39	1.20	1.68	1.88	1.83	2.78	1.23	1123.72	0.87	**1149.58**
R	25.42	1.39	3.14	3.23	1.61	1.80	3.95	1516.41	1.18	**1558.13**
Control	20.37	1.85	2.22	2.90	2.21	2.89	1.33	1026.93	1.15	**1060.04**
Range	10.71 - 29.75	1.29 - 2.01	1.48 - 3.14	1.64 - 4.52	1.54 - 2.61	1.80 - 3.73	0.01 - 3.95	535.95- 1662.46	0.66 - 1.45	**567.44 - 1691.55**
Average	19.43	1.65	2.05	3.04	1.99	2.76	1.45	921.95	1.10	**955.24**
SD	5.57	0.25	0.41	0.75	0.29	0.46	0.66	321.66	0.21	**323.95**

SD: Standard Deviation

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg**;** **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

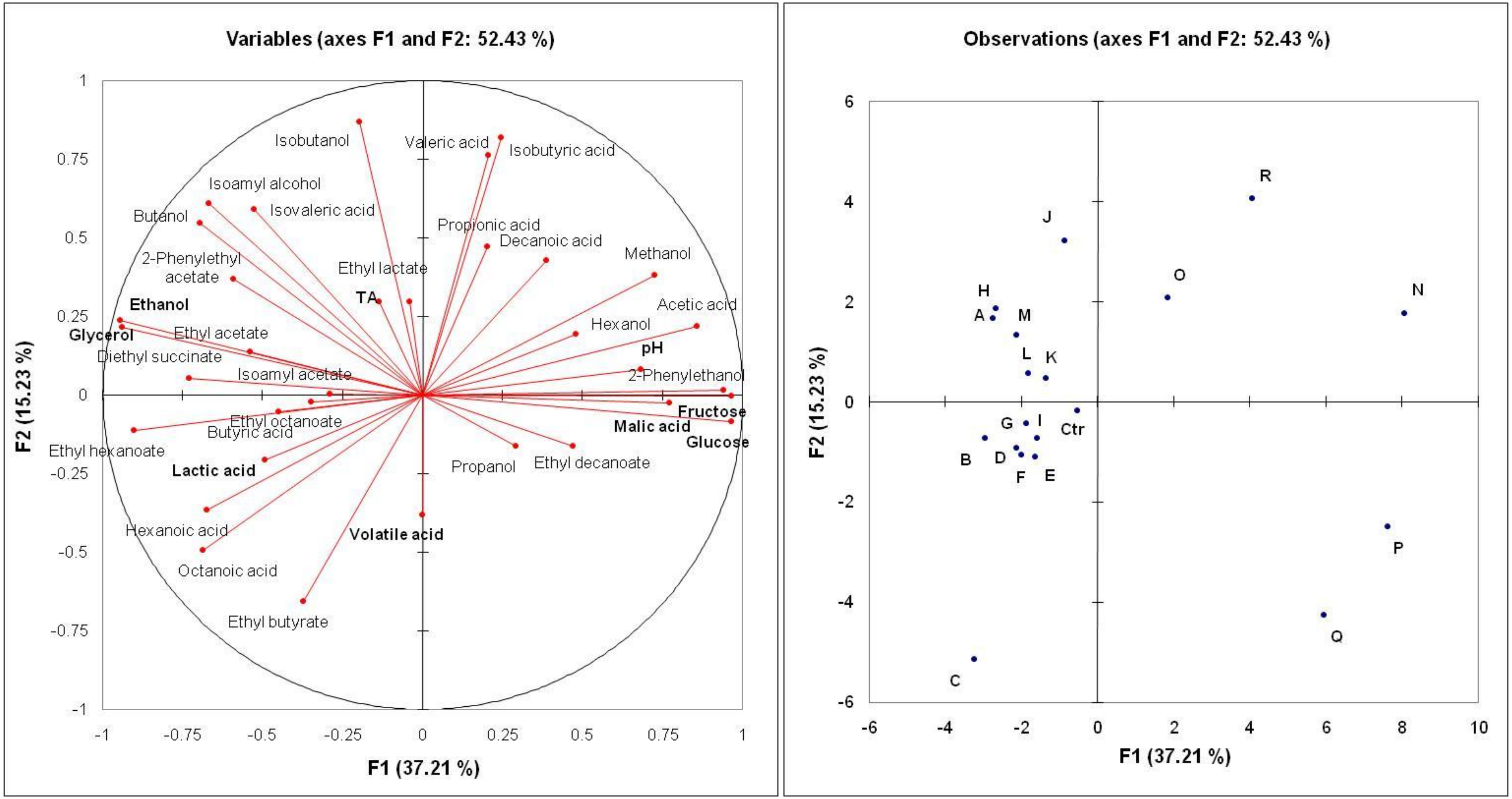

Figure 3 PCA loadings (left) and scores (right) plots for chemical attributes. Samples are indicated as the scores and the chemical attributes as the loadings. Compounds indicated in bold were measured with FTMIR. The first two principal components (F1 & F2) explain 52.43% of the variance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr)-Tassenberg.

3.2 Sensory attributes of the full set of wines

All the wines were analysed sensorially for first and second tier sensory attributes (Figure 2) on a line scale ranging from 0 (*None*) to 100 (*Prominent*) intensity. All first and second tier ANOVA results are illustrated in Tables 7 to 9, whereas selected first tier ANOVA results are given in Figures 4, 5 and 6. Finally, the PCA scores and loadings plots (Figure 7) summarize the complete sensory data set of the full set of wines.

The main descriptors (first tier) for aroma (orthonasal) in Figure 4 include *fruity*, *vegetative, woody*, *sweet associated* and *spicy*. The four control samples show the highest scores for orthonasal *fruity* aroma, with average scores ranging between 50 and 60. Most of the samples scored between 20 and 30 for *fruity* aroma, however, Sample I and O were the second highest for *fruity* aroma with values of 35.39 and 38.85, respectively. Sample I, an Italian red blend, had a very distinct *prune* (17.57) orthonasal aroma and hence its high *fruity* aroma value. Sample O, a Johannisberger Red, had a distinct *berry jam* orthonasal aroma (23.68). Samples scoring very low for orthonasal *fruity* aroma included Samples B, C, D and Q. Sample B, a Merlot, had the lowest *fruity* value (20.89). This sample was characterised by a very strong orthonasal *vegetative* aroma and this is therefore most likely the reason for the low *fruity* aroma score. When strong and distinct aromas occur in a sample, it may overpower many other aromas occurring in that specific wine (Jordão *et al*., 2006). Sample Q was a natural sweet red wine, with lower alcohol content (7.8 %v/v). The wine didn't show any distinct aromas and was also characterised as a *watery* sample during training of the panel. The lack of body and dimension may therefore be the main reason for the sample scoring low in *fruity* aroma.

When evaluating the scores obtained for orthonasal *vegetative* aroma, two samples had aroma values exceeding that of the other samples by far: Sample B (44.07) and Sample P (55.13). As was mentioned above, Sample B, a Merlot, was characterised by a strong *vegetative* aroma. This aroma was driven to a large extent by the presence of a strong *asparagus* note (20.91). This corresponds to findings from Sala *et al*. (2004,) which described Merlot wines as having a significant percentage of *vegetative* aromas. Sample P, a natural sweet red blend, had a very distinct and overwhelming *olive* (52.99) aroma. This was slightly less during the testing phase. According to Distell, South Africa (Personal communication: Prof. P van Rensburg, Distell, Stellenbosch, South Africa, 2009), this could be the result of commercial blending practices. The control samples scored the lowest for *vegetative*, with values between 1 and 6.

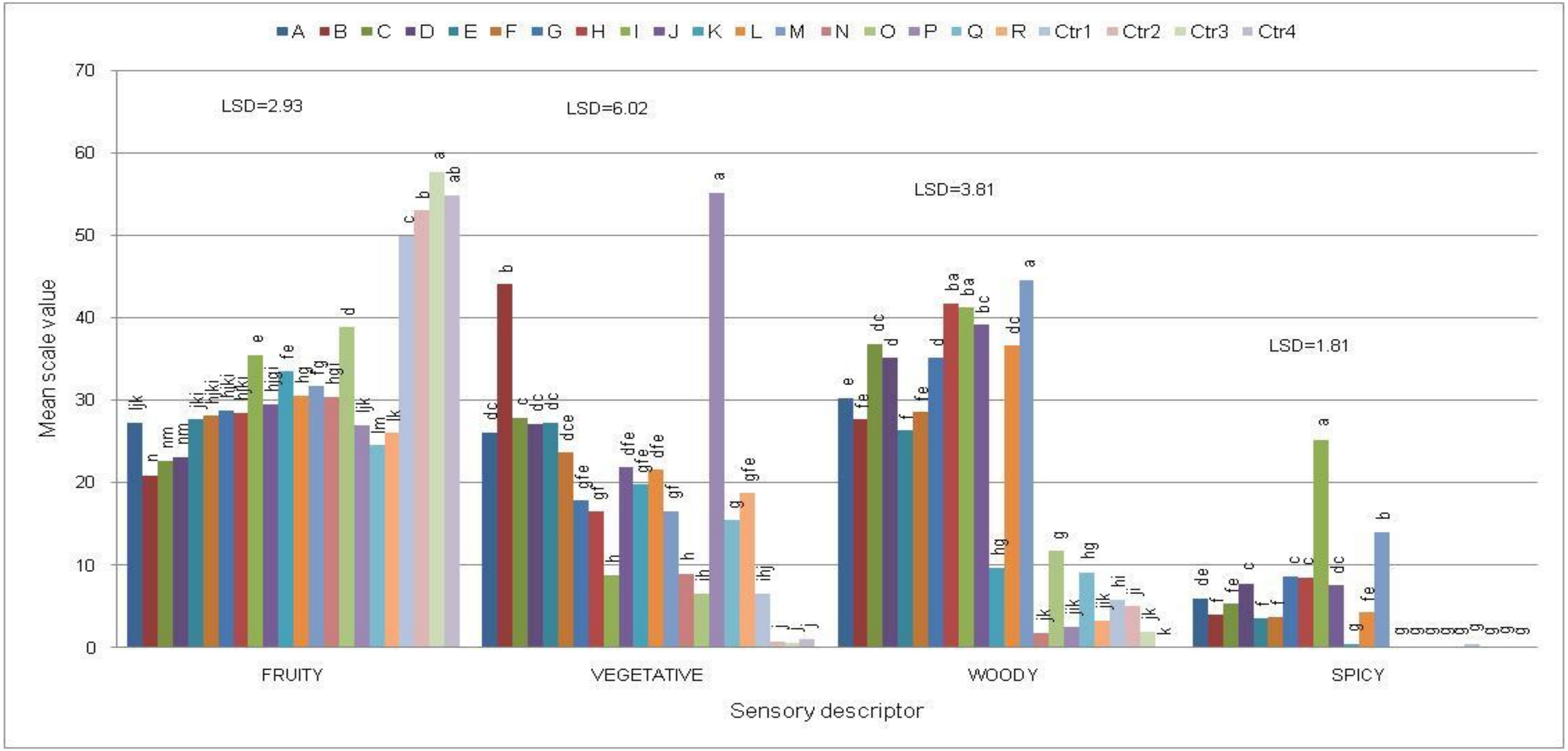

Figure 4 The main orthonasal sensory attributes of nineteen red wine samples, as well as four control samples. LSD = Least significant difference was calculated for each attribute. Means with different letters differ significantly at the 5% level of significance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr 1-4)-Tassenberg.

With regard to *woody* orthonasal aroma, Sample M, a red blend, scored the highest (44.55). This specific sample was a 2006 vintage, and the age of the wine could have played a part in the wine's complexity and therefore resulting in the distinct *woody* aroma. Investigation into the winemaking process, as indicated on the wine fact sheets (Addendum A), revealed that this wine was matured in French oak for 18 months which is relatively long in comparison to the other wine samples in this study. Most other sensory scores ranged between 28 and 40, while that of the control samples, as well as at the natural sweet samples (Samples N to R) ranged between 0 and 10. Sample K, a red blend, was the only dry red sample that scored quite low for *woody* aroma, i.e. below 10. This sample was packaged in a 1.5 L box and is classified by the producers as a *low-end*, affordable and easy drinking wine. This wine scored relatively low in all the first tier descriptors and was described during training and testing as a basic blend with little complexity. This may have contributed to its low score for *woody* orthonasal aroma.

For *spicy* orthonasal aroma Sample I, the Italian red blend scored the highest. This sample was characterised by a distinct *mixed spice* orthonasal aroma, most likely as a result of the French oak barrels used in the winemaking process. According to literature the latter usually results in the *spicy* orthonasal character of red wine (Díaz-Plaza *et al*., 2001). The natural sweet samples, Samples N to R, as well as the control sample, indicated no ortho- or retronasal *spicy* characters (Table 7 & 8).

Table 7 The orthonasal sensory attributes of nineteen red wine samples as well as four control samples. LSD = Least significant difference. Samples with a different superscript in the same row differ significantly at the 5% level of significance.

Sensory descriptor	**Samples**																						
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**Ctr1**	**Ctr2**	**Ctr3**	**Ctr4**	**LSD (p=0.05)**
FRUITY	27.31^{jkl}	20.89^{n}	22.67^{mn}	23.03^{mn}	27.63^{ijk}	28.08^{hijk}	28.79^{hijk}	28.50^{hijk}	35.39^{e}	29.50^{ghij}	33.57^{ef}	30.58^{gh}	31.73^{fg}	30.41^{ghi}	38.85^{d}	26.96^{jkl}	24.55^{lm}	26.01^{kl}	49.89^{c}	53.07^{b}	57.58^{a}	54.88^{ab}	2.93
Berry jam	16.28^{de}	11.27^{ghi}	10.02^{hij}	12.36^{fgh}	17.70^{d}	6.73^{k}	8.44^{ijk}	7.97^{jk}	6.02^{k}	15.27^{def}	23.59^{c}	13.51^{efg}	10.06^{hij}	8.58^{ijk}	23.68^{c}	15.98^{de}	12.62^{fgh}	12.13^{gh}	34.40^{a}	23.83^{c}	26.89^{b}	28.71^{b}	2.91
Blackcurrant	2.70^{cd}	2.69^{cd}	3.72^{c}	2.51^{cde}	2.56^{cde}	1.32^{defgh}	1.63^{defg}	0.89^{fgh}	0.19^{gh}	1.80^{def}	1.12^{efgh}	1.82^{def}	1.80^{def}	0.00^{h}	0.00^{h}	0.24^{gh}	0.12^{h}	0.00^{h}	6.08^{a}	11.43^{a}	11.88^{a}	12.72^{a}	1.48
Blackberry	10.58^{cdefgh}	8.21^{hij}	6.52^{ijk}	8.77^{ghi}	11.56^{cdef}	11.90^{cd}	11.54^{cdefg}	11.35^{cdefg}	10.18^{defgh}	11.67^{cde}	5.76^{jkl}	8.91^{efghi}	13.31^{c}	9.68^{defgh}	4.66^{kl}	3.06^{l}	4.42^{kl}	8.87^{fghi}	19.53^{b}	20.44^{ab}	22.33^{a}	23.00^{a}	2.78
Prune	0.39^{e}	0.55^{e}	0.42^{e}	1.01^{e}	0.93^{e}	4.41^{d}	6.05^{e}	7.03^{bc}	17.57^{a}	1.49^{e}	0.59^{e}	0.76^{e}	8.81^{b}	6.94^{e}	1.29^{e}	1.85^{e}	1.61^{e}	0.78^{e}	0.64^{e}	1.52^{e}	0.92^{e}	0.37^{e}	1.84
Raspberry	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.40^{b}	17.69^{a}	0.24^{b}	0.21^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.44^{b}	0.00^{b}	0.45
VEGETATIVE	26.06^{cd}	44.07^{b}	27.86^{c}	27.14^{cd}	27.27^{cd}	23.64^{cde}	17.89^{efg}	16.51^{fg}	8.74^{h}	21.84^{def}	19.84^{efg}	21.62^{def}	16.61^{fg}	9.00^{h}	6.60^{hi}	55.13^{a}	15.46^{g}	18.72^{efg}	6.52^{hij}	0.79^{j}	0.58^{j}	1.02^{j}	6.02
Olive	4.52^{cdef}	6.98^{bcd}	8.24^{bc}	8.67^{cd}	6.88^{bcd}	4.60^{cdef}	7.15^{bcd}	6.40^{bcde}	3.62^{cdef}	6.25^{bcde}	10.74^{b}	8.85^{cd}	3.56^{cdef}	5.33^{bcdef}	2.69^{def}	52.99^{a}	5.75^{bcde}	10.11^{b}	1.32^{ef}	0.00^{f}	0.19^{f}	0.00^{f}	5.45
Green Bean	7.59^{b}	9.99^{a}	6.35^{bcd}	6.22^{bcde}	7.30^{bc}	5.59^{cdef}	5.42^{def}	4.46^{ef}	1.23^{g}	7.28^{bc}	5.46^{def}	4.22^{f}	7.55^{b}	0.00^{g}	0.16^{g}	0.11^{g}	5.32^{def}	0.73^{g}	0.99^{g}	0.00^{g}	0.00^{g}	0.00^{g}	1.81
Asparagus	2.98^{b}	20.91^{a}	3.59^{b}	3.06^{b}	3.03^{b}	2.99^{b}	0.74^{c}	0.89^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.68^{c}	0.21^{c}	0.00^{c}	0.00^{c}	1.33
WOODY	30.24^{e}	27.67^{ef}	36.80^{cd}	35.19^{d}	26.36^{f}	28.53^{ef}	35.14^{d}	41.69^{ab}	41.19^{ab}	39.10^{bc}	9.63^{gh}	36.62^{cd}	44.55^{a}	1.86^{jk}	11.75^{g}	2.55^{ijk}	9.14^{gh}	3.27^{ijk}	5.84^{hi}	5.00^{ij}	1.93^{jk}	0.00^{k}	3.81
Coffee	10.33^{cde}	7.87^{def}	27.08^{a}	21.74^{b}	7.39^{ef}	10.04^{cde}	19.06^{b}	12.89^{c}	10.63^{cd}	0.66^{cd}	5.06^{h}	3.96^{fg}	0.00^{g}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.63^{h}	0.01^{h}	0.36^{h}	0.00^{h}	3.08
Mocha	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.19^{b}	7.07^{a}	0.28^{b}	0.53^{b}	0.57^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.66
Planky	7.39^{bcd}	7.03^{bcde}	5.48^{ef}	5.65^{cdef}	4.68^{fg}	4.93^{f}	7.78^{b}	11.24^{a}	11.99^{a}	1.99^{hi}	1.37^{hij}	2.89^{gh}	7.47^{bc}	1.30^{hij}	5.54^{def}	0.97^{j}	4.67^{fg}	1.73^{hij}	0.98^{j}	0.94^{j}	0.38^{j}	0.00^{j}	1.90
High roast	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	7.23^{d}	6.50^{d}	10.31^{c}	12.19^{c}	25.14^{b}	4.24^{e}	23.31^{b}	34.20^{a}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.93^{f}	0.28^{f}	0.00^{f}	2.17
SWEET ASS.	6.52^{bcd}	4.19^{cdefgh}	6.42^{bcde}	5.73^{bcdef}	6.36^{bcde}	1.78^{ghi}	7.83^{bc}	6.15^{bcdef}	3.08^{defghi}	5.44^{bcdefg}	2.48^{fghi}	4.94^{bcdefgh}	3.18^{defghi}	22.90^{a}	6.74	2.74^{efghi}	4.92^{bcdefgh}	3.08^{defghi}	8.43^{b}	2.43^{fghi}	1.48^{hi}	0.32^{i}	3.73
Vanilla	1.87^{cde}	1.21^{defg}	2.70^{abc}	3.29^{a}	2.72^{abc}	0.33^{gh}	3.67^{a}	3.57^{a}	1.27^{defg}	3.13^{ab}	0.83^{efgh}	2.23^{bcd}	0.99^{efgh}	0.00^{h}	0.00^{bcd}	0.00^{h}	0.00^{h}	0.00^{h}	1.47^{def}	0.61^{fgh}	0.35^{gh}	0.00^{h}	1.05
Honey	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0. 00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	16.88^{a}	3.29^{b}	1.81^{bc}	3.70^{b}	1.90^{bc}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.67
FLORAL	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0. 00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	15.75^{a}	3.22^{b}	2.43^{b}	2.58^{b}	3.11^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.02
Rose	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0. 00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	14.09^{a}	2.56^{b}	1.71^{bc}	2.30^{b}	2.55^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	1.83
BUTTERY	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0. 00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.01^{b}	1.17^{bc}	0.46^{c}	0.19^{c}	17.38^{a}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	1.54
SPICY	5.92^{de}	4.08^{f}	5.30^{ef}	7.81^{c}	3.57^{f}	3.80^{f}	8.56^{c}	8.54^{c}	25.20^{a}	7.55^{cd}	0.46^{g}	4.25^{ef}	14.05^{b}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{g}	0.47^{g}	0.00^{g}	0.19^{g}	0.00^{g}	1.81
Mixed Spice	3.12^{fg}	2.82^{fg}	2.65^{g}	3.96^{ef}	1.07^{h}	2.42^{g}	5.41^{cd}	5.79^{c}	17.52^{a}	4.54^{de}	0.53^{h}	2.39^{g}	8.38^{b}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.29^{h}	0.01^{h}	0.12^{h}	0.00^{h}	1.20

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz;**E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**(Ctr1-4)-Tassenberg.

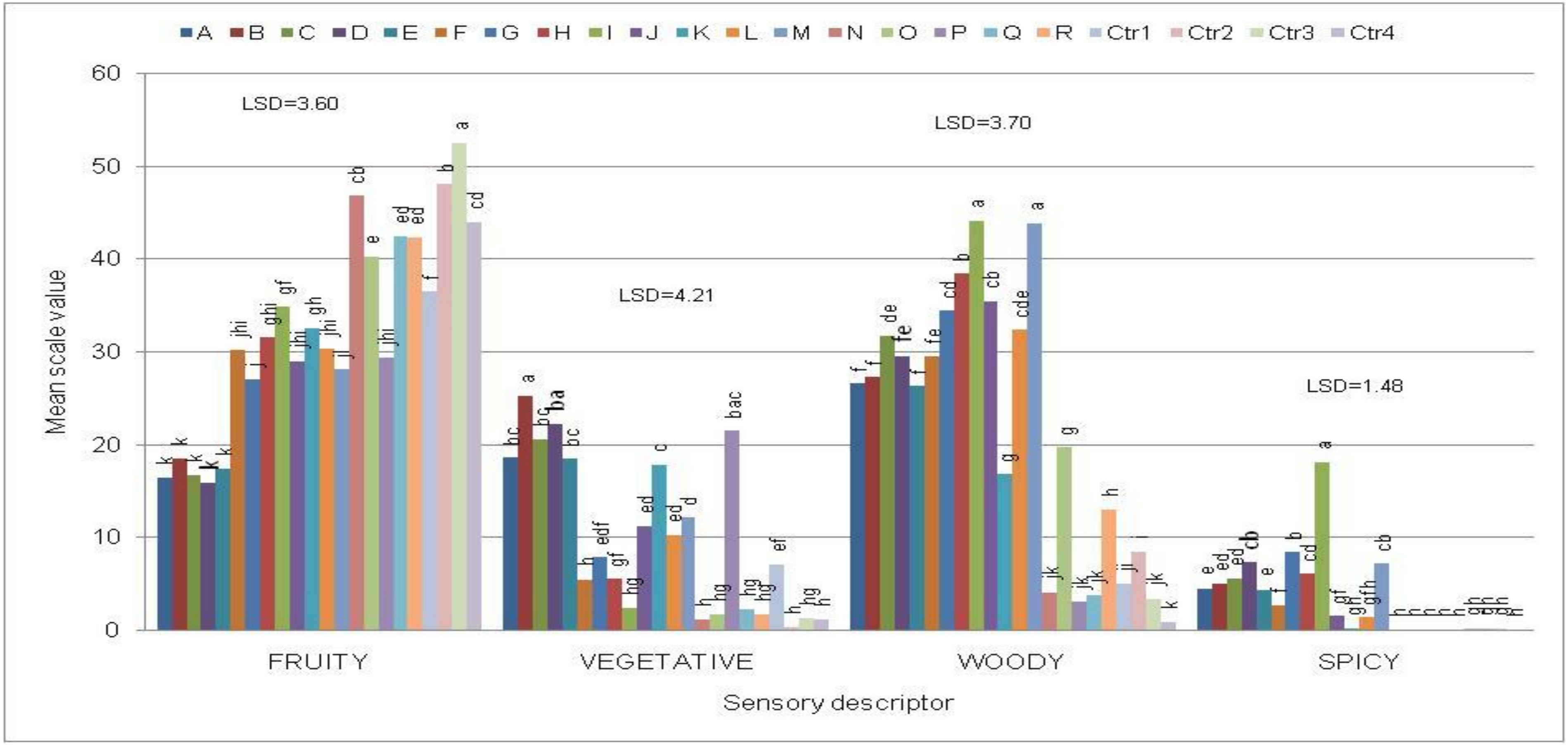

Figure 5 The main retronasal sensory attributes of nineteen red wine samples, as well as four control samples. LSD = Least significant difference was calculated for each attribute. Means with different letters differ significantly at the 5% level of significance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

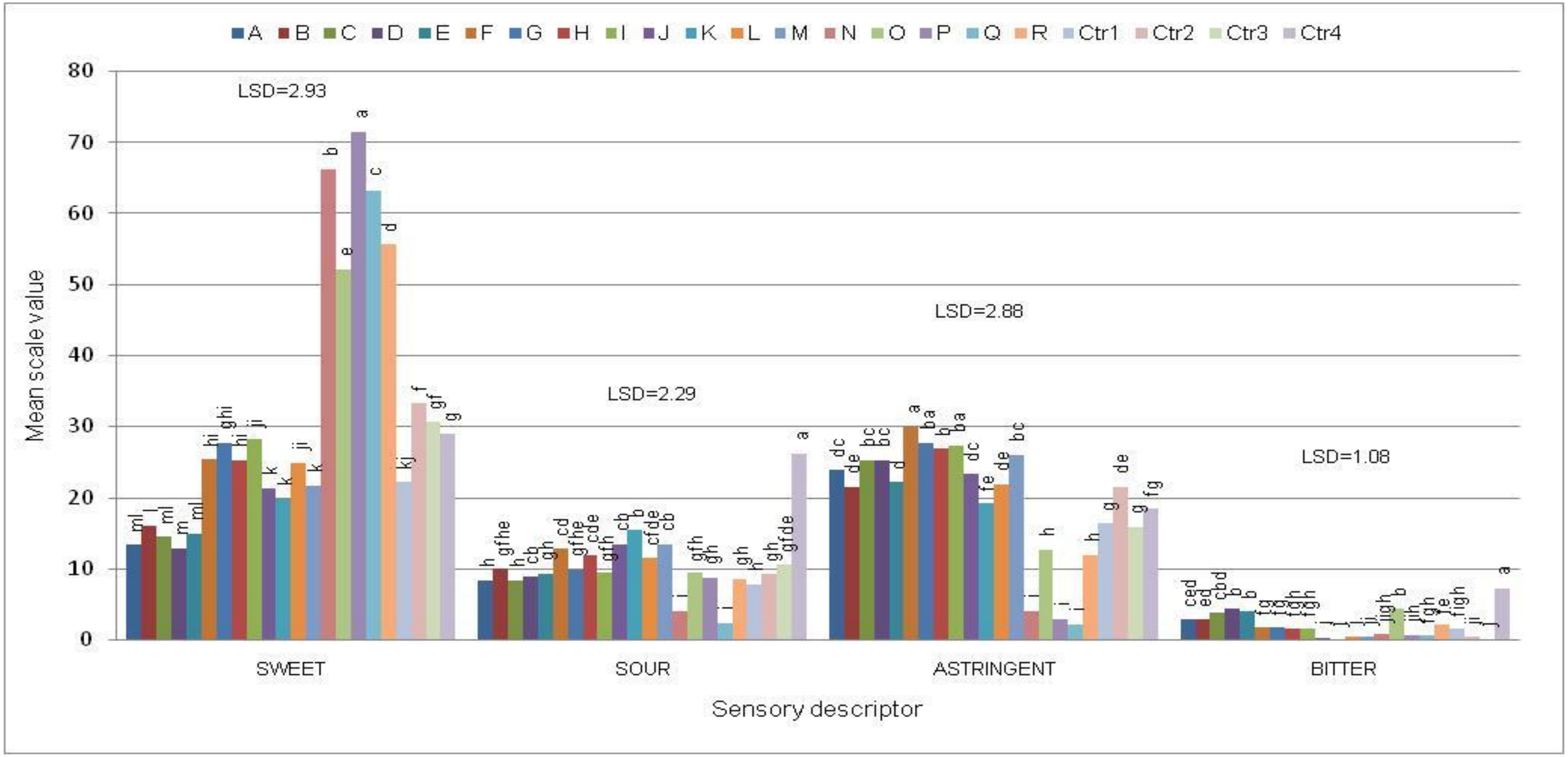

Figure 6 The basic tastes and mouthfeel attributes of nineteen red wine samples, as well as four control samples. LSD = Least significant difference was calculated for each attribute. Means with different letters differ significantly at the 5% level of significance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

The results for retronasal attributes are summarized in Table 8. Orthonasal and retronasal scores showed similar patterns over all the samples, except for the *fruity* descriptor. It seems that samples that scored highest for *fruity* aroma orthonasally, scored much lower for *fruity* retronasally. It can therefore be concluded that the presence of a *fruity* orthonasal attribute, will not necessarily result in a similar high score when analysed retronasally.

Regarding the basic tastes, *sweet sour* and *bitter*, and the mouthfeel attribute *astringent* (Table 9), the main differences between samples were found amongst the *sweet* and *astringent* descriptors, with little variation occurring between samples with regard to the *bitter* and *sour* attributes. As expected, the sweeter wines N, O, P, Q and R scored the highest for *sweet* taste, while there was little variation observed between the other samples. Slight differences can be seen between the cultivar specific samples and the dry red blends: it seem that the red blends scored slightly higher for *sweet* taste with values between 20 and 35, while the dry samples scored at an average value of 15 units. The mouthfeel attribute *astringency* again shows a clear division between the dry samples and the sweet samples, with the dry red cultivars and red blends scoring between 12 and 30, while the sweet red wine samples scored very low with values between 5 and12 (Ishikawa & Noble, 1995).

When investigating the PCA scores plot, six distinct groups can be distinguished (Figure 7b). Three groups on the right side represent the dry red wines and three groups on the left represent the sweet red wines. It seems that the cultivar specific wines (Sample A, B, C, D and E) in the top right quadrant are described with a wide range of sensory descriptors such as *woody*, *vegetative* and *fruity.* These attributes add to the complexity of wines. This can also be seen in Table 7 where it is evident that the orthonasal sensory results indicated a wide range of sensory attributes. The second group, mostly dry red blends, included Samples F, G, H and J. It seems that no specific sensory attribute discriminated between these wines. The main reason for this is that sensory notes occurring in these wines are relatively constant over all the samples (Table 7-9). Sample I, the Italian style red blend, lies further away on the right side of the PCA scores plot. This wine is quite singular with specific orthonasal attributes such as *spicy* (25.20) and *prune* (17.57) as indicated in Table 7.

The left side of the PCA loadings plot (Figure 7) is mainly dominated by *fruity* and *sweet* attributes and it is therefore evident that the sweet red wines, Samples N, O, P, Q and R, are found here. However, Samples N and P lie slightly further away from the rest. The latter two wines were characterised by attributes such as *floral* and *honey-like, as well as olive* notes, respectively. Sample K and the control samples (1-4) are the only dry wines found on the left side of the plot. Sample K had a distinct *raspberry* orthonasal aroma and the control samples a strong *berry-like* orthonasal aroma, this could be the main reason for these samples being more closely grouped with the sweet samples on the left, as the sweet samples were also characterised with *berry-like* orthonasal aromas.

Table 8 The retronasal sensory attributes of nineteen red wine samples as well as four control samples. LSD = Least significant difference. Samples with a different superscript in the same row differ significantly at the 5% level of significance.

Sensory descriptor	Samples																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	Ctr1	Ctr2	Ctr3	Ctr4	LSD (p=0.05)
FRUITY	16.44^{k}	18.40^{k}	16.66^{k}	15.87^{k}	17.30^{k}	30.12^{hij}	26.98^{j}	31.45^{ghi}	34.86^{fg}	28.96^{hij}	32.48^{gh}	30.25^{hij}	28.04^{ij}	46.76^{bc}	40.18^{e}	29.30^{hij}	42.43^{de}	42.31^{de}	36.40^{f}	48.00^{b}	52.42^{a}	43.94^{cd}	3.60
Berry jam	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}	7.77^{fgh}	5.95^{h}	9.11^{efgh}	5.70^{h}	8.19^{fgh}	12.58^{e}	9.66^{efg}	6.70^{gh}	28.66^{a}	11.17^{ef}	18.07^{d}	21.10^{cd}	20.72^{d}	0.00^{i}	24.45^{bc}	27.01^{ab}	29.68^{a}	3.54
Blackberry	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	10.12^{d}	8.47^{de}	8.48^{de}	6.44^{ef}	17.87^{abc}	18.71^{ab}	14.56^{c}	16.38^{bc}	4.69^{fg}	14.74^{c}	2.44^{gh}	5.33^{efg}	14.64^{c}	0.00^{h}	17.53^{abc}	15.43^{bc}	20.09^{a}	3.53
Prune	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	3.09^{bc}	2.91^{c}	4.38^{d}	15.85^{a}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{b}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	2.06^{c}	0.00^{d}	0.00^{d}	1.32
VEGETATIVE	18.55^{bc}	25.12^{a}	20.54^{bc}	22.13^{ab}	18.42^{bc}	5.43^{h}	7.89^{def}	5.47^{fg}	2.30^{gh}	11.20^{de}	17.75^{c}	10.24^{de}	12.08^{d}	1.08^{h}	1.60^{gh}	21.47^{abc}	1.66^{gh}	1.66h^{g}	7.07^{ef}	0.22^{h}	1.28^{gh}	1.06^{h}	4.21
Olive	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	4.18^{cd}	11.49^{b}	4.60^{c}	3.72^{cde}	0.36^{f}	1.30^{def}	21.85^{a}	0.50^{f}	0.92^{ef}	0.00^{f}	0.00^{f}	5.27^{c}	0.00^{f}	3.08
WOODY	26.52^{f}	27.19^{f}	31.65^{de}	29.50^{ef}	26.22^{f}	29.51^{ef}	34.36^{cd}	38.33^{b}	44.06^{a}	35.38^{bc}	16.75^{g}	32.34^{cde}	43.70^{a}	4.03^{jk}	19.70^{g}	2.98^{jk}	3.69^{jk}	12.92^{h}	4.98^{ij}	8.36^{i}	3.34^{jk}	0.84^{k}	3.70
Planky	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	3.02^{d}	0.99^{ef}	1.44^{e}	10.49^{a}	1.23^{ef}	4.40^{c}	0.67^{ef}	1.06^{ef}	7.42^{b}	0.00^{f}	0.00^{f}	0.00^{f}	0.44^{ef}	1.36
Coffee	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	8.65^{b}	16.87^{a}	10.11^{b}	15.55^{a}	5.56^{c}	1.16^{ef}	3.92^{cd}	2.49^{de}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.69^{f}	0.43^{f}	0.00^{f}	1.65
High roast	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	11.20^{e}	14.07^{d}	15.28^{d}	18.97^{c}	21.84^{b}	7.69^{f}	20.71^{bc}	28.06^{a}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	2.31^{g}	0.46^{gh}	0.00^{h}	1.36
SWEET ASS.	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	6.64^{a}	0.14^{c}	0.77^{bc}	1.48^{b}	0.28^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.91
Honey	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	4.30^{a}	0.43^{c}	0.50^{c}	1.38^{b}	0.45^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.68
SPICY	4.44^{e}	4.92^{de}	5.56^{de}	7.28^{bc}	4.32^{e}	2.63^{f}	8.37^{b}	6.03^{cd}	18.00^{a}	1.48^{fg}	0.09^{gh}	1.42^{fgh}	7.13^{bc}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.13^{gh}	0.20^{gh}	0.11^{gh}	0.00^{h}	1.48
Mixed Spice	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	1.05^{d}	3.31^{c}	3.66^{c}	13.69^{a}	0.79^{def}	0.00^{f}	0.92^{de}	6.07^{b}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.13^{ef}	0.10^{ef}	0.00^{f}	0.86

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg**;** **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge. **Sweet red wine samples**: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

Table 9 Basic taste and mouthfeel attributes of the selected wines and the four Controls samples. LSD = Least significant difference. Samples with a different superscript in the same row differ significantly at the 5% level of significance.

Sensory descriptor	Samples																						
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	Ctr1	Ctr2	Ctr3	Ctr4	LSD (p=0.05)
SWEET	13.34^{lm}	16.07^{l}	14.46^{lm}	12.82^{m}	14.94^{lm}	25.34^{hi}	27.75^{ghi}	25.31^{hi}	28.14^{gh}	21.24^{k}	19.81^{k}	24.87^{ji}	21.66^{k}	66.31^{b}	52.13^{e}	71.52^{a}	63.33^{c}	55.71^{d}	22.22^{jk}	33.31^{f}	30.67^{fg}	28.98^{g}	2.93
SOUR	8.23^{h}	9.98^{efgh}	8.30^{h}	8.77^{gh}	9.19^{gh}	12.78^{cd}	9.88^{efgh}	11.79^{cde}	9.35^{fgh}	13.39^{bc}	15.40^{b}	11.51^{cfde}	13.41^{bc}	3.94^{i}	9.37^{fgh}	8.63^{gh}	2.20^{i}	8.43^{gh}	7.75^{h}	9.16^{gh}	10.68^{defg}	26.14^{a}	2.29
ASTRINGENT	23.81^{cd}	21.44^{de}	25.30^{bc}	25.31^{bc}	22.25^{d}	29.87^{a}	27.74^{ab}	26.92^{b}	27.37^{ab}	23.28^{cd}	19.25^{ef}	21.88^{de}	25.98^{bc}	3.94^{i}	12.55^{h}	2.91^{i}	2.07^{i}	11.91^{h}	16.34^{g}	21.49^{de}	15.96^{g}	18.51^{fg}	2.88
BITTER	2.83^{cde}	2.76^{de}	3.71^{bcd}	4.33^{b}	3.87^{bc}	1.66^{fg}	1.66^{fg}	1.58^{fgh}	1.58^{fgh}	0.19^{j}	0.00^{j}	0.28^{j}	0.38^{ij}	0.71^{ghij}	4.24^{b}	0.57^{hij}	0.66^{ghij}	1.99^{ef}	1.44^{fghi}	0.39^{ij}	0.09i	7.23^{a}	1.08

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge. **Sweet red wine samples**: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

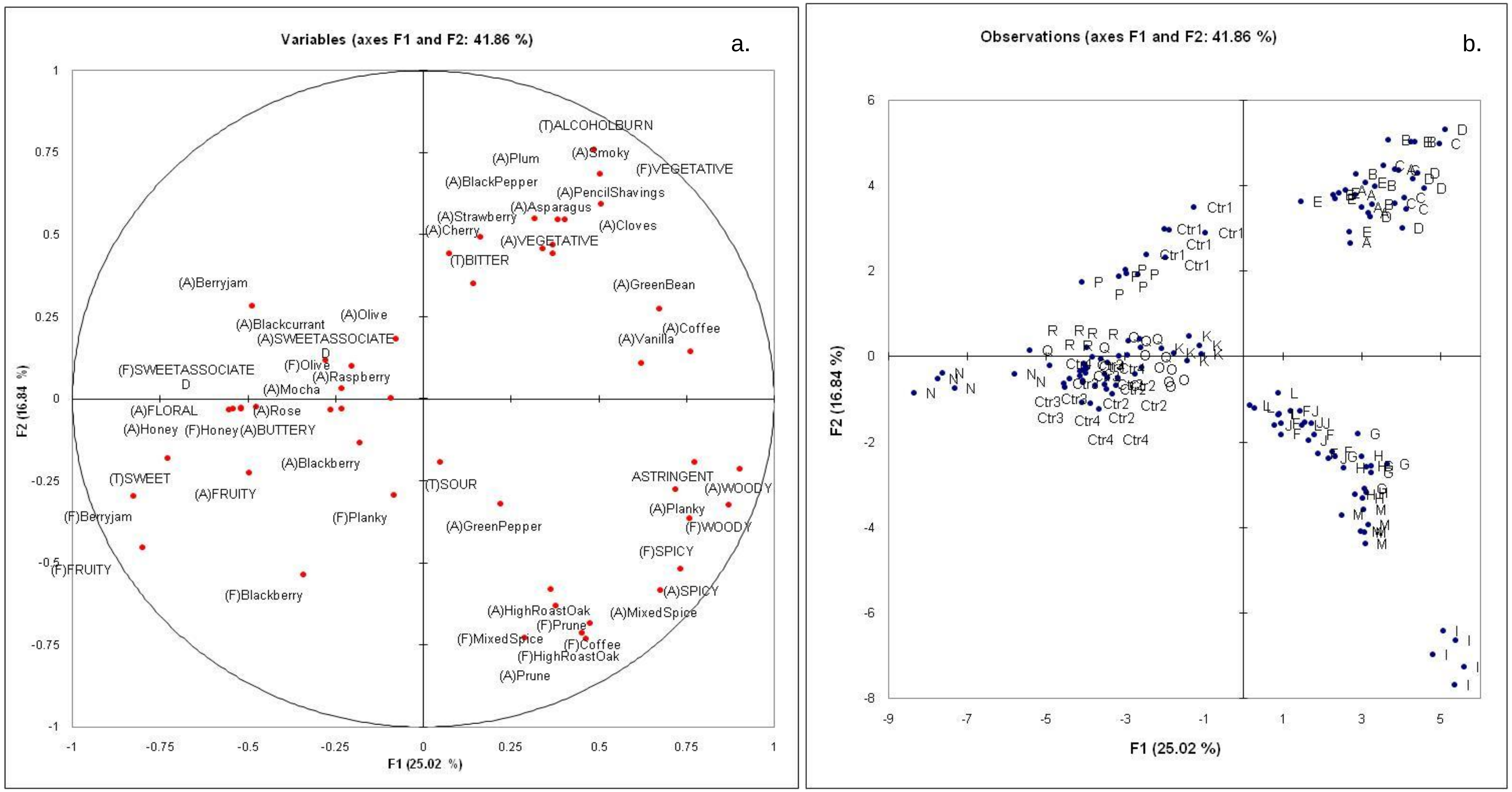

Figure 7 Principle Component Analysis loadings (a) and scores (b) plots for Groups 1 to 4. Samples are indicated as the scores and sensory attributes as loadings. The first two principal components (F1 & F2) explain 41.86 % of the variance. Except for Astringency, the letters 'A', 'F' and 'T' in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively. 18 wines indicated as A to R, control sample for Groups 1 to 4 as 1, 2, 3 and 4, respectively.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz ;**E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

3.3 Association between chemical and sensory attributes of full set of wines

The chemical and sensory profile for the dry red wine samples (Sample A-M) were investigated by using the odour activity values (OAV) and the odour threshold values (OTH) as seen in Table 10. It is important to note that Table 10 only contains data for the dry red wines. The values obtained for the sweeter samples (Samples N-R) were not included when calculating the range and average values as they have not been established. Using literature references, a list of sensory descriptors associating with the respective chemical compounds were compiled (Table 11).

Table 10 depicts the chemical compounds, their odour detection thresholds (OTH) and their odour activity values (OAV) as obtained for the dry red wine sample used in this study. The OAV's in Table 10 were calculated on the basis of their concentration in studied wines and the mentioned odour threshold values. OTH corresponds to the minimum concentration level where 50% of sensory tasters are no longer able to detect a sensory descriptor (Vilanova *et al*., 2010). These values were obtained from literature (See Table 10 for references).

The contribution of a volatile compound to a wine's aroma is estimated from its odour activity value (OAV). OAV is thus a measure of importance of a specific compound to the odour of a sample, especially of the OAV value is more than 1 (Gómez-Míguez *et al*., 2007). From Table 10 it is observed that not all the compounds surpassed the detection threshold and subsequently have OAV values below 1. Compounds with OAV's of less than 1 will not likely have an effect on the global wine aroma as detected by the human nose, as the concentration it was found at, is below the odour threshold value. However, it has been shown that with OAV's of less than 1 there is a possibility of playing a role due to synergistic effects (Gil *et al*., 2006).

Table 11 indicates the sensory descriptors usually associated with specific compounds, as indicated by literature. The compounds with OAV's of more than 1 are indicated in bold and the respective sensory attributes will most probably be detected positively by the human nose.

According to the information captured in Tables 10 and 11, as well as in Figure 8, the following is apparent: with regard to Figure 8, four distinct groups of red wine samples are decerned. It seems that most of the red blends are grouped in the upper left quadrant and are driven by the presence of alcohols and esters, and by the woody sensory descriptors such as *high roast oak, coffee* and *mixed spice*. The red cultivars are mostly associated in the bottom left quadrant and driven by fatty acids and esters and the vegetative sensory descriptors such as *green bean* and *asparagus*. The sweet red blends are all grouped on the right side, with the sweetest samples lying in the upper right quadrant, closely grouped with the acids, most likely because of the balancing effect it has with regard to the sugar content and the sensory perception thereof (Nurgel *et al*., 2004). Sensory descriptors associating in this quadrant are mainly the *sweet associated* and *floral* descriptors like; *honey* and *rose*, which are typical sweet wine descriptors. The less sweet samples are found in the bottom left quadrant. Few chemical, as well as sensory descriptors are found in this quadrant and wines are likely to be less complex. Both wines in this quadrant, Sample P and Q, did not have a complex sensory profile except for the distinct presence of an *olive* aroma in Sample P (Lawless, 1999).

Table 10 Odour threshold values (OTH) obtained from literature, concentration ranges, and averages (mg/L) determined in the study, as well as the calculated Odour Activity Values (OAV). Values indicated are only for dry red wine samples used in the study, this includes Samples A – M as well as control sample.

Analyte	OTH[a]	Range	Average	OAV[b]
Methanol	668.00[(2)]	162.62 - 315.03	255.85	0
Propanol	306.00[(1)]	31.52 – 78.64	57.78	0
Butanol	150.00[(2)]	2.06 – 2.53	2.30	0
Isobutanol	40.00[(2)]	40.98 – 69.56	59.09	1
Isoamyl alcohol	30.00[(1)]	193.30 – 403.08	303.84	10
Hexanol	8.00[(1)]	1.54 – 2.72	1.92	0
2-Phenylethanol	14.00[(5)]	1.08 – 1.27	1.43	0
Ethyl acetate	12.26[(1)]	74.51 -137.35	104.66	9
Ethyl butyrate	0.02[(1)]	0.47 – 0.68	0.53	23
Isoamyl acetate	0.03[(3)]	0.43 – 1.17	0.78	27
Ethyl hexanoate	0.01[(3)]	0.57 – 0.72	0.68	48
Ethyl lactate	154.60[(4)]	158.52 – 345.52	251.67	2
Diethyl succinate	200.00[(2)]	8.87 – 21.22	15.53	0
2-Phenylethyl acetate	0.25[(1)]	0.04 – 0.61	0.55	2
Ethyl decanoate	0.20[(2)]	0.07 – 0.17	0.13	1
Ethyl octanoate	0.01[(2)]	0.02 – 0.16	0.09	18
Acetic acid	200.00[(1)]	535.95 – 926.14	759.45	4
Propionic acid	20.00	10.71 – 29.75	18.52	1
Isobutyric acid	2.30[(2)]	1.48 – 2.44	1.97	1
Butyric acid	0.17[(2)]	1.01 – 2.12	1.62	9
Isovaleric acid	0.03[(3)]	1.64 – 1.93	3.24	98
Valeric acid	-	0.66 – 1.27	1.07	-
Hexanoic acid	0.42[(2)]	1.54 – 1.77	2.10	5
Octanoic acid	0.50[(3)]	2.26 – 2.73	2.93	6
Decanoic acid	1.00[(2)]	0.91 – 1.87	1.28	2

[a]OTH, odour threshold. The numbers in parentheses refer to the literature source. [b]Odour activity value
[1](Guth, 1997), [2](Etièvant, 1991), [3](Ferreira *et al*., 2000), [4](Tominaga *et al*., 1998), [5](Santos *et al*., 2004).

Table 11 Odour descriptions as found in literature for the measured chemical compounds. Compounds in bold had a positive contribution to the global wine aroma with regard to the OAV.

Analyte	Aroma descriptor
ALCOHOLS	
Propanol	Ripe fruit, alcohol[2, 4]
Butanol	Medicinal, phenolic, alcohol, fusel[4, 6]
Isobutanol	**Oily, bitter, green, fresh, fusel, alcohol**[2, 3, 4, 5]
Isoamyl alcohol	**Sweet, fusel, bitter, harsh**[1, 3]
Hexanol	Flowers, green, cut grass, dry, toasted, vegetable[3]
2-Phenylethanol	Roses, sweetish[2, 6]
ESTERS	
Ethyl acetate	Fruity, solvent[2, 4, 5]
Ethyl butyrate	**Fruity, papaya, butter, sweetish, acid fruit, strawberry**[1, 2, 4, 5, 6]
Isoamyl acetate	**Banana**[2, 4, 5]
Ethyl hexanoate	**Green apple, fruity, sweetish, anise, strawberry**[1, 2, 3, 5, 6]
Ethyl lactate	**Acid, medicine, milky, lactic, strawberry, raspberry** [2,4, 5, 6]
2-Phenylethyl acetate	**Floral, rose, honey, tobacco**[3, 4, 6]
Ethyl decanoate	**Fruity, pleasant, soapy**[2, 5]
Ethyl octanoate	**Sweet, fruity, fresh, soapy**[1, 2, 5]
FATTY ACIDS	
Acetic acid	**Sour, pungent, vinegar, spicy**[1, 3, 4]
Propionic acid	**Pungent, rancid, soy**[4]
Isobutyric acid	**Rancid, butter, cheese, fatty, acid, phenolic** [1, 2, 4, 5]
Butyric acid	**Rancid, cheese, sweat, spicy**[1, 2, 3, 4, 5, 6]
Isovaleric acid	**Sweet, acid, rancid, fatty, blue cheese, spicy**[1, 2, 3, 4, 5]
Hexanoic acid	**Green, sweat, cheese, geranium, vegetable**[2, 4, 5, 6]
Octanoic acid	**Sweat, cheese, fatty, unpleasant, rancid, harsh**[1, 2, 4, 5, 6]
Decanoic acid	**Rancid, fat, soap**[2, 4, 5, 6]

[1](Aznar *et al*., 2001), [2](Gil *et al*., 2006), [3](Gómez-Míguez *et al*., 2007), [4](Sánchez-Palomo *et al*., 2010), [5](Santos *et al*., 2004), [6](Vilanova *et al*., 2010)

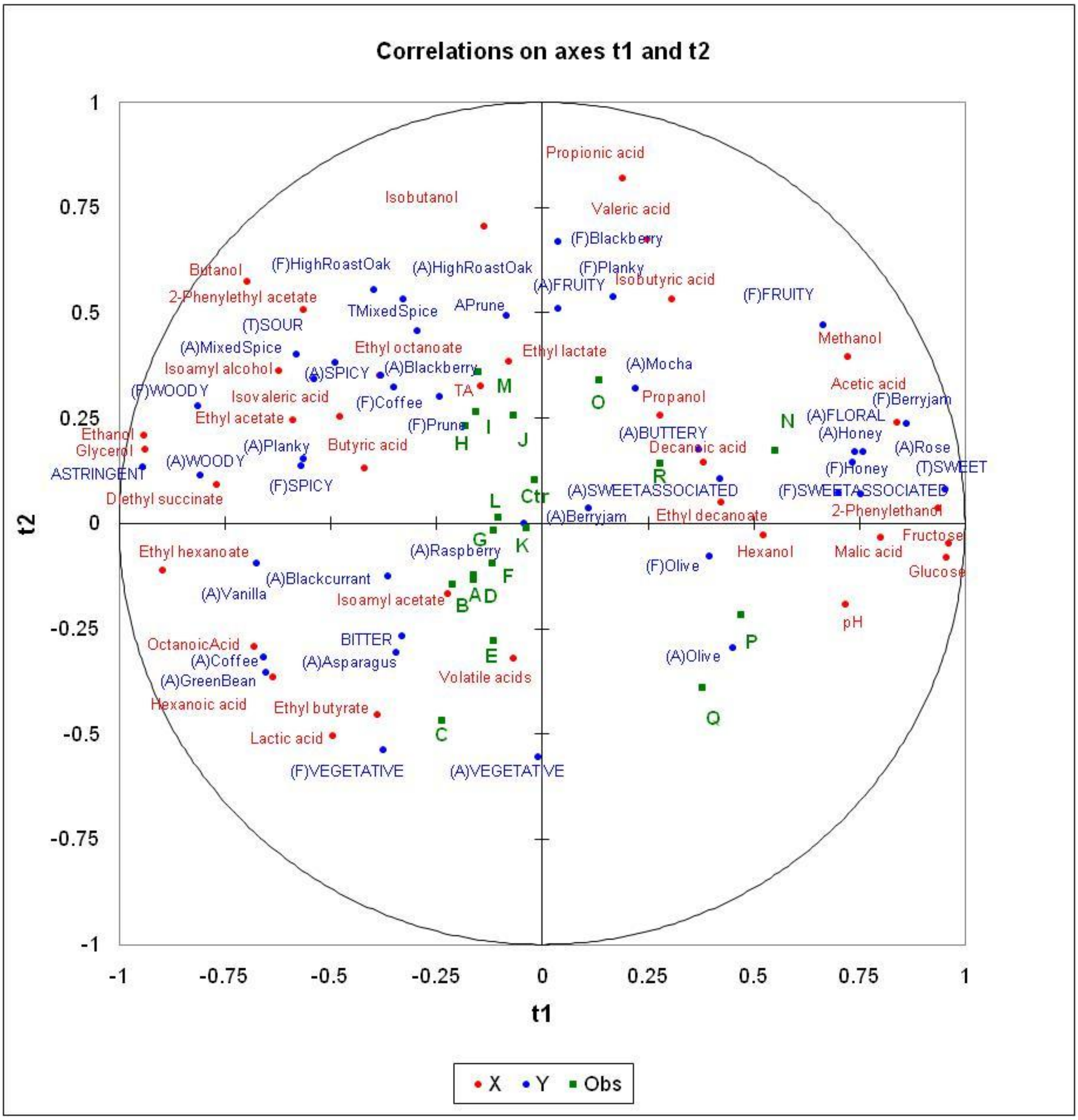

Figure 8 Partial Least Squares plot indicating the position of the sensory attributes (indicated in blue) in relation to the wines studied (capital letters) and the chemical compounds (indicated in red). Except for Astringency, the letters 'A', 'F' and 'T' in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively. 18 wines indicated as A to R, control sample is indicated as Ctr.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-NederburgPinotage; **D**-Nederburg Shiraz ;**E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**(Ctr1-4)-Tassenberg.

3.4 Consumer profiling of sub-set of wines

3.4.1 Relating consumer liking and sensory data

The purpose of this part of the study was to determine the degree of liking of a subset of wines using specifically black consumers from the Western Cape area, South Africa. The subset of wines can be seen in Table 12.

Table 12 Subset of 7 wines analysed by the consumer panel.

Group	Sample	Brandname	Classification
1	B	Nederburg Merlot	Cultivar wine
1	E	Nederburg Baronne	Red blend
2	I	Nederburg Ingenuity Red	Italian red blend
3	K	Namaqua Dry Red	Red blend
4	N	Four Cousins Natural Sweet Red	Natural sweet red blend
4	P	Robertson Winery Natural Sweet Red	Natural sweet red blend
4	O	Cellar Cask Johannisberger Red	Natural sweet red blend

In the consumer analyses the target consumer was asked to evaluate the degree of liking and purchase intent of seven red wines after tasting the respective wines blind. Then the purchase intent of the seven wines was again analysed using a *simulated shelf scenario* in a wine outlet.

Associations between sensory, consumer data and wines were investigated using PLS regression. Figure 9 indicates the consumer degree of liking and purchase intent for the blind tasting and Figure 10 the purchase intent for the informed scenario.

From Figure 9 it is clear that the consumers preferred and would most probably also purchase the sweet red blends (Samples N, O & P) more than they would the drier red wines (Samples B, E, I & K). Sensory descriptors that correlated positively with degree of liking and purchase intent were *fruity* aroma, both orthonasal and retronasal, as well as the secondary descriptor *berry jam*, as well as *sweet taste*. From this it is clear that the black consumer in the Western Cape prefers less complex red blends, i.e. wines with sensory descriptors they can relate to, and most probably that they are accustomed to (Verdú Jover *et al.,* 2004).

In consumer research, the determination of the so-called *ideal point* can supply vital information to a wine marketer. Although the sweeter wine samples, i.e. Samples N (7.36), O (7.22) and P (7.20) were highly liked and were preferred over and above ($p \leq 0.05$) the four dry samples Samples B (5.48), E (5.44), I (5.38), and K (5.48), the sweeter wine samples were not significantly correlated to the tested *concept of consumer degree of liking*. Although the *ideal point* was not tested, it could be possible that the latter three wines do not fall within the so-called *ideal* *point* area. When measuring *ideal point*, consumers have to indicate the *idealness* of a specific product, if no products are found within the *ideal point area*; one can identify a gap in the market. In view of this, one could argue that in this research project the area around the concept of *degree of liking* could be classified as a potential gap in the market (Jaeger *et al*., 2003). From Figure 9 it is also clear this group of consumers responded less positively to wines with complex sensory descriptors such as *woody* and *spicy,* i.e. sensory attributes associated with the drier red wines.

The results illustrated in Figure 10, i.e. where consumers had to indicate purchase intent when viewing actual photographs of the respective wines, are totally different to that of Figure 9. It is clear that this group of consumers' blind tasting response does not correlate with a so-called *informed choice*. This result was also found by Guinard *et al.* (2001), i.e. that a difference in degree of liking occurred when consumers tasted wine blind versus informed. According to Figure 10 the black consumers from the Western Cape prefer to buy Samples N (Four Cousins Natural Sweet Red) a sweet red blend, as well as B (Nederburg Merlot) and E (Nederburg Baronne) which are both dry premium red wines. It is important to note that in this analysis the wines were only assessed visually and this is therefore the main reason for this change in the results. Consumers make decisions on how a bottle of wine is perceived and the value they ascribe to a specific style or brand of wine (Mueller & Szolnoki, 2010). Samples B, E and N are familiar brands in South Africa and the wine sales of these wines are excellent nationally but to a certain extent also within the black communities (data not shown; Personal communication: D Schmidt, Distell, Stellenbosch, South Africa, 2009). In a study by Ndanga *et al.* (2009) it was indicated that Nederburg Baronne was regarded as *the* favoured red wine of the up-and-coming young black consumer. Samples B and E are cultivar specific premium wines with elegant labels and a perception of value and style. Even though these samples did not score high in the blind tasting session of this project, consumers indicated that they would buy these wines. When purchasing wines, consumers aren't always able to taste wines before purchasing it, and the appearance and perception of a bottle of wine are therefore very important drivers of choice (Murray *et al*., 2001).

3.4.2 Socio-demographics and correlation with preference and purchase intent

In any consumer study, socio-demographic data sourced from the consumer can be studied and correlated with specific variables and this enables the clustering of consumers into different categories or groups according to their different profiles (Geel *et al.,* 2005). In this study gender, age and consumption frequency of wines were obtained from each consumer. In the ANOVA table (Table 13) the significant interactions are indicated in bold. There were positive interactions between consumption and sample, gender and sample, as well as age and sample for most of the consumer concepts tested. These significant interactions were investigated further in the PCA plots (Figures 11 – 13). From Figure 11 it is clear that both male and female preferred the sweet red wine samples; N, O and P. Some segmentation occurred within the sweet samples; it seems that the female consumers prefer Sample P (Robertson Winery Natural Sweet) and O (Cellar Cask

Johannisberger), while the male consumers preferred Sample N (Four Cousins Natural Sweet). Similar results are illustrated in Figure 12. Again the consumers indicated that would rather purchase the sweeter red wines after they tasted the wines blind.

Figure 13 indicates the association between consumption frequency and purchase intent when viewing the photographs of the respective brands. It is important to note that in this analysis the wines weren't tasted and only evaluated on the bottle and label appearance. It was concluded that black consumers who drink wine frequently (more than once a week) were most likely to purchase Samples I (Nederburg Ingenuity), B (Nederburg Merlot) and E (Nederburg Baronne) when purchasing wines in a supermarket or wine outlet, whereas black consumers who drink wine less frequently (less than once a week), prefer to buy Samples N (Four Cousins Natural Sweet) and P (Robertson Winery Natural Sweet). These results indicate different modes of conduct amongst this group of consumers when tasting wines and giving an appraisal of the wines versus looking at the outer package and purchasing a wine for consumption (Guinard *et al*., 2001). When investigating Samples I, B and E (all three are Nederburg wines), it is clear that the label format and bottle shape of these wines could have played a role in the findings, as it could be argued that the label format and bottle shapes is more sophisticated and looks more expensive than the rest of the wine samples. The consumers therefore possibly experienced a perception of value when looking at these wines and are most likely to buy these wines when browsing in a wine outlet. Another explanation could be that they are familiar with the *Nederburg* brand name. According to Figure 13 the black consumers who drink wine less frequently preferred Samples N and P. These two red blends are also well known brands within the South African market, known for *easy drinking* and *affordable price*. It seems that black consumers that don't drink wine often, prefer to buy wines that they are familiar with and can relate to, while consumers that drink wine more frequently, enjoy to experiment with more expensive brands of wine. It seems that the image of the wine plays an important role, possibly even more than actual preference and price. These results are substantiated by the study of Guinard *et al*. (2001), who found that consumer's hedonic ratings changed significantly from the blind to the informed tasting conditions when tasting commercial larger beers.

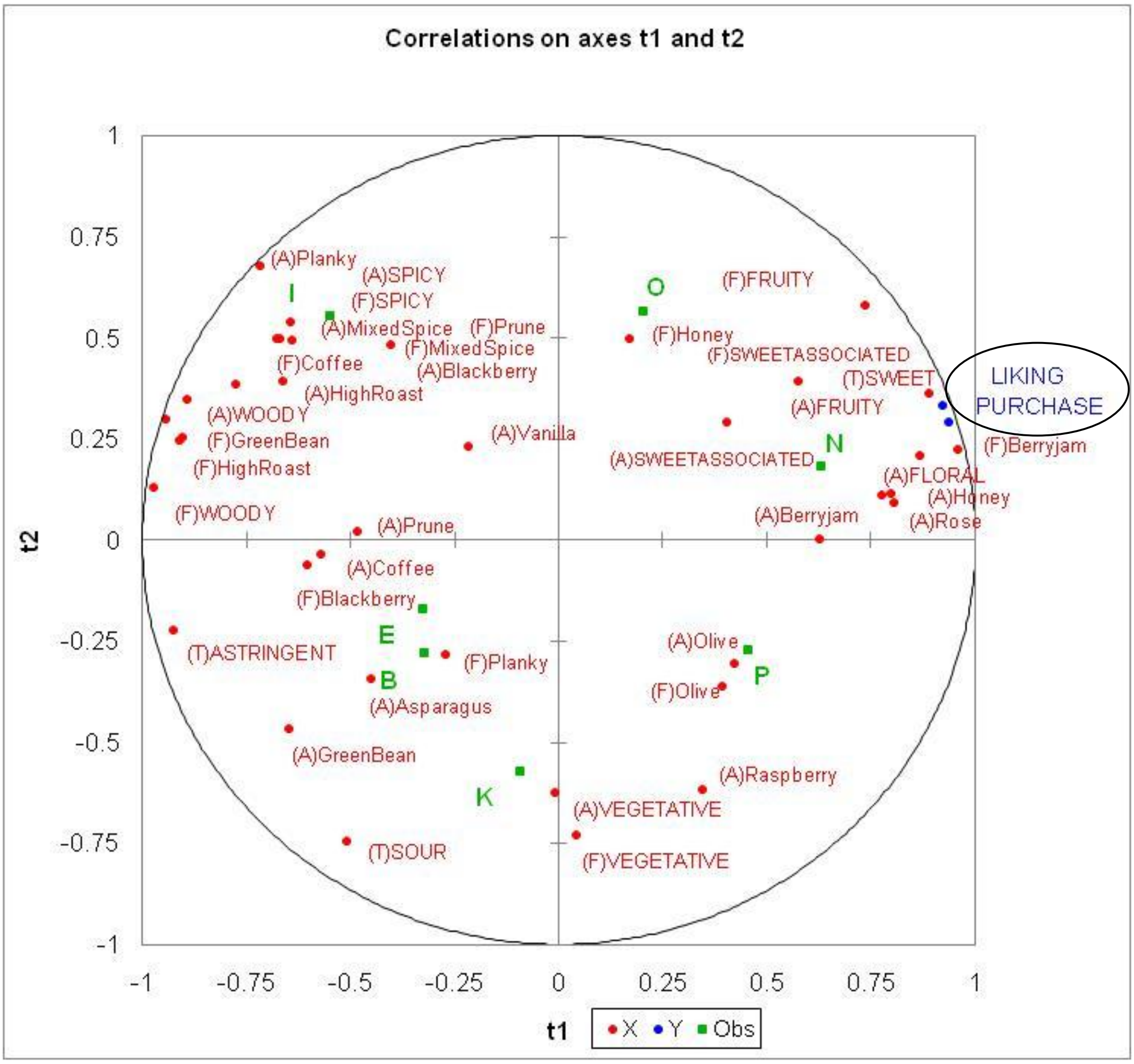

Figure 9 PLS plot indicating the position of the sensory attributes (indicated in red), in relation to the seven red wine samples (capital letters) and the degree of liking and purchase intent (indicated in blue & circled). The map was obtained using partial least squares regression, where the sensory attributes (*X*-space) was regressed onto the consumer data (*Y*-space). t_1 indicates the first component and t_2 the second component. Except for Astringency, the letters 'A', 'F' and 'T' in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively.

Dry red wine samples: **B**-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

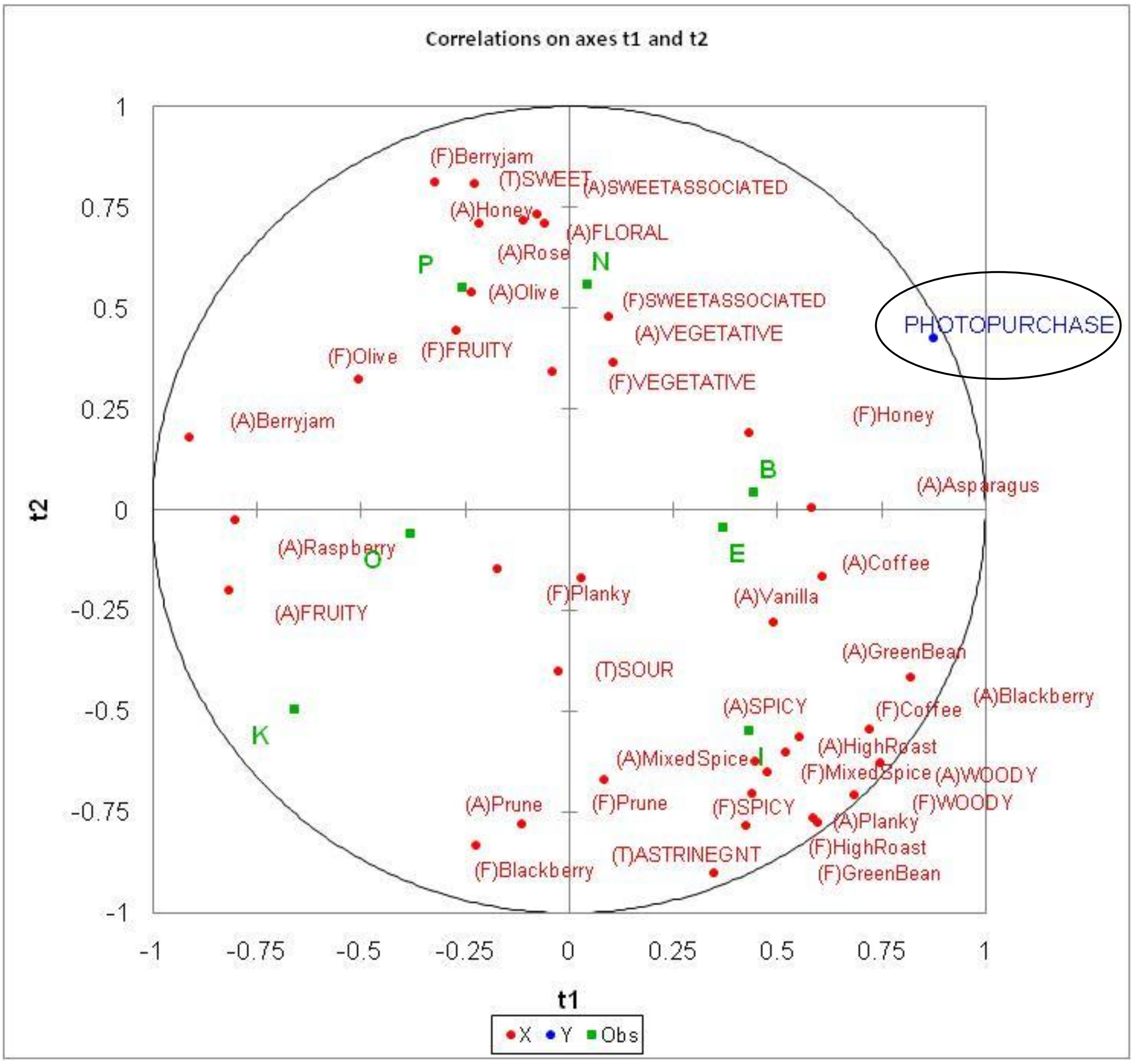

Figure 10 PLS plot indicating the position of the sensory attributes (indicated in red), in relation to the seven red wine samples (green capital letters) and the photo purchase intent (indicated in blue & circled). The map was obtained using partial least squares regression, where the sensory attributes (*X*-space) was regressed onto the consumer data (*Y*-space). t_1 indicates the first component and t_2 the second component. Except for Astringency, the letters 'A', 'F' and 'T' in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively.

Dry red wine samples: **B**-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

Table 13 ANOVA table for liking, purchase intent and photo purchase intent. Significant interactions are indicted in red.

		Liking	Purchase intent	Photo purchase intent
	DF	Pr> F	Pr> F	Pr> F
Gender	1	0.147	0.287	0.061
Age	2	0.465	0.365	0.323
GenderxAge	2	0.012	0.368	0.396
Consumption	1	0.356	0.061	0.001
GenderxConsumpion	1	0.172	0.274	0.593
AgexConsumption	2	0.933	0.922	0.132
GenderxAgexConsumption	2	0.011	0.067	0.112
GenderxAgexConsumption (Judge)	139	<.001	<.001	0.001
Sample	6	<.001	<.001	<.000
GenderxSample	6	**0.001**	**0.011**	**0.008**
AgexSample	12	0.995	0.983	**0.005**
GenderxAgexSample	12	0.896	0.634	0.824
ConsumptionxSample	6	0.597	0.163	**0.012**
GenderxConsumptionxSample	6	0.848	0.818	0.992
AgexConsumptionxSample	12	0.747	0.727	0.068
GenderxAgexConsumptionxSample	12	0.747	0.436	0.212

DF = Degrees of freedom, Pr> F = P-values for degree of liking and purchase intent

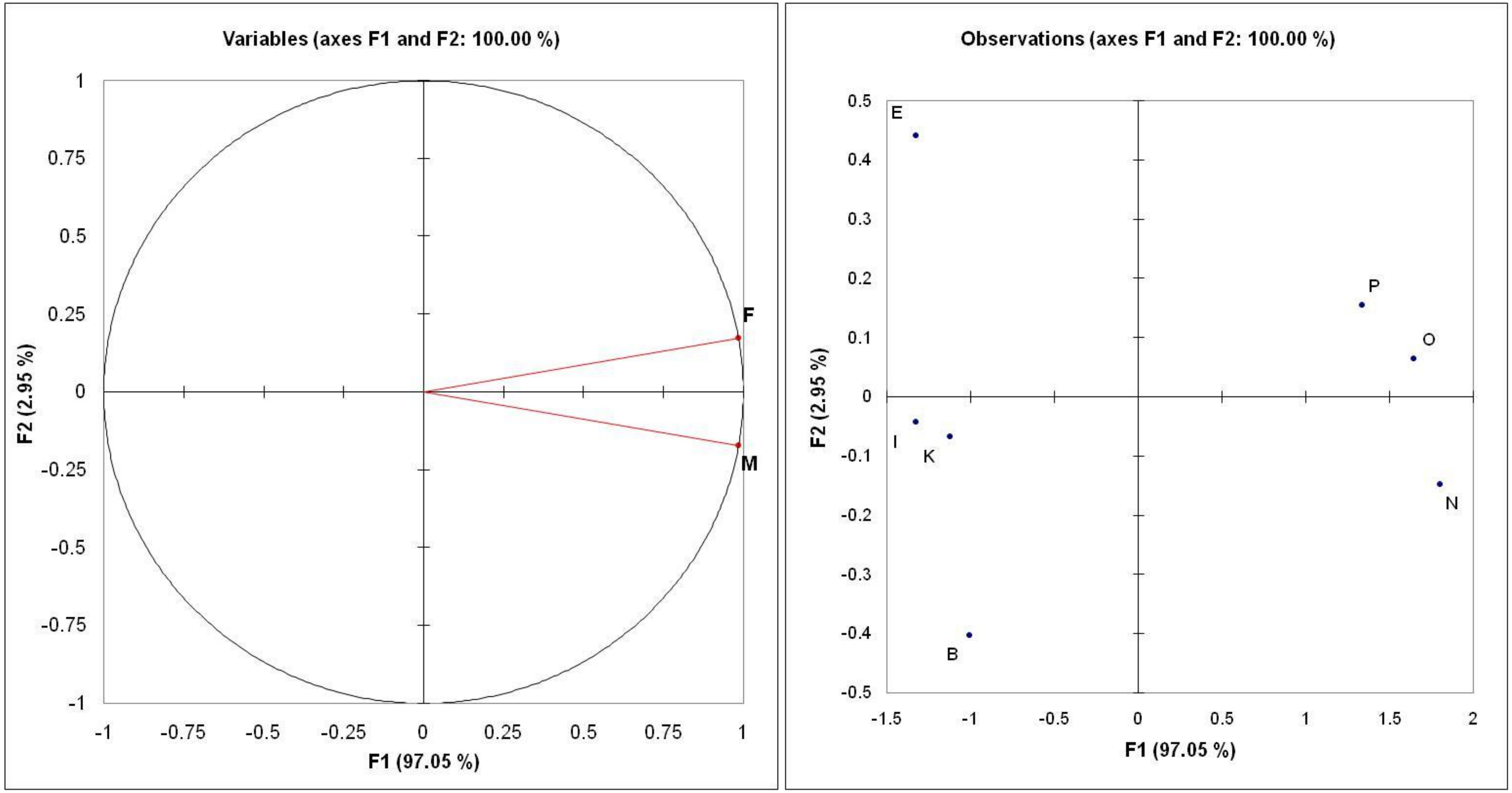

Figure 11 Principal Component Analysis loadings (a) and scores (b) plots for the seven wines samples with regard to degree of liking of the wines during the blind tasting phase. Samples are indicated as the scores and gender (Male or Female) as loadings. The first two principal components (1 & F2) explain 100.00 % of the variance.

Dry red wine samples: **B**-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

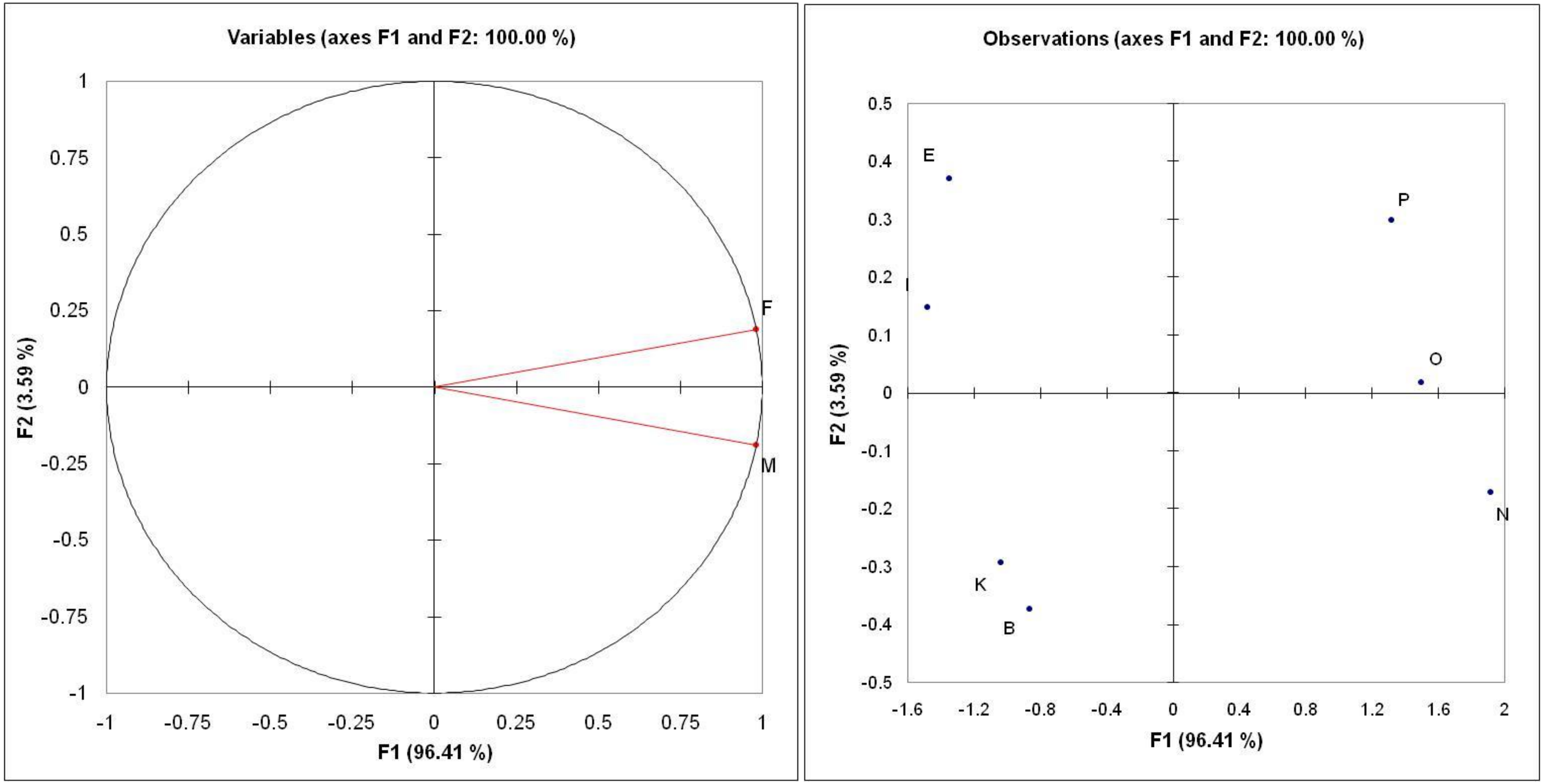

Figure 12 Principal Component Analysis loadings (a) and scores (b) plots for the seven wine samples with regard to purchase intent during the blind tasting phase. Samples are indicated as the scores and gender (male and female) as the loadings. The first two principal components (F1 & F2) explain 100% of the variance (F= Female consumer & M= Male consumer).

Dry red wine samples: **B**-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

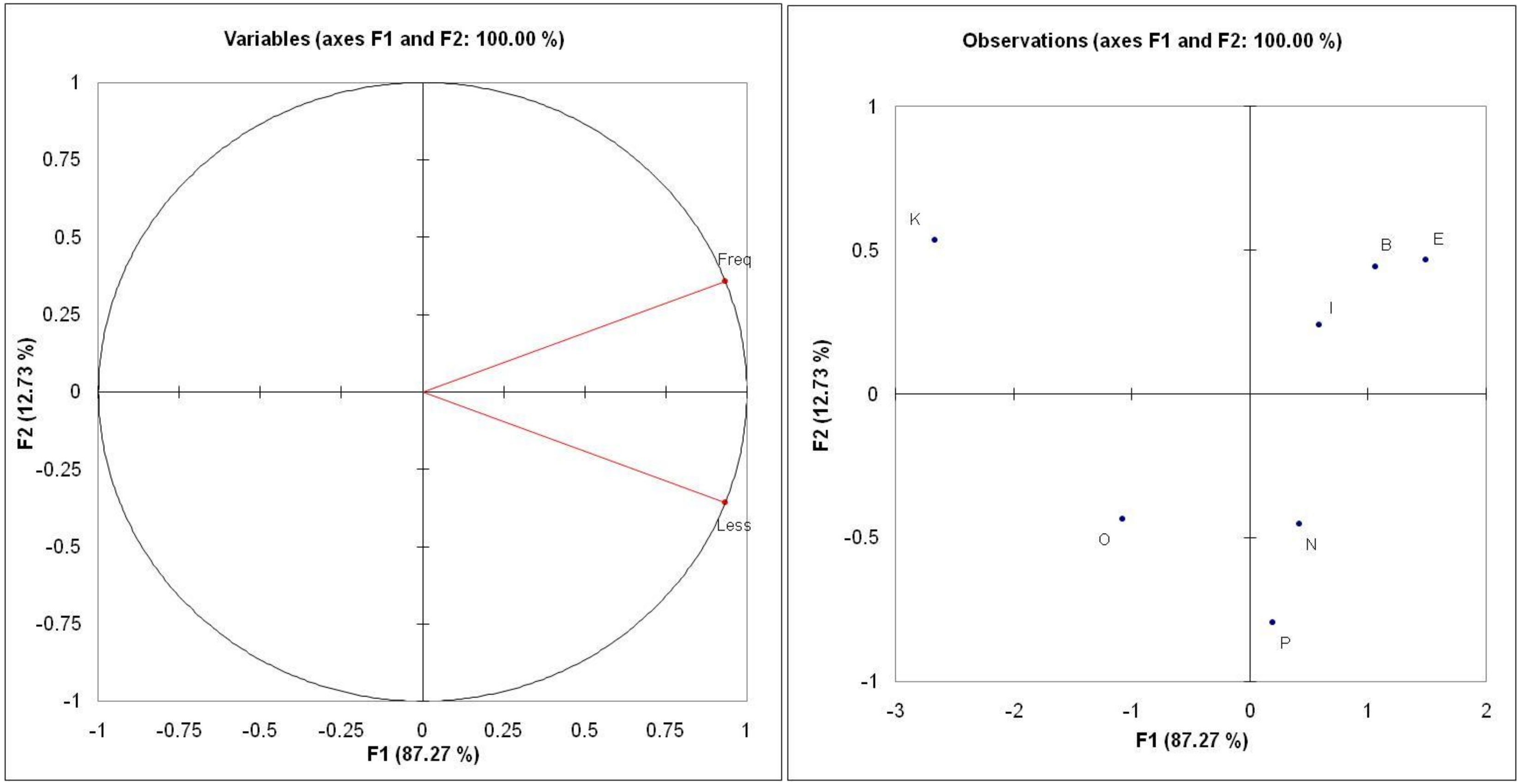

Figure 13 Principal Component Analysis loadings (a) and scores (b) plots for the seven wines with regard to the purchase intent. The consumers evaluated photographs of the seven wines simulating a supermarket shelf scenario for purchase intent. Samples are indicated as the scores and frequency of consumption as loadings. The first two principal components (F1 & F2) explain 100% of the variance (Freq = Consume wine more than once a week; Less = Consume wine less than once a week).

Dry red wine samples: **B**-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

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3.5 Cluster analysis of consumer liking data

The degree of liking results for the total group of consumers have already been discussed (Figure 9), however, market researchers are usually interested to explore sub-segments of consumers within a larger group of consumers (Parpinello *et al.,* 2009). To determine whether the consumers' degree of liking scores of this study would result in different clusters, a clustering technique, discriminant analysis (DA), was applied to the full data set of the degree of liking scores. Figure 14 indicates that there were four clusters, namely:

- Cluster 1: Consumers inclined to *equally favour dry & sweet red wines*
- Cluster 2: Consumers inclined to *strongly favour sweet reds & moderately dry red wines*
- Cluster 3: Consumers inclined to *strongly favour sweet red wines*
- Cluster 4: Consumers inclined to *strongly favour dry red wines*

A PCA was done using the above-mentioned cluster data to see how the respective clusters of consumers associate with the seven wines. According to Figure 15**,** Cluster 4 associates with the four dry red wines, i.e. the two cultivar wines *Nederburg Merlot* and *Nederburg Baronne* and the two dry red blends, *Nederburg Ingenuity* and *Namaqua Dry*. Cluster 1, associates equally strong with both the red dry cultivar wines and the dry red blends, as well as the three sweet red blends, *Four Cousins Natural Sweet, Cellar Cask,* and *Robertson Winery Natural Sweet*. According to Figure 14 two of the clusters, Cluster 2 and 3, representing 62% of the total group of consumers, overlap. This association is also evident in Figure 15 where Cluster 2 (*Strongly favour sweet red wines & Moderately favour dry red wines*) and Cluster 3 (*Strongly favour sweet red wines*) are closely associated.

Further PCA's performed on each of the respective clusters (Figure 16 & 17) revealed that, the consumers of Cluster 1 (Figure 16a) associate equally strong with the dry red and the sweet red wines. The overlap of Clusters 2 and 3 depicted in Figure 14 is evident in the corresponding PCA bi-plots (Figure 16b & Figure 17a), respectively. The latter result indicates that the difference in degree of liking of Clusters 2 and 3 for the respective wines was not considerable. Cluster 4, on the other hand, with a group of 17 consumers prefer the dry red wines, especially the two well-known premium Nederburg wines, *Nederburg Merlot* (Sample B) and *Nederburg Baronne* (Sample E).

It is interesting to note how the association of the wines and degree of liking of Cluster 4 shifted from Figure 15 to Figure 17b. In Figure 15 Cluster 4 is closely associated with Sample I (*Nederburg Ingenuity*) and Sample B (*Nederburg Merlot*), while in Figure 17b Sample I is not strongly associated with Cluster 4. The main reason for this could most propably be the sensory composition of Sample I, which differs quite significantly form all the other samples; Sample I had distinct *spicy* and *prune* characters, which was not prominent in any of the other samples.

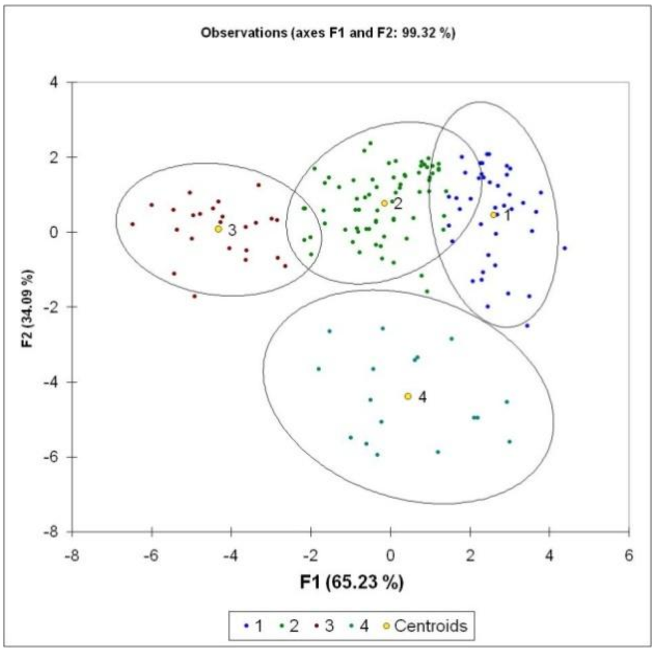

Figure 14 Clustering of consumers based on degree of liking scores of seven red wines using DA (Cluster 1 = Consumers inclined to equally favour *dry* and *sweet red wines* (N=41), Cluster 2 = Consumers inclined to strongly favour *sweet reds* & moderately *dry red wines* (N=69), Cluster 3 = Consumers inclined to strongly favour *sweet red wines* (N=24), Cluster 4= Consumers inclined to strongly favour *dry red* wines (N=17).

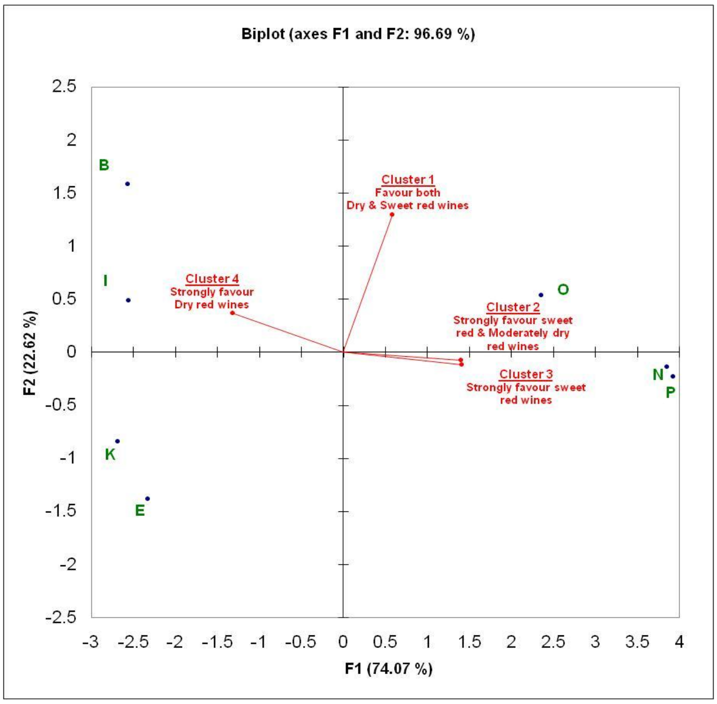

Figure 15 PCA bi-plot of the association of liking scores of the seven wines and four clusters of consumers. The bi-plot explains 96.69% of the variance.

Dry red wine samples: B-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

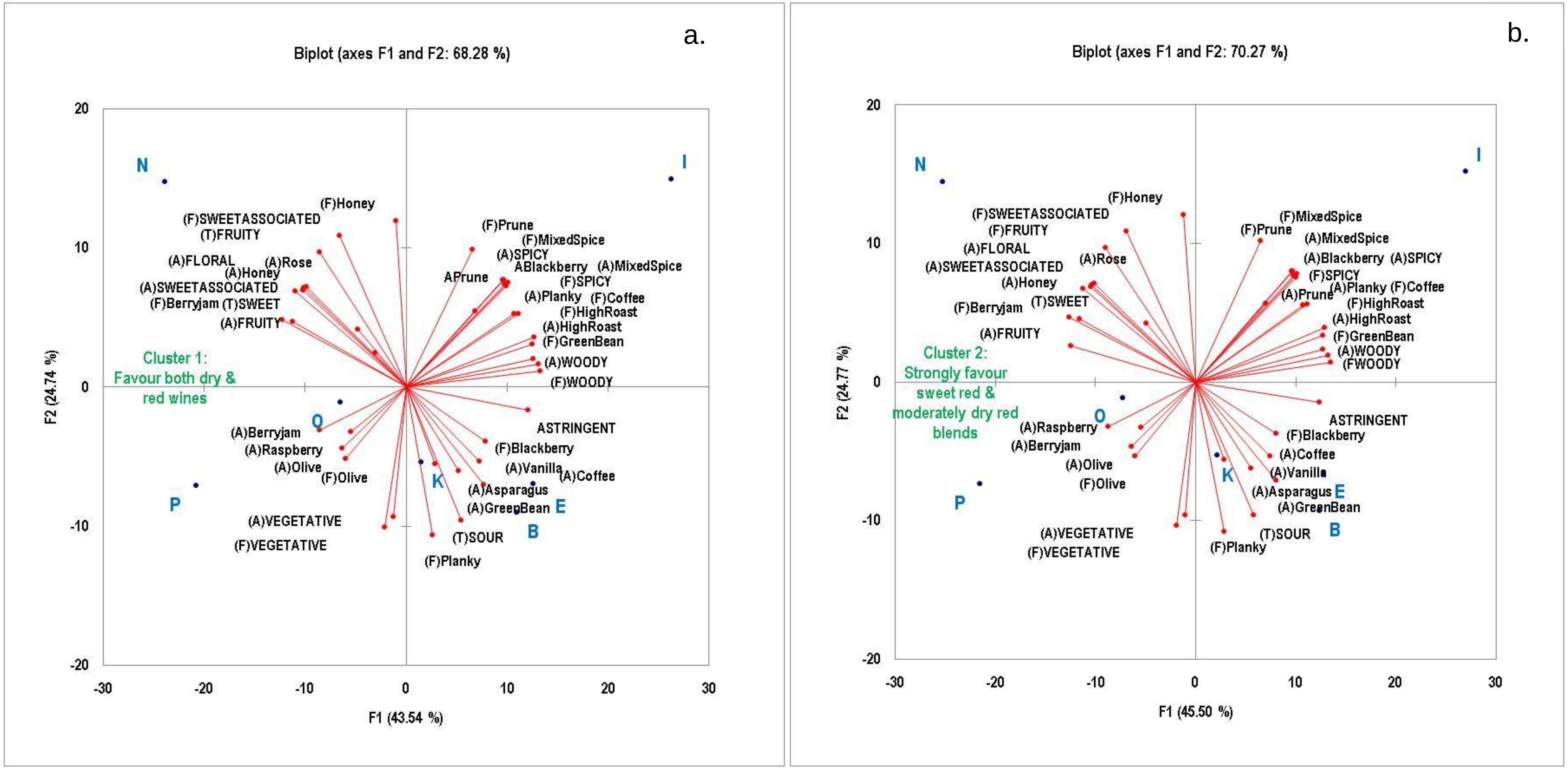

Figure 16 Association between sensory attributes and consumer liking for (a) Cluster 1 (*Favour both dry & sweet red wines)* and (b) Cluster 2 (*Strongly favour sweet wines & moderately dry red wines*). Except for Astringency, the letters ‘A’, ‘F’ and ‘T’ in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively. The PCA bi-plots explain 68.28% and 70.27% of the variance respectively.

Dry red wine samples: B-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

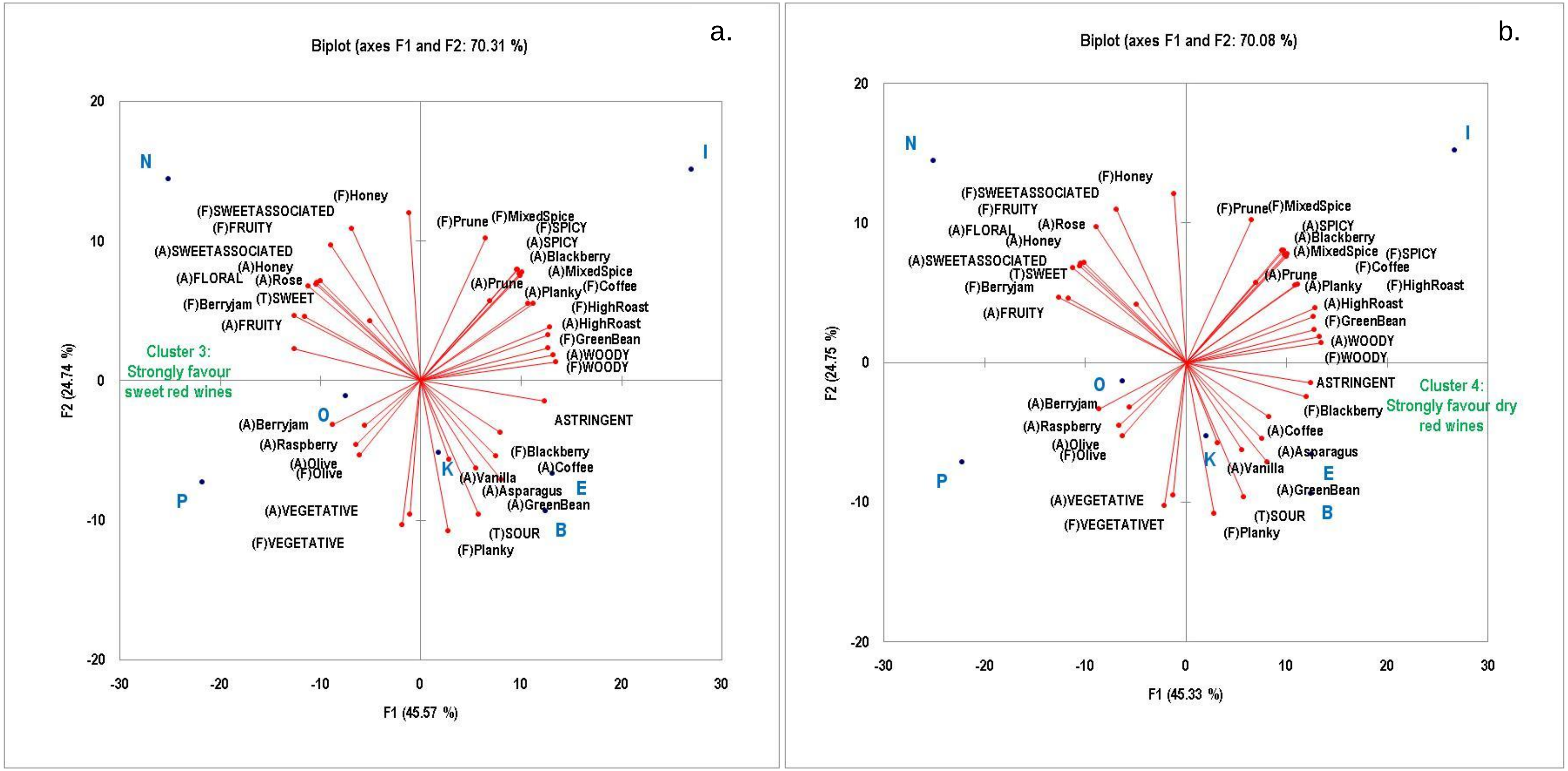

Figure 17 Association between sensory attributes and consumer liking for (a) Cluster 3 (*Strongly favour sweet red wines)* and (b) Cluster 4 (*Strongly favour dry red wines*). Except for Astringency, the letters ‘A’, ‘F’ and ‘T’ in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively. The PCA bi-plots explain 70.31% and 70.08% of the variance, respectively.

Dry red wine samples: B-Nederburg Merlot; **E**-Nederburg Baronne; **I**-Nederburg Ingenuity; **K**-Namaqua Dry.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

3.6 Consumer opinions on red wines in general and wine-related aspects

In research where *sensory attributes* and *degree of liking* of a selection of wines are tested, general opinions on the products and related aspects regarding the products are usually also investigated (Verdú Jover *et al*., 2004; Mueller & Szolnoki, 2010). In this study the group of consumers were probed on their *general opinions* or *perceptions* on the consumption and purchasing of wines and other alcoholic beverages, as well as the factors that drive these opinions (Table 14). These opinions and associated factors were all tested on 9-point category scales as indicated in Table 14 (Green & Srinivasan, 1978). The group of 151 black consumers, all residents of the Western Cape, were sourced to include male and female consumers from two different age groups. ANOVA and PCA were firstly performed on the opinions of total group of consumers, thereafter further ANOVA were performed on the data of the respective clusters, previously indicated in Figure 15.

3.6.1 Opinions of the total group of consumers on consumption and purchasing of red wines and other alcoholic beverages

The ANOVA table (Table 15) illustrates the respective statistical interactions. It is clear that the factors *Age* and *Gender* did indeed play a role in the opinions of the total group of consumers and it could be expected that age and/or gender will promote segmentation.

From Figure 18 it is clear that consumers' opinions differ from each other when questioned about their degree of liking for *red wines, rose wines, semi-sweet white* and *dry white wines* ($p \leq 0.05$). Black consumers residing in the Western Cape clearly favour *red wines* significantly more than the other types of wine, with *white wine* being liked significantly less than the other three types of wine ($p \leq 0.05$). When investigated how consumers' responses differed across gender and age, clear differences were noted in the respective PCA bi-plots (Figure 19). Female consumers indicated that they preferred *rose wines,* while male consumers preferred the *red wines*. Across age a similar division was identified; younger consumers (18 – 23 years) prefer *rose wine*, while it seems that both the other age groups (24 – 29 and 30+) prefer all types of *red wine.*

Figure 20 indicates that, in terms of favouring specific types of red wine, this group of black consumers indicated that they like all types of red wine. Although there were significant differences, the mean scores for the respective red wines ranged from approximately 6 to 7 and these values indicate a preference for red wines. *Shiraz* scored the highest, while no significant difference in preference ($p > 0.05$) was found between *Pinotage, Cabernet Sauvignon, Merlot* and the sweet red wines. Interestingly, this group of consumers favour dry red blends the least, significantly less than *Shiraz*. The fact that this group of consumers favour sweet red blends more than dry blends is contradicting, however, the PCA bi-plots might explain the latter (Figure 21).

Table 14 Range of general opinions influencing the purchase and consumption of wines and other alcoholic beverages.

Opinions and associated factors tested		**Scale used**	**Short title**
Inclination to favour different types of wine	Dry white wine Semi-sweet white wine Rose wine Red wine	1=Dislike extremely 9=Like extremely	Wine types
Inclination to favour different types of red wine	Merlot Shiraz Pinotage Cabernet Sauvignon Dry red blends Natural sweet red blends	1=Dislike extremely 9=Like extremely	Red wine types
Inclination to favour different formats of packaging	750 ml 1.5 L Wine in a box	1=Dislike extremely 9=Like extremely	Volumes
Aspects influencing the purchasing of red wines	Winery Cultivar Alcohol level Label Vintage Origin Awards Price Screw cap as closure Cork as closure	1=Not important 9=Extremely important	Aspects
Appropriate outlets for the purchasing of red wine	Restaurant Supermarket Liquor Store Shebeen Wine farm	1=Not appropriate 9=Extremely appropriate	Places purchased
Occasions influencing the drinking of red wine	Chilling with friends While having a meal While watching TV While watching sports Pre-dinner drinks While in a meeting Entertaining at home after work While *braaing* Celebrating	1=Not appropriate 9=Extremely appropriate	Occasions
Importance of having drinking partners	With my partner With my family With my friends With business colleagues	1=Not important 9=Extremely important	People
Venues influencing the drinking of red wine	At home At a friend's place Tavern / *Shebeen* Bar / Pub Wine farm Night Club	1=Not appropriate 9=Extremely appropriate	Places
Inclination to favour different types of alcoholic beverages	Beer / Stout Ciders Sorghum beer White Spirits Brown Spirits Wine	1=Dislike extremely 9=Like extremely	Beverages

Table 15 ANOVA table illustrating significant interactions (p≤0.05).

		Wine types	Red wine types	Volumes	Aspects	Place purchased	Occasions	People	Places	Beverages
	DF					Pr> F				
Gender	1	0.002	0.587	0.332	0.067	0.316	0.043	0.505	0.116	<.001
Age	2	0.787	0.963	0.386	<.001	0.044	0.010	0.030	<.000	0.004
Gender x Age	2	0.563	0.440	0.323	0.066	0.242	0.078	0.882	0.570	0.865
Consumption	1	0.010	<.001	0.003	0.014	0.283	0.001	0.622	0.709	<.001
Gender x Consump	1	0.846	0.004	0.203	0.150	0.362	0.018	0.621	0.111	0.626
Age x Consump	2	0.025	0.016	0.830	0.002	0.609	0.011	0.008	0.782	0.437
Gender x Age x Consump	2	0.779	0.229	0.082	0.122	0.934	<.018	0.008	0.053	0.838
Gender x Age x Consump (judge)	139	0 .004	<.001	0.025	<.001	<.001	<.001	<.001	<.001	<.001
Question	9	**<.001**	**0.003**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
Gender x Question	9	**<.001**	0.186	0.669	**0.040**	**0.023**	**0.001**	**0.044**	**0.002**	**<.001**
Age x Question	18	0.379	0.674	**0.023**	**0.009**	0.158	**0.001**	**0.019**	**0.004**	**0.001**
Gender x Age x Question	18	0.640	0.156	0.343	0.641	0.405	0.505	0.641	0.814	0.330
Consump x Question	9	0.140	0.034	0.137	0.774	0.065	0.136	0.476	0.004	0.106
Gender x Consump x Question	9	0.218	0.247	0.921	0.250	0.516	0.575	0.771	0.616	0.130
Age x Consump x Question	18	0.173	0.224	0.784	0.704	0.901	0.709	0.095	0.423	0.405
Gender x Age x Consump x Question	18	0.267	0.364	0.195	0.935	0.091	0.938	0.338	0.023	0.883

DF = Degrees of freedom

The young consumers (18-23) and the female consumers associate more with sweet red blends, whereas as the males and older consumers strongly favour *Pinotage* and *Shiraz*, and to a lesser extent *Cabernet Sauvignon*, *Merlot* and *Dry red blends*. From this one can deduct that in the *dry category* the majority of the consumers favour cultivar wines more than the blends, possibly because they are not familiar with the concept of *dry* red blends.

When asked about different packaging formats of red wines, consumers indicated that they favoured the normal *750 mL* wine bottle, significantly more (p≤0.05) than the larger volume of *1.5 L* and even boxed wine (Figure 22). This pattern is also observed in Figure 23, which indicated that all consumers segments, in terms of gender and age, preferred the *750 mL* bottle to a larger degree and boxed wine to a lesser degree.

It is well-known that there are product-specific aspects that drive the consumer's purchasing process (Chaters & Pettigrew, 2007; Grunert, 2007). Figure 24 indicates that *alcohol content*, *label* of the bottle, *vintage*, *price* and *cultivar* are the most important aspects when purchasing red wine, while *awards* and *type of closure* (*screw cap* or *cork*) are regarded as the least important. This result on awards and closures was also found in a large study done on Australian wines and according to Lattey *et al.* (2007) grape variety was of greatest significance when purchasing wines, with medals on the bottle and type of closure being of lesser importance. In another study of Australian wines Mueller *et al.* (2010) found price to be the dominant driver when purchasing wines. With regard to age and gender (Figure 25), is seems that *cultivar* and *vintage* are important to females, while *winery* and *alcohol* content are important to the male consumers. Young consumers between 18 and 23 indicated that *price* is an important aspect when purchasing red wines, while the concept of *cultivar* drives consumers between 24 and 29. The older group of consumers (30+) was influenced by aspects such as *winery*, *vintage*, *label* and *alcohol content* (Guinard *et al*., 2001; Mueller & Szolnoki, 2010).

When consumers were asked about the suitability of different outlets when purchasing red wines (Figure 26); this group indicated that *wine farms* would be the most appropriate place. The latter outlet did not differ significantly ($p>0.05$) from restaurants, and then again restaurants did not differ significantly from *liquor stores* and *supermarkets.* The least appropriate outlet, as indicated by this group of consumers, was a *shebeen.* However, according to Figure 26 it seems that the former four outlets were all regarded as highly important. Furthermore Figure 27 indicates how the scores of males and females differed. Females indicated *restaurants* as appropriate outlets, while males indicated *liquor stores*. Consumers between 18 and 23 indicated *restaurants* as appropriate outlets to purchase wines, while both the older age groups indicated *wine farms* and *supermarkets* as highly suitable outlets.

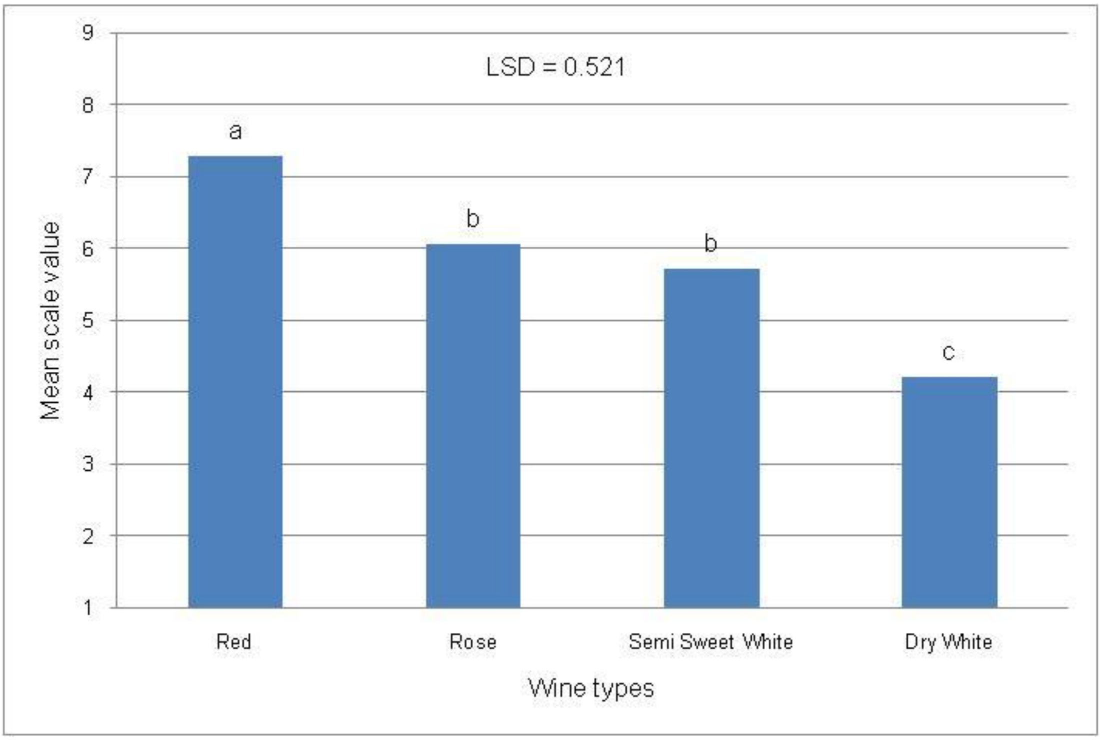

Figure 18 Inclination to favour different wine types. Scores ranged from 1 = *Like extremely* to 9 = *Dislike extremely*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

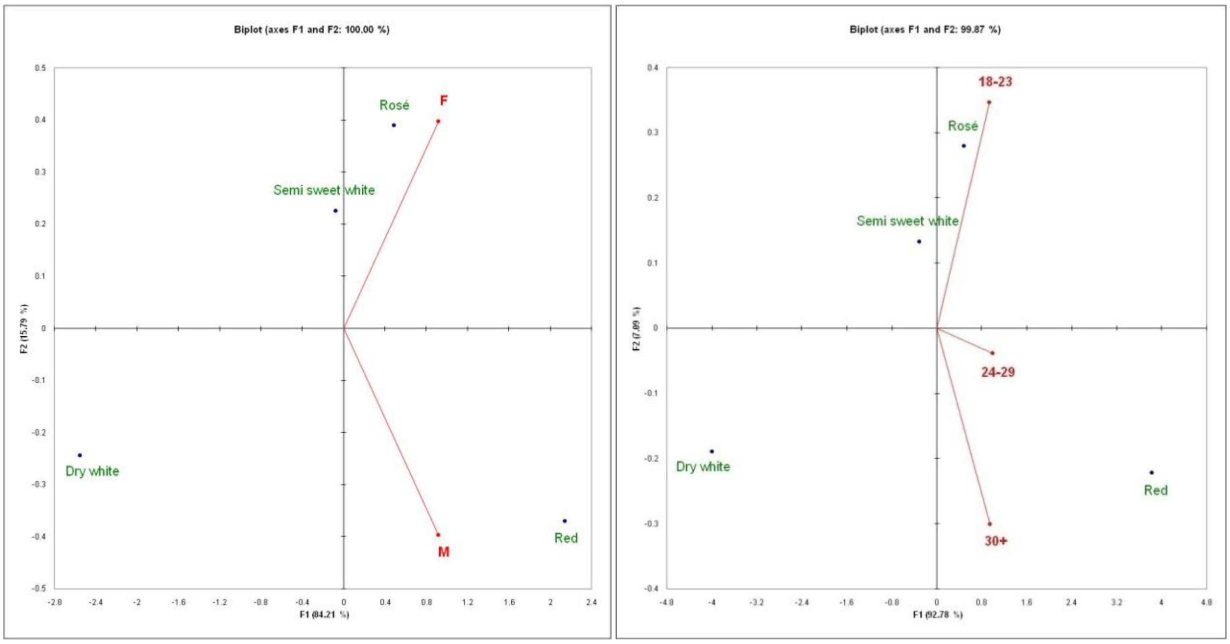

Figure 19 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the inclination to favour different types of wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 99% of the variance, respectively in both plots.

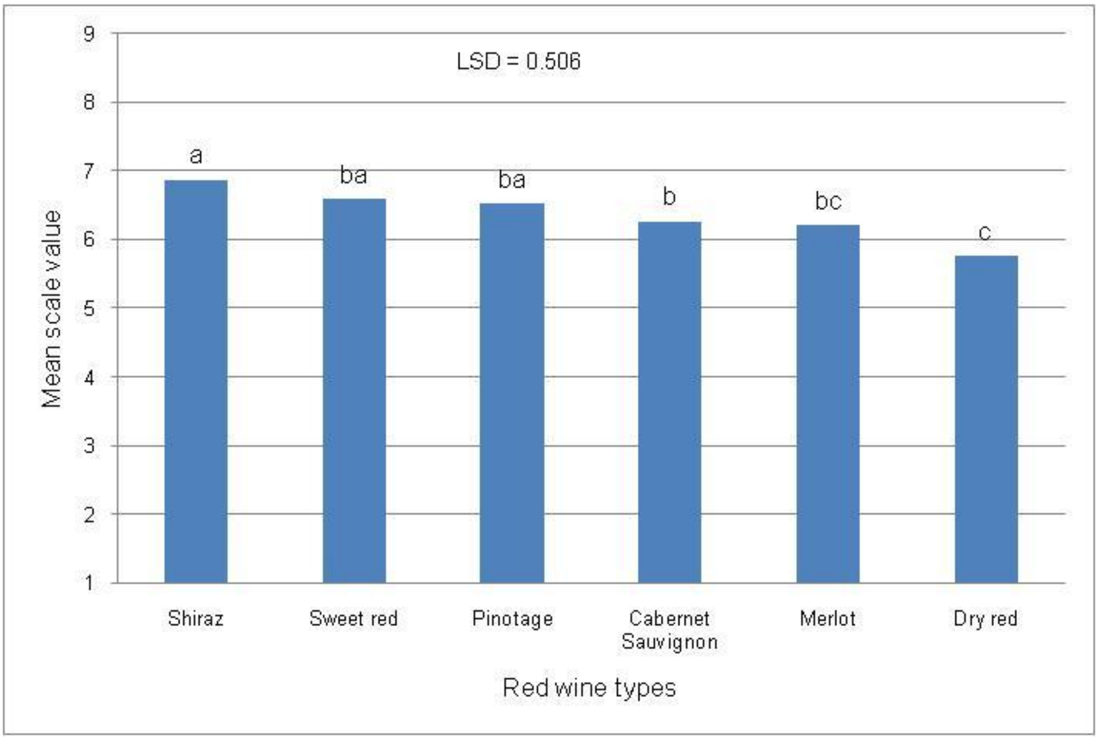

Figure 20 Inclination to favour different types of red wine. Scores ranged from 1 = *Like extremely* to 9 = *Dislike extremely*.LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

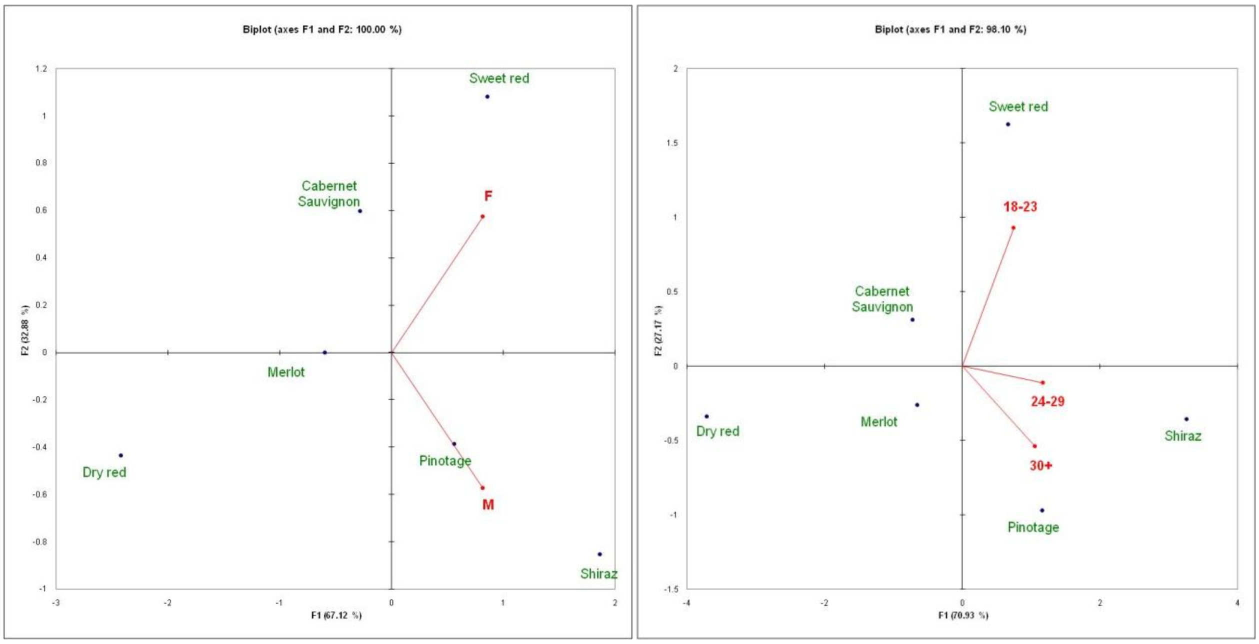

Figure 21 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to inclination to favour different red wine types (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 98% of the variance, respectively in both plots.

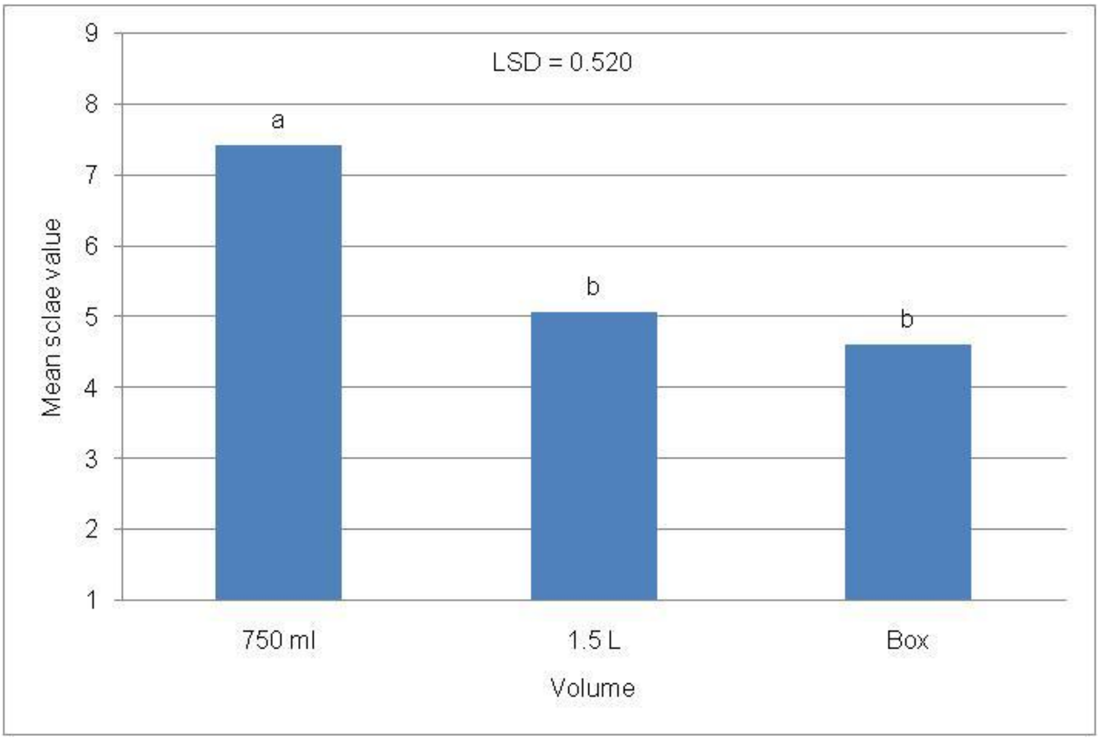

Figure 22 Inclination to favour different formats of wine packaging. Scores ranged from 1 = *Dislike extremely* to 9 = *Like extremely.* LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

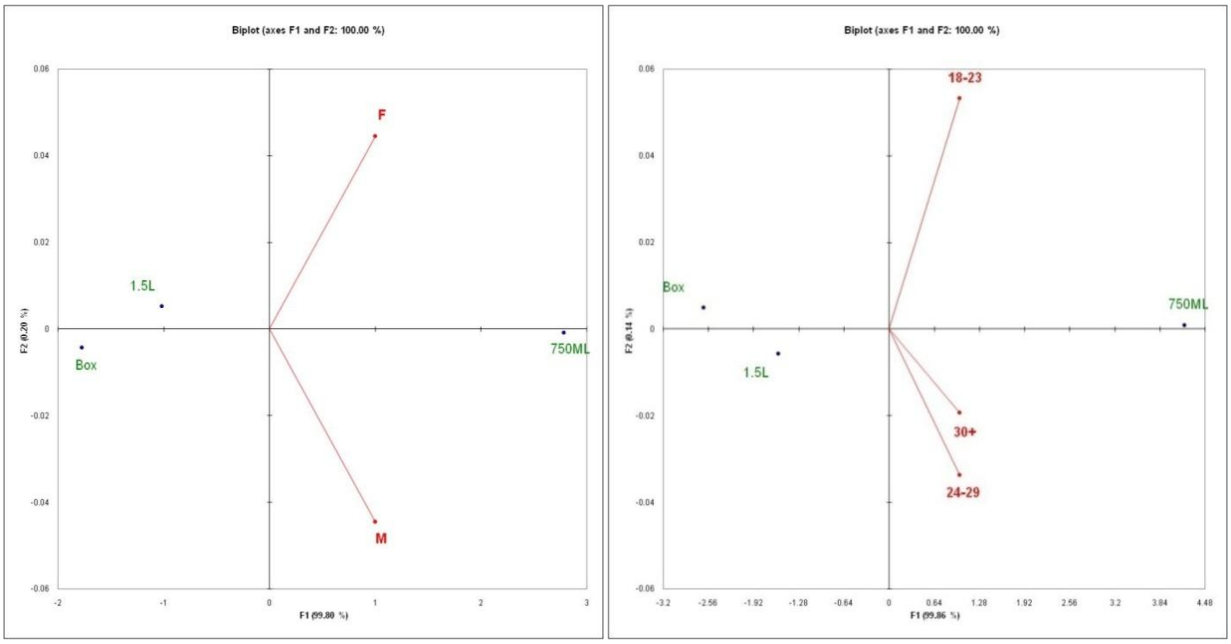

Figure 23 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the different formats of packaging of wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% of the variance, respectively in both plots.

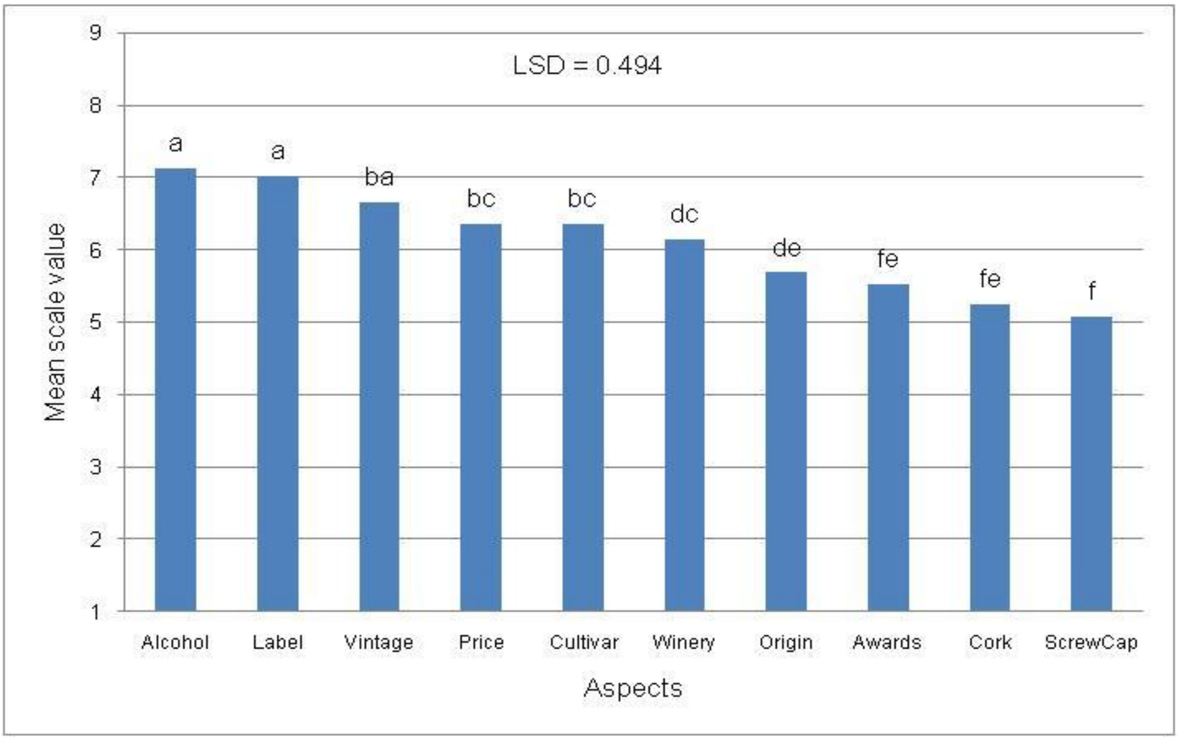

Figure 24 Scores obtained for importance of different aspects when purchasing red wine. Scores ranged from 1 = *Not important* to 9 = *Extremely important*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

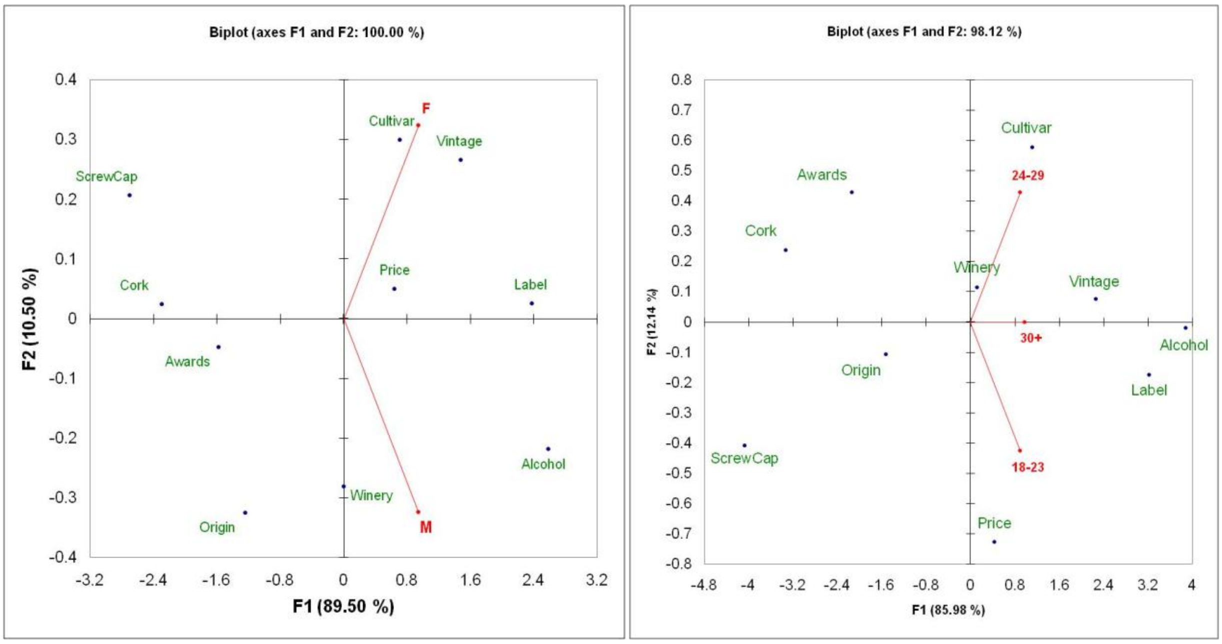

Figure 25 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to different aspects driving the purchasing red wines (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 98.12% of the variance, respectively in both plots.

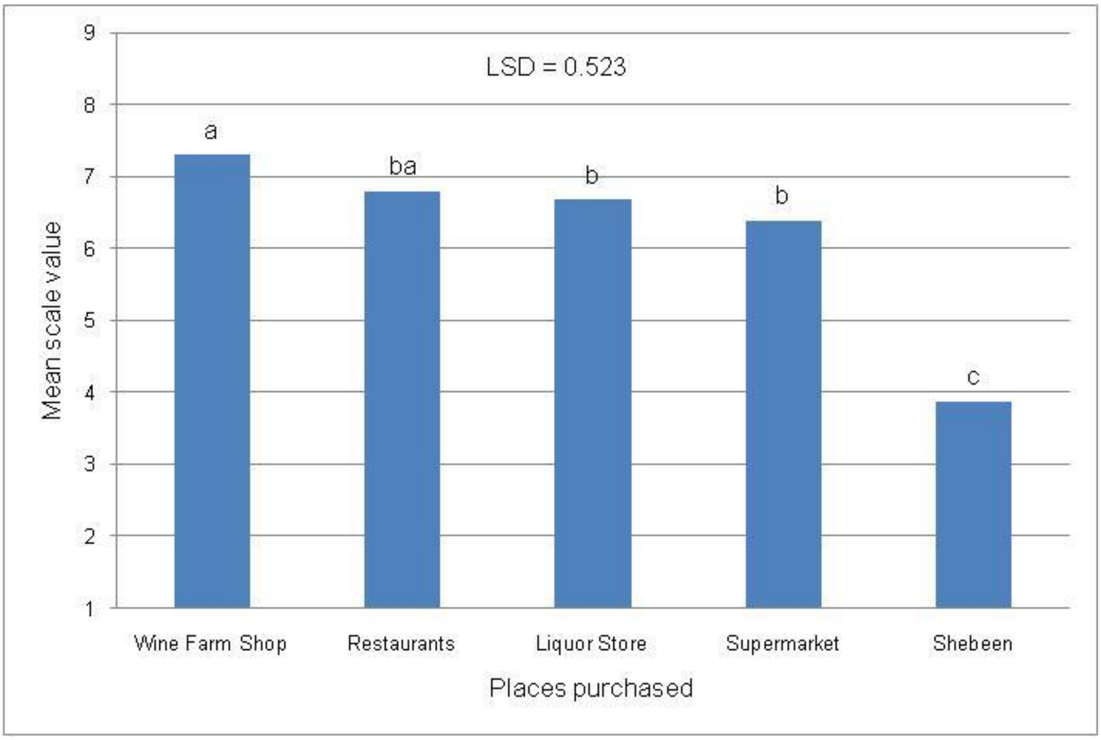

Figure 26 Appropriateness of different outlets when purchasing red wine. Scores ranged from 1 = *Not appropriate* to 9 = *Extremely appropriate*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

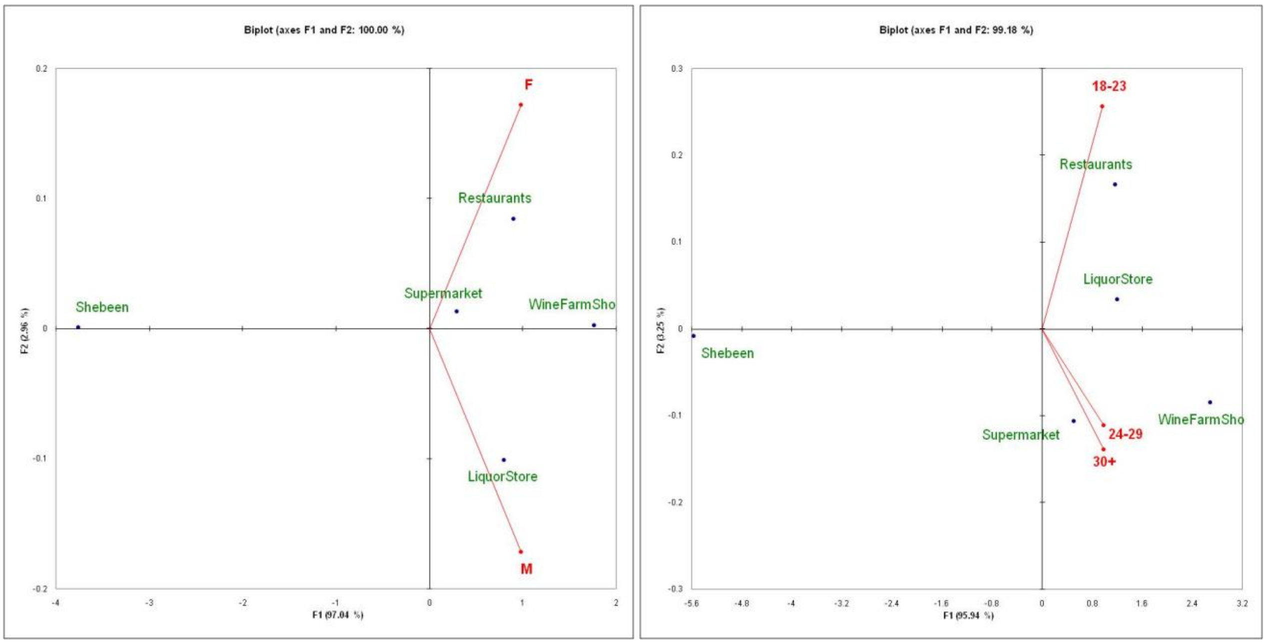

Figure 27 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the appropriateness of different outlets when purchasing red wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 99% of the variance, respectively in both plots.

The consumers illustrated that the most suitable occasion for drinking red wine (Figure 28), was *celebrating* birthdays, anniversaries, weddings, etc. *chilling with friends*, *braaiing*, *entertaining* and *wine with a meal*, also scored above a mean value of 6 indicating that these occasions are regarded as very appropriate. All other occasions scored between 3 and 6, whereas *consuming wine during a meeting* obtained the lowest score and the latter is thus seen as the least appropriate occasion for drinking red wine. From Figure 29 it can be deduced that females were closely associated with *entertaining*, while males where more closely associated with *celebrating* and *chilling with friends*. Younger consumers were more closely associated with *celebrating* and *chilling with friends*, while the older consumer (24 – 30+) indicated that *entertaining* and *meals* as more appropriate occasions for drinking red wine.

When asked to evaluate the appropriateness of different people to enjoy a glass of wine with, *friends* and *partners* scored highest with all consumers. The latter two also differed significantly ($p \leq 0.05$) from *colleagues* and *family*, with family scoring the lowest (Figure 30). When investigating the differences between gender and age (Figure 31), it is clear to see that the 30+ consumer preferred to drink red wine with their *partner*, while 18-23 and 24-29 preferred to drink red wine with *friends.*

Figure 32 iillustrates that consumers found *a friends place, restaurants, home* and *wine farms* as the most suitable places to drink red wine, and these places differed significantly ($p \leq 0.05$) from *bar* as venue*.* It is interesting that *night clubs* and *taverns* scored the lowest. It seems that males preferred *home* as the most appropriate venue to drink red wine, while females indicated *wine farms* and *restaurants*. Younger consumers (18-23) indicated *wine farms*, while the mid age group (24-29) indicated *restaurants* and a *friends place* as the most appropriate venues for drinking red wine, and again it seems that the older consumer 30+ preferred drinking red wine at *home* (Figure 33).

With regard to preference for other alcoholic beverages, consumers indicated that they preferred *wine* as the alcoholic beverage of choice, while *sorghum beer* scored the lowest (Figure 34). Females preferred *ciders*, while *males* preferred *beer*. More or less the same split occurred with consumers between 18 and 23 years of age, i.e. the younger consumer prefers *ciders* and the older consumers (24-29 and 30+) associate more closely with *beer* and *wine.*

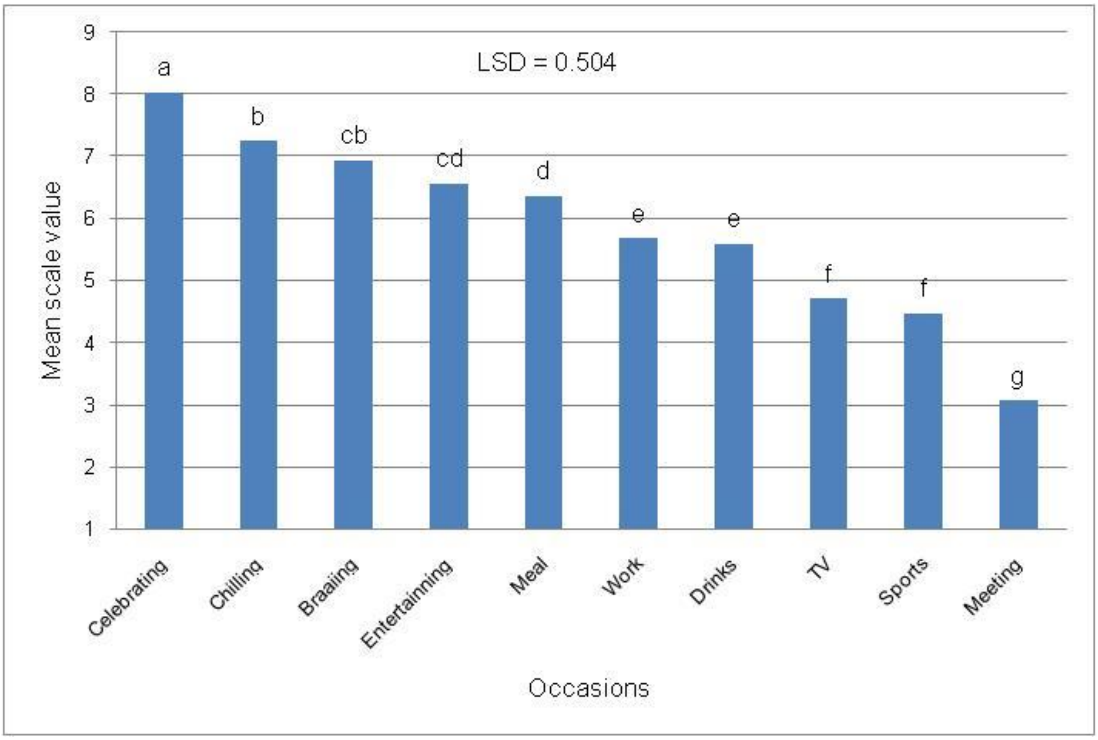

Figure 28 Appropriateness of different occasions when drinking red wine. Scores ranged from 1 = *Not appropriate* to 9 = *Extremely appropriate*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

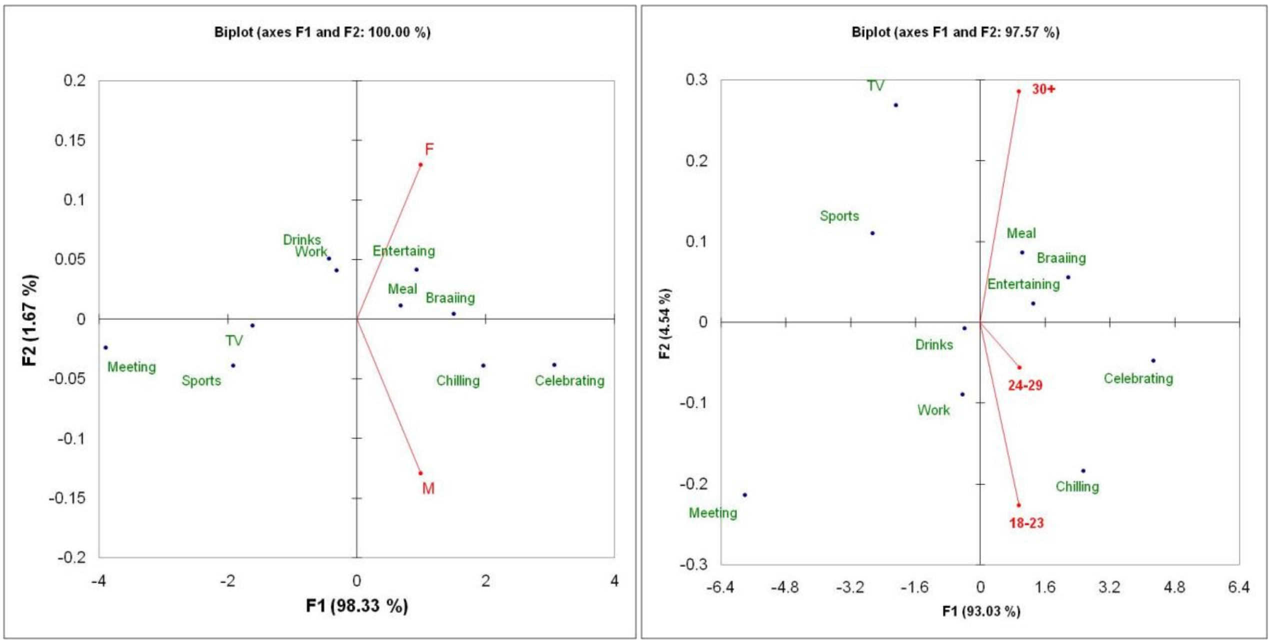

Figure 29 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the appropriateness of different occasions when drinking red wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 97.57% of the variance, respectively in both plots.

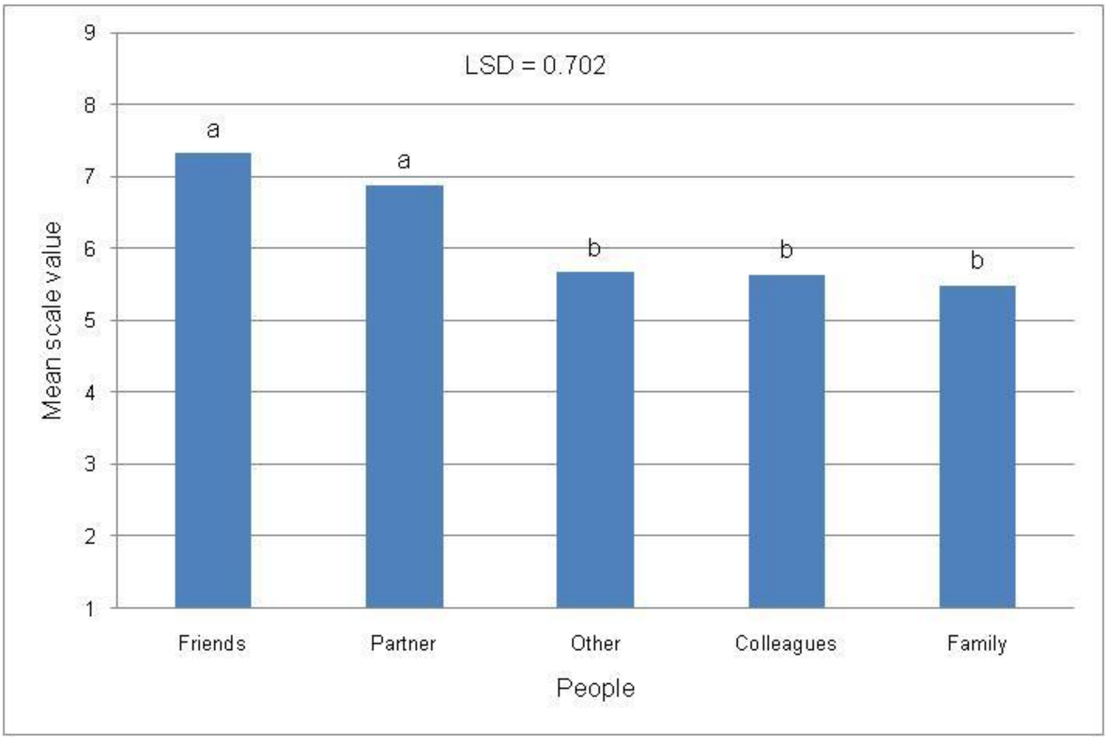

Figure 30 Choice of company when drinking red wine. Scores ranged from 1 = *Not appropriate* to 9 = *Extremely appropriate*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

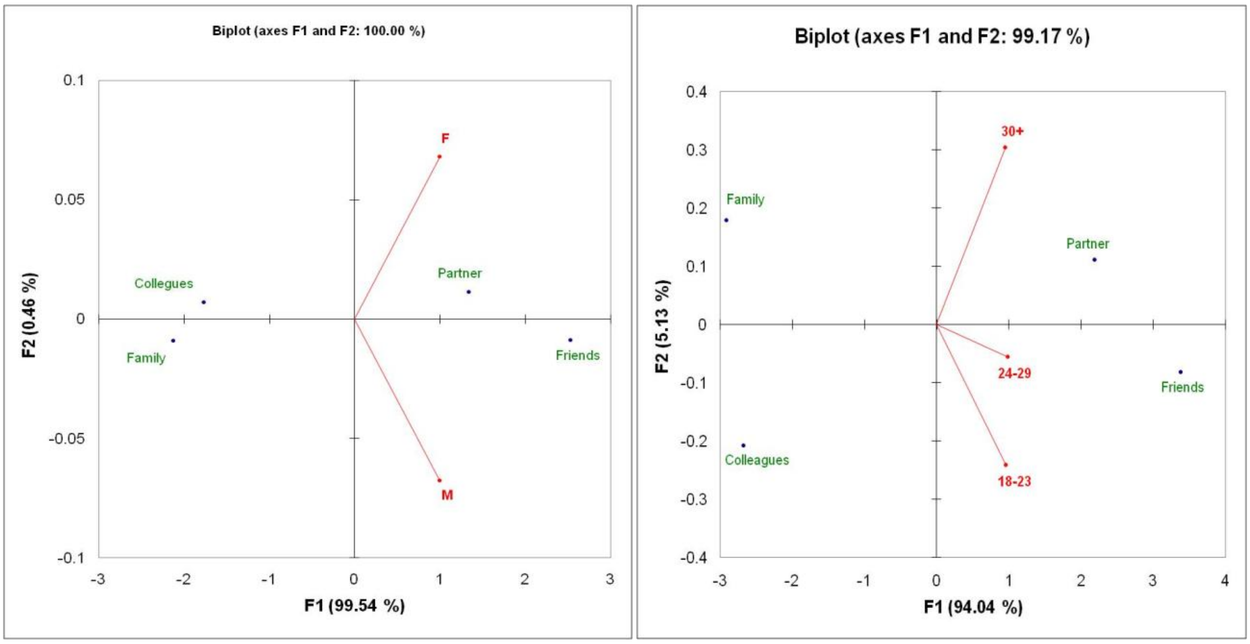

Figure 31 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to having different partners when drinking red wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 99.17% of the variance, respectively in both plots.

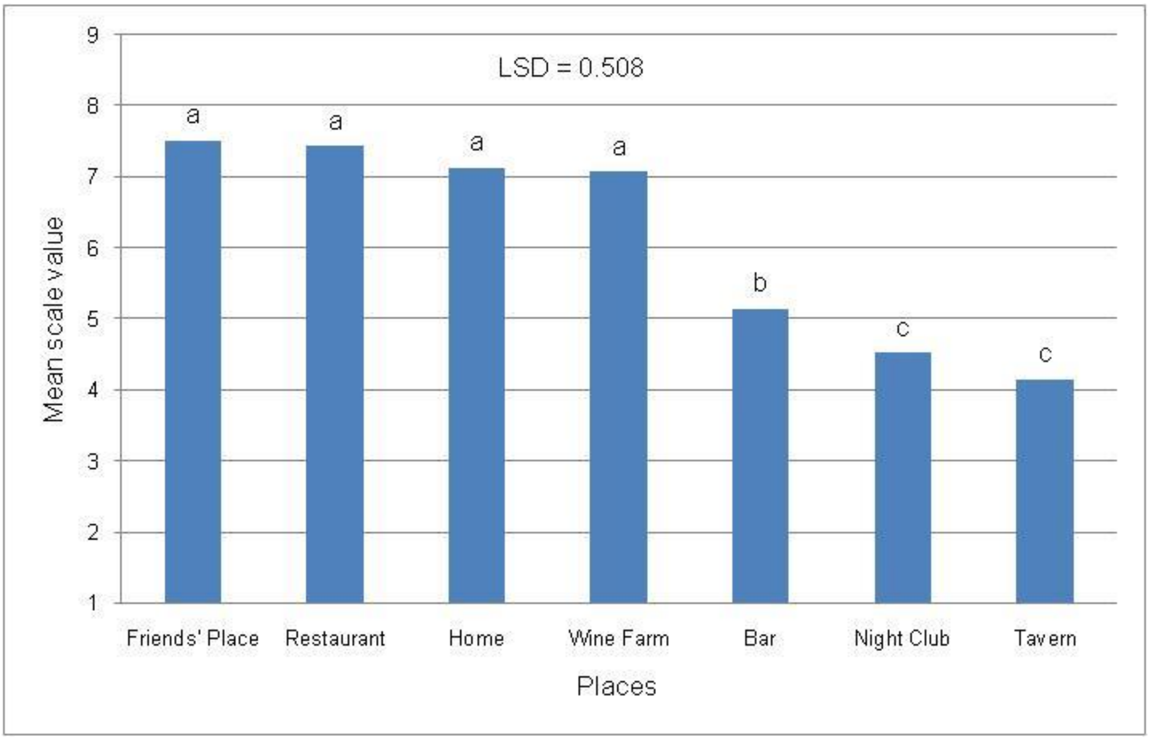

Figure 32 Appropriateness of different venues when drinking red wine. Scores ranged from 1 = *Not appropriate* to 9 = *Extremely appropriate*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

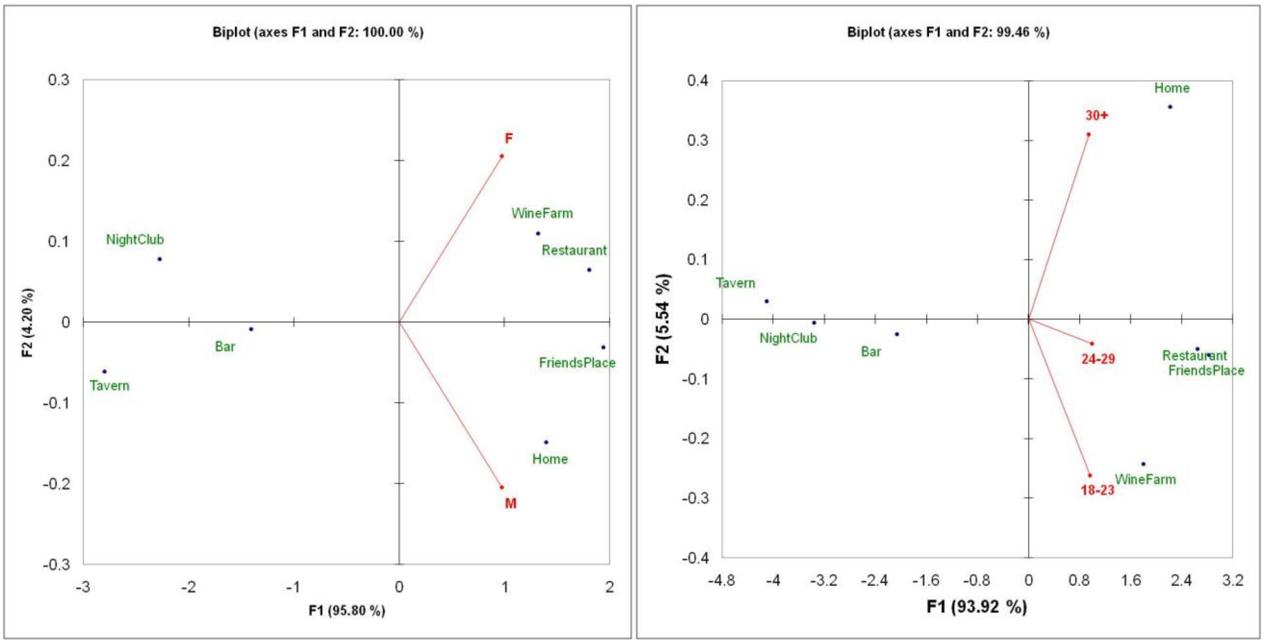

Figure 33 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the appropriateness of different venues when drinking red wine (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 99% of the variance, respectively in both plots.

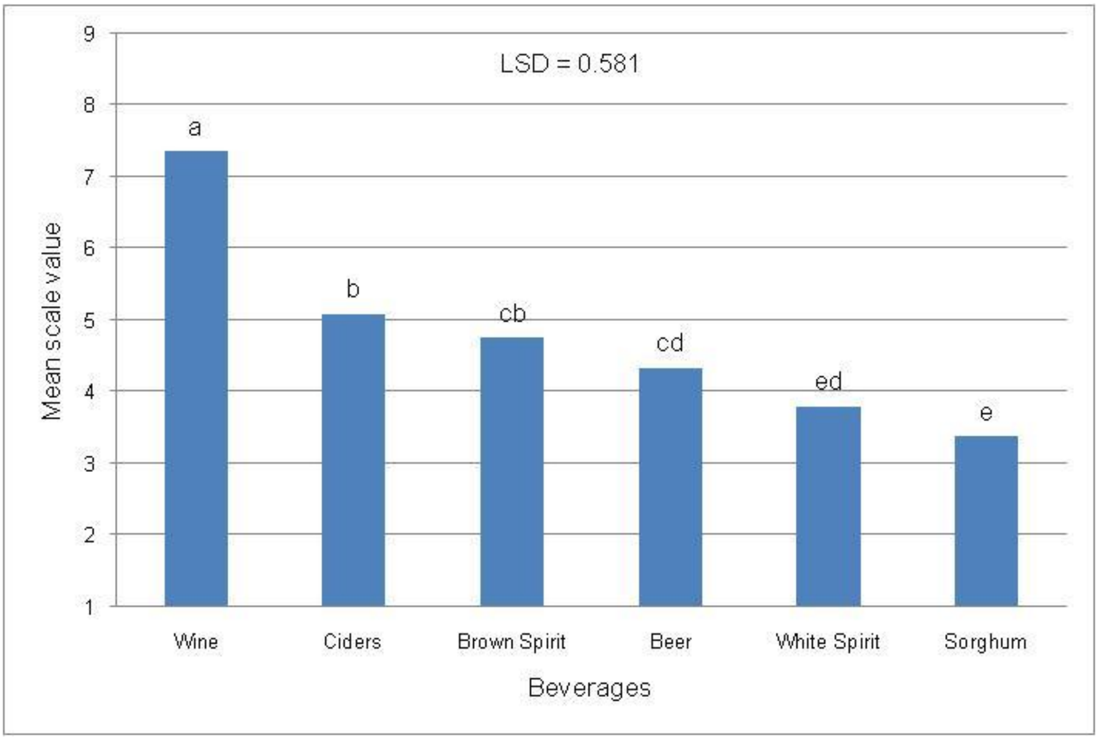

Figure 34 Liking of different alcoholic beverages. Scores ranged from 1 = *Dislike extremely* to 9 = *Like extremely*. LSD = Least significant difference. Means with different letters differ significantly at the 5% level of significance.

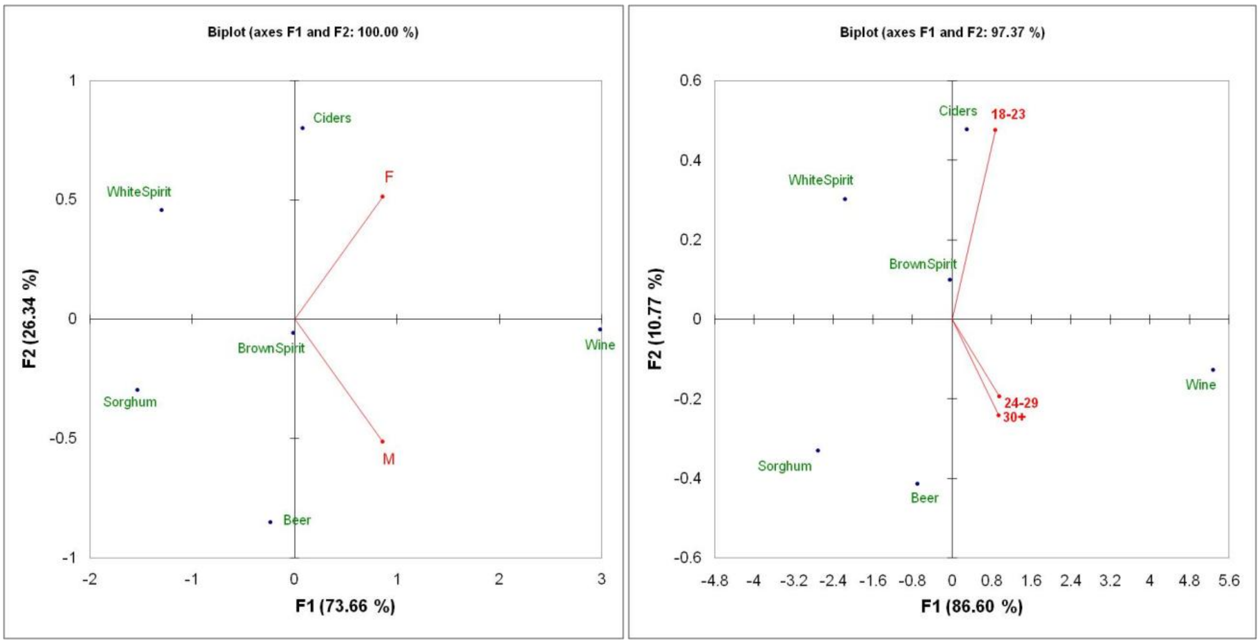

Figure 35 PCA bi-plots indicating the position of gender (a) and age (b) (loadings) in relation to the inclination to favour different alcoholic beverages (scores). Gender is indicated as Male (M) and Female (F) and age as 18-23, 24-29 & 30+. The first two principal components explained 100% and 97.37% of the variance, respectively in both plots.

3.6.2 Clustering of consumer opinions related to consumption and purchasing of wines

As already indicated, ANOVA was also performed on the opinion data, i.e. according to the four clusters indicated in Figure 15. Tables 16 to 24 illustrate the significant differences ($p \leq 0.05$) within each cluster for the respective opinions on the consumption and purchasing of red wines and other alcoholic beverages. This discussion deals with some of the most significant and interesting results obtained within and between the clusters indicated in Tables 16 to 24.

The four different clusters of consumers identified in Figure 15 can be compared to the results in Table 17, the latter indicating consumer's opinions towards different types of red wine. Cluster 1 which favoured *dry* and *sweet red* wine samples equally (Figure 15); indicated similar scores for both *dry* and *sweet red* wines (Table 17). Cluster 2 and 3 which favoured *sweet red* wines (Figure 15), showed similar results, with high scores for *sweet red,* 7.15 and 7.64 respectively (Table 17). Table 16 also confirms, as is also apparent from Figure 15 that Cluster 2 likes *sweet red* wines strongly and *dry red* wines, moderately, while Cluster 3 mainly likes *sweet red* wines. Cluster 2 had a score of 5.97 for *dry red* wine and Cluster 3 a score of 2.86.

Table 19 indicates the importance of different aspects when purchasing red wine; and it is clear that consumer responses differed across the four clusters. To compare the clusters in Table 19, the LSD was deduced from the highest mean in each respective cluster. This can give an indication of the *most important* or *least important* aspects per cluster. Cluster 4, who favours dry red wines strongly (Figure 15), indicated that all the aspects, except *awards* and *screw cap* are important. Again, this result concurs with what Lattey *et al.* (2007) found when testing for drivers of consumer liking of Australian wines. Cluster 1, who favoured both dry and sweet red wine equally (Figure 15), indicated that all the aspects except *winery, origin, awards*, and *closures (cork* and *screw cap)* are important when purchasing wines. Clusters 2 and 3 both favoured the sweet red wines. According to Table 19, Cluster 2 is of the opinion that *alcohol content, label* and *vintage* are important, whereas Cluster 3 is of the opinion that *alcohol content, label* and *price* are important aspects when purchasing wines. It is interesting to note that the discerning consumer, who likes high-end wines, takes more aspects into consideration when purchasing wines, whereas the consumer who favours low-end wines only takes a few aspects into consideration.

When comparing the four clusters, only *label* and *alcohol content* scored reasonably high for all four clusters. It is, however, important to note that this doesn't automatically indicate that a *high alcohol content* is regarded as favourable, it just indicates that *alcohol content*, whether high or low, is considered when purchasing wines. It would thus seem beneficial to place more emphasis on the specific alcohol content. This could be done by means of general marketing or by indicating reduced alcohol content more prominently on the label. Further investigation should, however, be done on the preferred *alcohol content*, in both blind and informed conditions; among male and female black consumers of different age groups.

These ANOVA results of the respective clusters of consumers could be of great value to the South African wine industry, especially those wine distributers who are interested in entering the black market as potential point of sale. Important to keep in mind, is that the results depicted in Tables 16 to 24 only represent the black consumer residing in the Western Cape. It is well known that the consumption and purchasing perceptions of black consumers in Gauteng are quite different from those in the Western Cape (Personal communication: D. Schmidt, Distell, Stellenbosch, South Africa, 2009).

Table 16 ANOVA table of different opinions per cluster of consumers: *Wine types.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Red	8.049[a]	7.130[a]	5.583[b]	8.529[a]
Rose	5.500[b]	6.559[ab]	7.208[a]	3.764[c]
Dry White	4.415[c]	3.970[c]	3.708[c]	5.353[b]
Semi Sweet White	5.325[bc]	6.368[b]	6.292[ab]	3.235[c]
LSD (p=0.05)	0 .939	0.664	1.170	2.080

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 17 ANOVA table of different opinions per cluster of consumers: *Red wine types.*

	Cluster 1	Cluster 2	Cluster 3	Cluster4
Pinotage	6.313[ab]	6.634[ab]	4.929[b]	7.882[a]
Shiraz	7.129[a]	6.891[a]	5.077[b]	7.750[a]
Dry Red blends	5.882[b]	5.977[c]	2.867[c]	7.471[a]
Cabernet Sauvignon	6.355[ab]	6.250[bc]	4.923[b]	7.188[a]
Merlot	6.563[ab]	6.022[bc]	5.133[b]	7.067[a]
Sweet Red blends	6.563[ab]	7.154[a]	7.647[a]	3.647[b]
LSD (p=0.05)	0.980	0.630	1.342	1.158

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 18 ANOVA table of different opinions per cluster of consumers: *Volumes.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
750 mL	7.488[a]	7.441[a]	6.826[a]	8.000[a]
1.5 L	5.268[b]	5.294[b]	4.609[b]	5.000[b]
Box	4.634[b]	4.826[b]	4.125[b]	3.588[b]
LSD (p=0.05)	1.018	0.728	1.709	1.018

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 19 ANOVA table of different opinions per cluster of consumers: *Aspects.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Winery	6.175[bc]	5.928[bc]	5.792[bcd]	7.563[a]
Cultivar	6.775[ab]	6.075[b]	5.652[cd]	7.412[a]
Alcohol	6.659[ab]	7.391[a]	7.125[a]	7.177[ab]
Label	7.122[a]	6.913[a]	7.042[ab]	7.177[ab]
Vintage	6.781b[a]	6.812[a]	5.565[cd]	7.177[ab]
Origin	5.878[bc]	5.412[bc]	5.458[cd]	6.647[abc]
Cork	4.600[d]	5.536[bc]	4.625[d]	6.471[abc]
Price	6.805[ab]	6.015[b]	6.667[abc]	6.235[abc]
Awards	5.550[c]	5.507[bc]	5.333[d]	5.824[bc]
Screw Cap	4.526[d]	5.261[c]	5.130[d]	5.500[c]
LSD (p=0.05)	0.931	0.696	1.275	1.518

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 20 ANOVA table of different opinions per cluster of consumers: *Places purchased.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Supermarket	6.875^{a}	6.188^{b}	5.783^{b}	6.941^{a}
Wine Farm Shop	7.366^{a}	7.435^{a}	7.167^{ab}	6.824^{a}
Restaurants	7.317^{a}	6.536^{b}	7.292^{a}	6.353^{a}
Liquor Store	7.317^{a}	6.580^{b}	6.125^{ab}	6.294^{a}
Shebeen	4.175^{b}	4.217^{c}	2.875^{c}	3.235^{b}
LSD (p=0.05)	0.941	1.970	1.496	2.048

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds;**Cluster 4**= Strongly favour dry reds.

Table 21 ANOVA table of different opinions per cluster of consumers: *Occasions.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Celebrating	7.951^{a}	8.101^{a}	7.417^{a}	8.765^{a}
Braaiing	6.878^{bc}	6.855^{b}	6.348^{abc}	8.253^{ab}
Chilling	7.220^{ba}	7.044^{b}	7.250^{ab}	8.059^{ab}
Meal	6.415^{bc}	6.119^{cd}	6.083^{bc}	7.529^{ab}
Entertaining	6.475^{bc}	6.441^{cb}	6.435^{abc}	7.353^{bc}
Work	5.395^{de}	5.391^{ed}	5.913^{c}	7.188^{bc}
Drinks	6.053^{cd}	5.101^{ef}	4.167^{d}	6.059^{cd}
TV	4.550^{e}	4.896^{ef}	4.167^{d}	5.059^{de}
Sports	4.750^{e}	4.435^{f}	4.046^{d}	4.471^{e}
Meeting	2.900^{f}	3.309^{g}	3.042^{d}	2.471^{f}
LSD (p=0.05)	0.731	0.731	1.265	1.393

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 22 ANOVA table of different opinions per cluster of consumers: *People.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Friends	7.415^{a}	7.177^{a}	7.375^{a}	7.625^{a}
Partner	7.200^{ab}	6.841^{a}	6.500^{ab}	6.813^{ab}
Family	5.875^{bc}	5.294^{b}	5.208^{b}	5.688^{ab}
Colleagues	5.850^{bc}	5.284^{b}	6.333^{ab}	5.600^{b}
Other	5.714^{c}	5.462^{b}	0.000^{c}	6.250^{ab}
LSD (p=0.05)	1.411	0.916	1.404	1.974

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 23 ANOVA table of different opinions per cluster of consumers: *Places.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Friends Place	7.375^{a}	7.338^{a}	8.364^{a}	8.412^{a}
Restaurant	7.385^{a}	7.235^{a}	7.667^{a}	7.941^{ab}
Home	7.513^{a}	6.957^{a}	6.500^{b}	7.765^{ab}
Wine Farm	6.900^{ab}	6.913^{a}	8.364^{a}	6.412^{bc}
Bar	5.951^{bc}	4.721^{b}	4.875^{c}	5.177^{cd}
Night Club	5.300^{cd}	4.177^{b}	4.304^{c}	4.353^{d}
Tavern	4.474^{d}	4.029^{b}	4.130^{c}	3.882^{d}
LSD (p=0.05)	1.034	0.697	1.032	1.698

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

Table 24 ANOVA table of different opinions per cluster of consumers: *Beverages.*

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Wine	7.600[a]	7.275[a]	6.304[a]	8.471[a]
Brown Spirits	4.854[b]	4.507[c]	4.458[bc]	6.235[b]
Ciders	4.718[b]	5.246[b]	5.583[ab]	4.588[bc]
Beer	4.854[b]	4.536[bc]	3.458[cd]	4.235[c]
White Spirits	3.975[b]	3.725[d]	3.458[cd]	4.125[c]
Sorghum	3.950[b]	3.391[d]	2.261[d]	3.471[c]
LSD (p=0.05)	1.019	1.968	1.578	1.737

Cluster 1 = Favour dry & sweet reds; **Cluster 2** = Strongly favour sweet reds & moderately dry reds; **Cluster 3** = Strongly favour sweet reds; **Cluster 4**= Strongly favour dry reds.

4. CONCLUSIONS

This research firstly provides a better understanding regarding the volatile composition and sensory quality of an industry-selected range of South African red wines. These results could be an indication of specific wine aromas desired in the final product, as well as basic taste and mouthfeel attributes. Although multivariate statistical methods, such as PLS, indicated associations between chemical and sensory descriptors, more sophisticated instrumental research is necessary to determine which specific chemical compounds drive sensory quality.

It seems that this specific group of black consumers preferred sweet red wines in a blind tasting scenario. Sensory results indicated that consumers preferred less complex wines with *fruity*, and *berry jam* characters. These descriptors are indeed very typical of sweet red wines. Although the sweet samples were correlated with these descriptors, none of the samples associated strongly with overall consumer liking and purchase intent. The latter *lesser* association seen in the PLS plots could thus be identified as a possible gap or an *ideal point*. The results should be investigated with regard to the chemical and sensory descriptors to see whether wine making process could be adapted to meet the specifications.

Four different clusters of consumers were identified, when investigating the degree of liking of the consumers for red wines. The clusters were described as:

Cluster 1 – prefer both *dry* and *sweet red wines* equally

Cluster 2 – *strongly favoured sweet red wines* and *moderately liked dry red wines*

Cluster 3 – s*trongly favoured sweet red wines* with little preference for *dry red wines*

Cluster 4 – prefer *dry red wines*

These clusters give an indication of the number of black consumers preferring sweet and/or dry red wines. The black wine consumers residing in the Western Cape clearly preferred the sweeter wines when tasting the wines. However, when viewing a depiction of a labelled bottle of wine, the informed choice resulted in a slightly different answer, i.e. that this group of consumers will definitely choose dry red wines of a higher quality, price and style such as *Nederburg Baronne*.

This study also provides an insight into the relative importance of product expectation and the actual sensory experience. Conclusions can also be made with regard to the appearance of the wine bottle and label of sweet red blends. As a large proportion of the consumers indicated that they liked the flavour of the sweet red blends, but the elegant appearance of the high-end wines, wine marketers should focus on adding value and style to the natural sweet red wines.

Emphasis should also be placed on the alcohol content, and further studies should be conducted in order to determine what consumers want considering alcohol content. Focus should be placed on marketing, branding, label, alcohol content and bottle design, all which will aid in the value perception of the product. Furthermore, a model should be developed to understand the role of both intrinsic and extrinsic factors that underline preference, as well as perception of wines. Consumer demands can then be turned into product specifications which are realistic from a production point of view.

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CHAPTER 4

Pre-processing and quality control of data

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1. INTRODUCTION

This research focuses on the investigation of underlying relationships between chemical and sensory attributes, as well as the consumer profiling of a range of red wines. In sensory and chemical studies of wines, the securing of valid and reliable results is vitally important. A challenge frequently encountered when dealing with a combination of chemical, sensory and consumer data lies in the inherent nature of the respective datasets; in terms of the size of the datasets, the *values* representing the data and the fact that multi-block designs needs to be used (Tenenhaus & Esposito Vinzi, 2005). For example modern analytical techniques can generate a vast amount of chemical data within a large number of samples, whereas in the generation of sensory datasets, i.e. where humans are trained to act as *analytical instruments*, it is much more difficult to handle large sample sets due to cost and time implications.

2. INVESTIGATION INTO THE HANDLING OF VALUES BELOW LEVEL OF DETECTION AND QUANTIFICATION IN A CHEMICAL DATA SET OF RED WINES

2.1 Introduction

In the chemical analysis of wines, e.g. when routine and automated instrumental methods such as gas chromatography with flame ionization detection (GC-FID) are applied, the handling of a large number of samples poses no problem. Furthermore, large chemical datasets can be analysed effectively with an array of appropriate multivariate methodologies such as principal component analysis (PCA). However, in multivariate data analyses, the handling of values, such as LOQ (limit of quantification) and LOD (limit of detection), which in fact still have a value, can pose problems. This chapter proposes a methodology for handling non-numerical values in the statistical analysis of chemical data.

On-going advances in analytical techniques resulted in enabling researchers to quantify a multitude of chemical compounds contributing to wine character within a relatively short period of time. Together with the development of new analytical techniques, significant advances have also been made in the field of statistical data analysis. The use of multivariate data analysis or *chemometrics* has been proven to provide valuable insight into complex data sets by comprehensively representing their multi-dimensional variability (Rebolo *et al*., 2000).

In terms of the *values* encountered in chemical datasets, the variation ranges from absolute numerical values and non-significant numerical values and lastly missing values. This necessitates the investigation into how to best compare the data sets in a logical multivariate way, without potentially losing information, but, more importantly not too include information that is irrelevant or redundant.

Two important performance characteristics of any analytical method for the analysis of chemical constituents in a sample are the *limit of detection* (LOD) and the *limit of quantification* (LOQ). The former indicates the lowest concentration at which a certain compound can be detected and the latter the lowest concentration at which the compound can be accurately quantified (Bianchi *et al*., 2005). Both these parameters are determined during method development and validation and are inherently unique to that specific method. It is therefore unavoidable that in any given dataset, some compounds will be reported as <LOD (below limit of detection) or <LOQ (below limit of quantification).

2.2 Materials and methods

For Samples, Spectroscopic determination of the principal wine parameters (FT-MIR), Gas chromatographic determination of principal wine volatiles and Statistical analysis of data see Chapter 3, Materials and Methods.

2.3 Results and conclusions

As is the case with all targeted analytical methods, some of the major volatiles determined by GC-FID in this study were present at levels below the LOD (limit of detection) or LOQ (limit of quantification). Therefore, in the dataset obtained, the *concentrations* for these compounds were indicated as <LOD or <LOQ, respectively, since this method does not allow for their accurate quantification. These are classified as non-numerical values and the occurrence of these values can be quite problematic in standard multivariate data analysis such as principal component analysis (PCA). In this research project several chemical datasets were generated.

Prior to any data pre-processing, the strategic parameters for classifying non-numerical values such as LOD and LOQ were investigated. Table 1 indicates the specific margin values for each of the chemical compounds determined by GC-FID. The occurrence of non-numerical values was only present in the dataset for some of the esters (Table 2). Table 1 was thus used to replace non-numerical data points in the latter dataset with either LOD or LOQ values. It is, however, important to note that the respective <LOD or <LOQ values for the specific compounds could be between zero and the margin value, but not zero. This approach of replacing non-numerical values with LOQ or LOD values is described as *Method 1*.

In *Method 2* the non-numerical data points were replaced with zeros (0), since one can argue that the compounds are usually present at such lower levels that it could be regarded as not being present at all.

Thirdly, in *Method 3,* all non-numerical values were regarded as so-called *missing* values in the data analysis, therefore the non-numerical values were replaced with blanks, as is a common procedure for the statistical package used in this research (XLStat, Addinsoft, Paris).

After the above-mentioned pre-processing of data was completed, principal component analysis (PCA) was done using the full set of chemical data, i.e. the full spectrum of chemical compounds determined by both the FT-MIR and GC-FID analyses. Too ascertain how the three approaches or methods of pre-processing would affect the results obtained; the respective PCA plots were compared.

The results for Method 1 and 2 are depicted in Figure 1 and Figure 2, respectively. Samples are distributed in a similar fashion in both score plots. The sweet red blends (Samples N, O, P, Q & R) are all situated on the right side of the scores plot, whereas the rest of the samples, mostly dry red blends and cultivar wines, are situated in the left side of the scores plot. It can thus be concluded that both pre-processing approaches (Methods 1 & 2) gave similar results and can be used interchangeably before further statistical analyses are employed and that whether zero or the respective LOD's and LOQ's are used, the influence on multivariate data analysis results are negligible. One could argue that the values used in Method 1 are extremely close to zero, thus very similar to the values used in Method 2. In conclusion, it is evident that the red wine samples differentiated similarly in both PCA plots.

Using Method 3, however, a totally different PCA scores plot (Figure 3) was obtained. Note that a number of the wine samples are missing in this scores plot. When there are a reasonable number of missing values in a row of a data sheet, the statistical program used (XLStat, Addinsoft, Paris), leaves out the entire row, and therefore also the wine sample in question. When using Method 3 with this specific software package, too much valuable data and ultimately a large proportion of the sample set, was lost. Method 3 is thus deemed inappropriate when confronted with a chemical dataset similar to the one obtained in this study.

Table 1 The limit of detection and quantification (LOD & LOQ) margin values for twenty-five major volatiles as determined by GC-FID analysis.

Analyte	**Linearity**	
	LOQ (mg/L)	**LOD (mg/L)**
Methanol	36.594	10.978
Propanol	0.820	0.246
Butanol	0.200	0.060
Isobutanol	0.160	0.048
Isoamyl alcohol	0.061	0.018
Hexanol	0.054	0.016
2-Phenylethanol	0.203	0.061
Ethyl acetate	0.348	0.104
Ethyl butyrate	0.055	0.016
Isoamyl acetate	0.047	0.014
Ethyl hexanoate	0.072	0.022
Ethyl lactate	1.723	0.517
Diethyl succinate	0.094	0.028
2-Phenylethyl acetate	0.035	0.010
Ethyl decanoate	0.228	0.068
Ethyl octanoate	0.058	0.017
Acetic acid	4.035	1.211
Propionic acid	0.732	0.220
Isobutyric acid	0.203	0.061
Butyric acid	0.067	0.020
Isovaleric acid	0.095	0.028
Valeric acid	0.095	0.028
Hexanoic acid	0.054	0.016
Octanoic acid	0.125	0.038
Decanoic acid	0.124	0.037

LOQ: Limit of quantification

LOD: Limit of detection

Table 2 Concentration ranges in mg/L for all esters. The range, average and standard deviation (SD) are also included for each compound.

Analyte	Ethyl acetate	Isoamyl acetate	Ethyl butyrate	Ethyl hexanoate	Ethyl lactate	Diethyl succinate	2-Phenyl-ethyl acetate	Ethyl decanoate	Ethyl octanoate
A	100.80	0.74	0.47	0.68	274.35	17.16	0.57	0.12	<.LOD
B	112.72	0.54	0.55	0.72	297.34	27.67	<LOQ	0.13	0.07
C	115.86	0.92	0.62	0.84	287.03	14.41	<LOQ	0.13	0.10
D	111.07	0.62	0.53	0.66	241.48	19.74	0.54	0.11	0.06
E	90.35	0.76	0.54	0.67	218.59	16.05	0.31	0.17	0.06
F	74.51	1.12	0.55	0.72	158.51	10.75	0.58	0.13	<LOQ
G	81.85	1.10	0.49	0.71	202.41	11.85	0.59	0.13	0.09
H	135.68	0.59	0.49	0.69	331.94	21.21	0.56	0.12	0.05
I	137.34	0.43	0.47	0.63	269.24	20.63	0.56	<LOQ	0.08
J	109.30	0.60	<LOD	0.57	285.57	13.03	0.57	<LOQ	0.11
K	80.95	1.16	0.55	0.67	199.49	8.87	0.61	<LOQ	<LOD
L	95.30	0.86	0.60	0.67	223.69	11.13	0.57	0.17	<LOD
M	122.04	0.56	0.50	0.68	314.26	17.82	0.57	0.12	0.15
N	63.81	0.55	<LOD	<LOD	220.55	5.40	<LOQ	<LOQ	<LOD
O	73.40	0.74	0.51	0.58	345.52	10.83	0.59	<LOQ	0.12
P	76.84	0.57	0.68	<LOQ	329.44	3.66	<LOQ	<LOQ	<LOQ
Q	78.50	0.50	0.50	0.52	161.92	5.17	<LOQ	<LOQ	<LOQ
R	115.04	0.91	<LOD	0.52	274.05	7.83	<LOQ	<LOD	<LOQ
Control	97.43	0.98	0.52	0.63	219.42	7.04	0.61	<LOD	0.11
Range	63.81 - 137.35	0.43- 1.17	0.47- 0.68	0.52- 0.84	158.52- 345.52	3.66- 21.22	0.31- 0.61	0.11 - 0.17	0.05 - 0.15
Average	63.81	0.75	0.54	0.66	255.52	13.18	0.57	0.13	0.09
SD	1.12	11.15	0.06	0.08	8.30	1.14	0.08	0.02	0.03

Average and Standard Deviation (SD) were calculated without <LOD and <LOQ values

Dry red wines samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-NederburgPinotage; **D**-Nederburg Shiraz;**E**-NederburgBaronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-FourCousins Natural Sweet; **O**-CellarCask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-NamaquaJohannisberger; **Control**-Tassenberg.

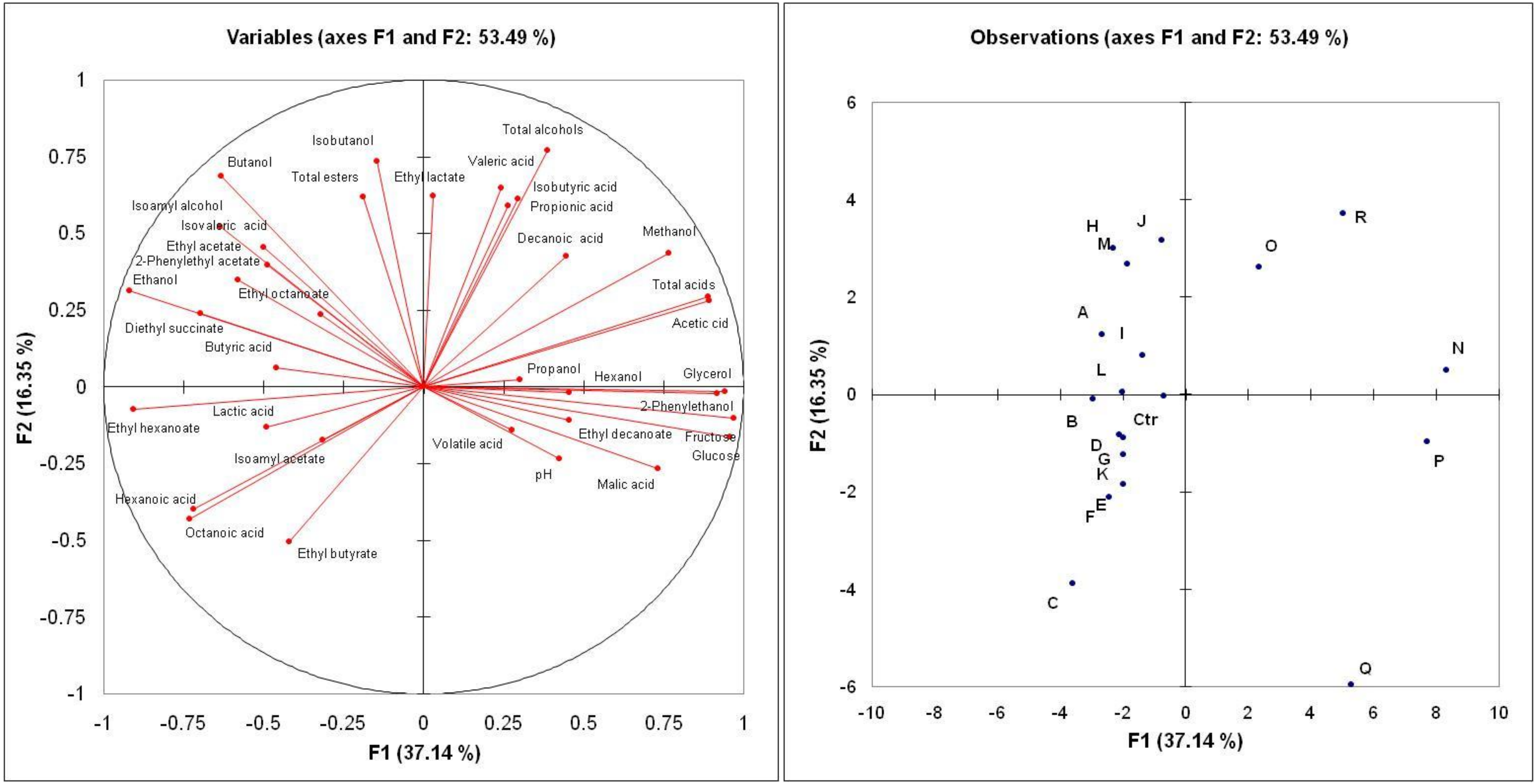

Figure 1 Method 1**:** PCA loadings (left) and scores (right) plots for GC-FID and FT-MIR results. Non-numerical values were replaced with the corresponding *LOQ and LOD values* as indicated in Table 2. Samples are indicated as scores and chemical attributes as the loadings. The first two principal components explain 53.49% of the variance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-NederburgPinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

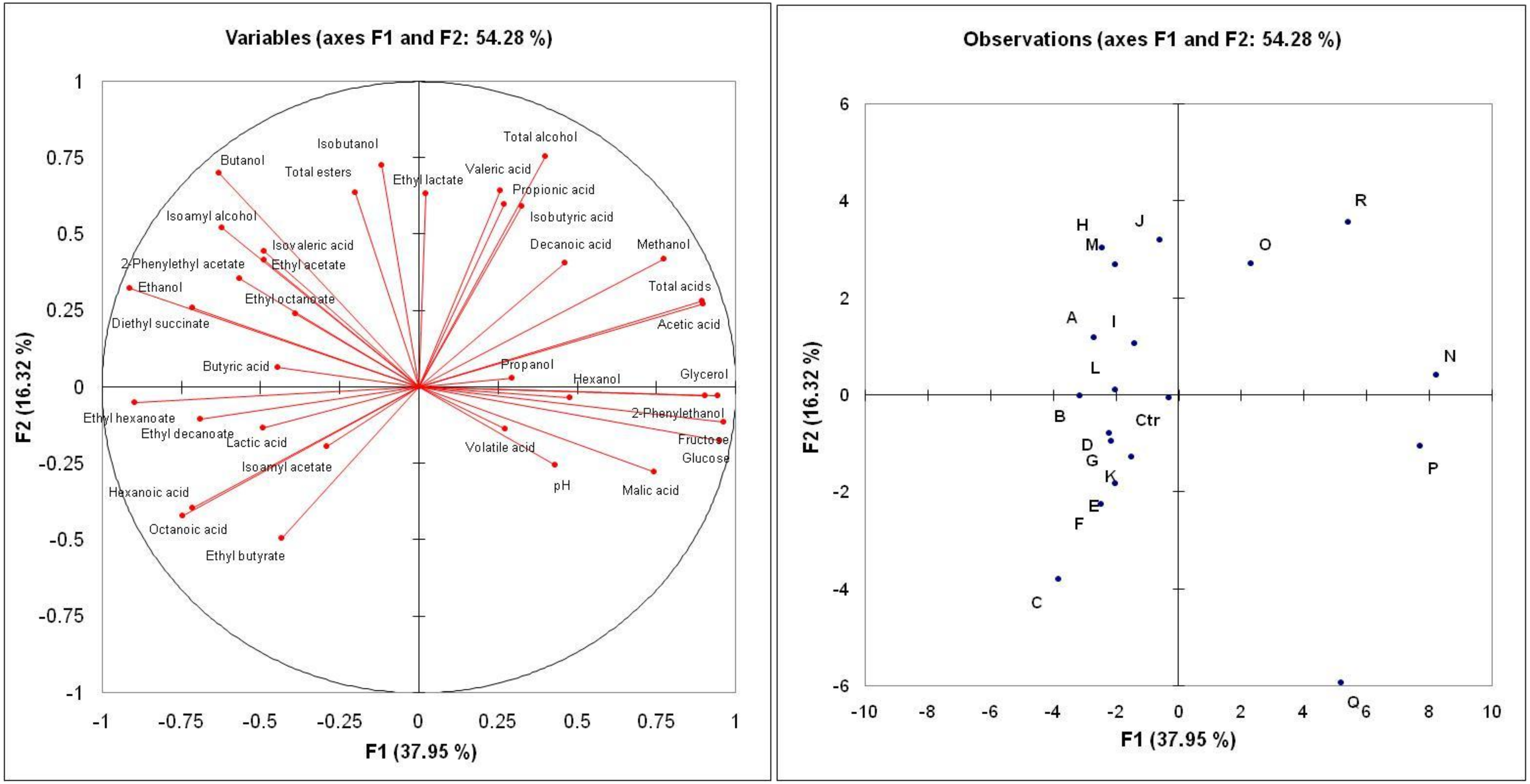

Figure 2 Method 2: PCA loadings (left) and scores (right) plots for GC-FID and FT-MIR results. Non-numerical values were replaced with *zero.* Samples are indicated as scores and chemical attributes as the loadings. The first two principal components explain 54.28% of the variance.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control**-Tassenberg.

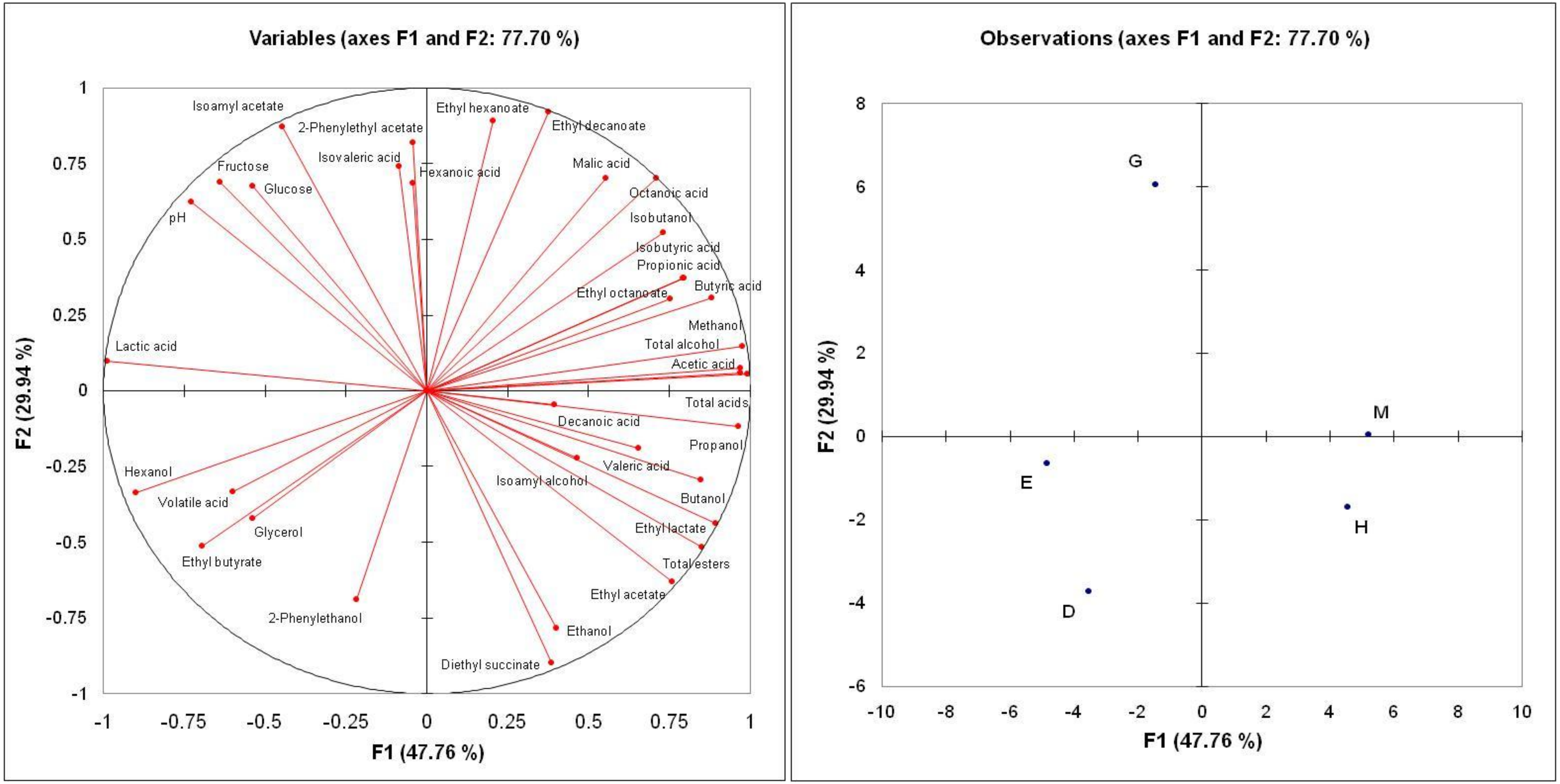

Figure 3 Method 3: PCA loadings (left) and scores (right) plots for GC-FID and FT-MIR results. Non-numerical values were indicated as *missing.* Samples are indicated as scores and chemical attributes as the loadings. The first two principal components explain 77.7% of the variance.

Dry red wine samples: **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **G**-Obikwa Shiraz; **H**-Roodeberg; **M**-Alto Rouge.

3. QUALITY CONTROL OF SENSORY DATA

3.1 Introduction

In sensory wine research the handling of a large number of wines can, as mentioned, be problematic and the quality control of sensory data is therefore important to ultimately ensure valid and reliable results (Næs *et al.,* 2010). Sensory analysis of wines should therefore be performed on a manageable number of wines, especially if a complete block design is used (Lesschaeve, 2007). Here we investigated how the researcher can apply appropriate sensory analysis methodologies on a small set of wines (18) in a complete block design set-up to ultimately ensure valid and reliable sensory results.

Descriptive sensory analysis is frequently used to obtain a comprehensive sensory profile of products such as wine. It is extremely useful in situations where a detailed specification of the sensory attributes of a product or a comparison of several products is required.

Descriptive sensory analysis, also known as Quantitative Descriptive Analysis or QDA, usually involves the 1) training of the judges to score the respective samples according to the specific sensory attributes on a line scale; 2) determination of judge reproducibility or consistency; and 3) testing of samples and analysis of data using appropriate univariate and/or multivariate statistical techniques (Lawless & Heymann, 2010). Sensory professionals consider sensory panels as equivalent to sensitive analytical instruments, and therefore expect sensory data collected from panels to be accurate and reproducible. Judges are therfore selected based on their sensory sharpness and are usually trained extensively to perform sensory tasks objectively and consistently (Lesschaeve, 2007).

A number of statistical methodologies are available for the *quality control* of sensory profile data. Some of the methods are multivariate in nature and may be used to obtain an overview of the data, however, other methods are univariate and provide a detailed study of individual attributes (Næs *et al.,* 2010).

In this part of the research, descriptive sensory analysis (QDA) and appropriate univariate and multivariate methodologies were employed to investigate accuracy of sensory panel data.

3.2 Materials and methods

For Wine samples and reference standards and Descriptive sensory analysis (QDA) see Chapter 3, Materials and Methods.

As indicated in Chapter 3, the full set of 18 wines was divided into four groups (Chapter 3, Table 1). Each group of wine was subjected to QDA, however, each group of wines also included a control sample. The control sample was used as a point of reference and to conduct sensory analysis reliably over a long period of time. Therefore after completion of the QDA there were four sets of data, with each set having data for the control sample. During the analysis of data, the data of all eighteen samples, as well as the four sets of data for the control sample were captured in one datasheet, where after data analyses, as described in Chapter 3, were conducted.

3.3 Results and conclusions

Initially the experimental set-up of the sensory analysis (QDA) entailed the profiling of the 18 wines, grouped into four sub-groups, with the control sample serving as a constant reference standard with each group of wines (Chapter 3, Table 1). Following this, the strategy was to statistically analyse the data of all eighteen wines, as well as that of the control samples, simultaneously.

When investigating the principal component analysis (PCA) plots of the 18 wines visually (Figure 4), distinct clusters were identified. A similar pattern was evident in the discriminant analysis (DA) plot (Figure 5). Note that the clusters in the PCA plot (Figure 4) correspond very well with that of the DA plot (Figure 5) thus viable clusters of samples could be identified. However, it is important to note the position of the four control samples in Figures 4 and 5. The control sample, Tassenberg, was used as a point of reference during the QDA of each of the four groups of wine. The four control samples were marked Ctr1 to Ctr4 in Figure 4 and 5, respectively. According to the PCA and DA plots, control sample 1 lies slightly further away from the closely associated control samples 2 to 4. According to winemakers (Personal communication: Prof. Pierre van Rensburg; Distell, Stellenbosch, South Africa, 2009), variation can occur in wine from production batch to production batch and it can also happen within the same production batch. The control sample was a boxed wine and was purchased, as required, over a period of three months. Although these wines were from the same vintage, the panel members mentioned that the control sample changed slightly in overall *fruity* and *vegetative* aroma (orthonasal) between the evaluation of the Group 1 wines and the evaluation of the Group 2 to 4 wines: the control wine was regarded as having a slightly *vegetative* aroma during the analysis of the Group 1 wines, whereas during the analysis of the wines from Groups 2 to 4, the *vegetative* aroma in the control wine was not present, as a matter of fact, then the control wine had a more prominent *fruity* aroma. This could be the reason why control 1 shifted in Figure 4, as well as in Figure 5. The latter situation can be verified even further by investigating the PCA loadings plot (Figure 4), where it is noted that control 1 associate more closely with the *vegetative* descriptors than the *fruity* descriptors, and *vice versa* for control samples 2, 3 and 4. This change in the intensity of the *fruity* and *vegetative* aromas (orthonasal) of the control samples can also be seen in Table 3. Control 1 scored 6.52 for *vegetative* aroma (orthonasal), while the other three control samples did not score more than 1.02 units. Although this difference was not significant ($p>0.05$) for the four control samples, it was significant ($p\leq0.05$) for *fruity* aroma (orthonasal) with control 1 having a significantly lower *fruity* aroma (orthonasal) than the other three control samples.

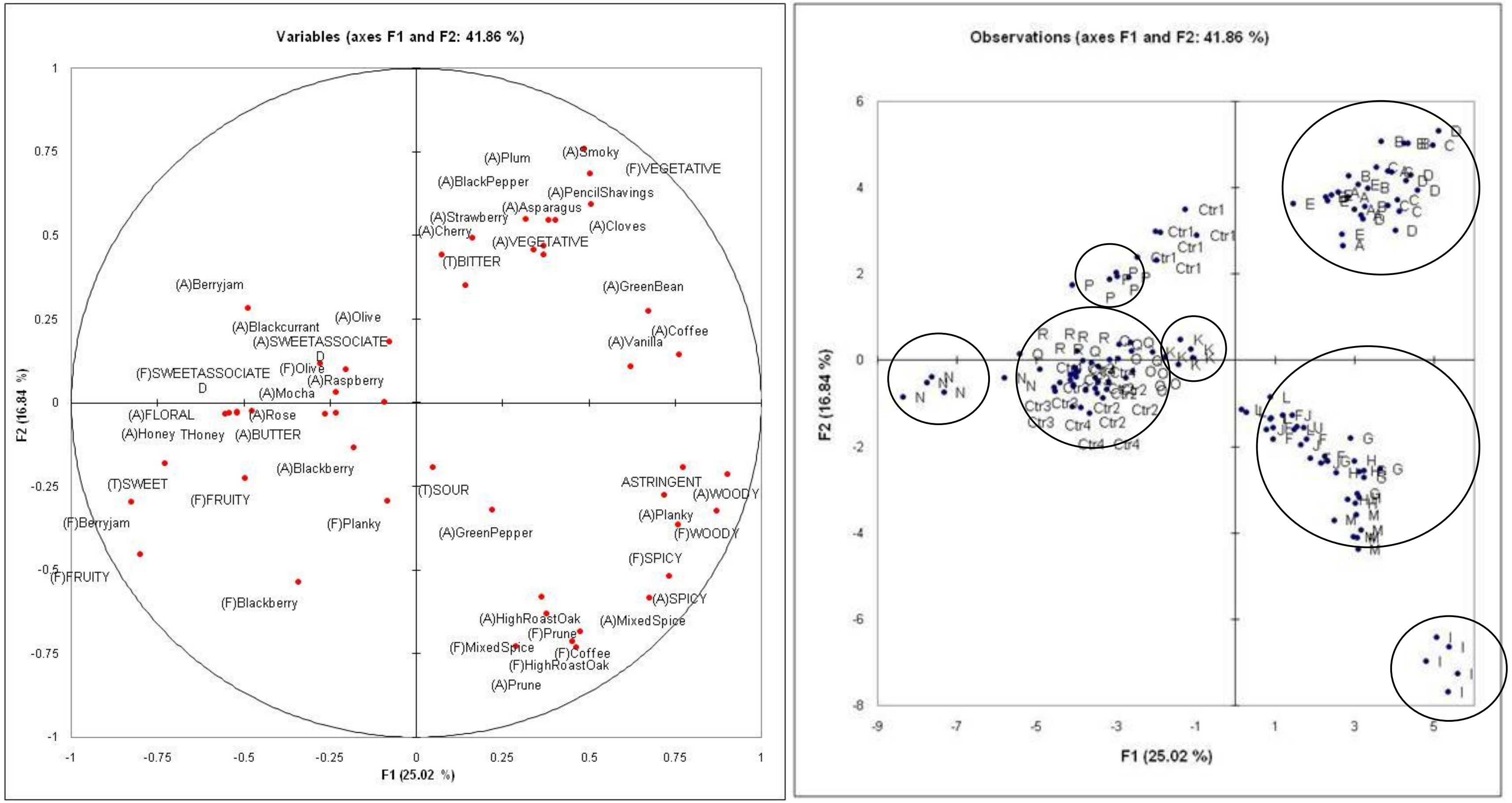

Figure 4 PCA loadings (left) and scores (right) plots for all 18 wines, as well as control samples. Samples are indicated as scores and sensory attributes as loadings. The first two principal components explain 41.86% of the variance. Except for Astringency, the letter ‘A’ ‘F’ and ‘T’ in front of an attribute refer to aroma (orthonasal), flavour/palate aroma (retronasal) and basic taste attributes, respectively. The 18 wines are indicated as A to R, the control samples for Groups 1 to 4 are indicated as 1, 2, 3 and 4, respectively.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

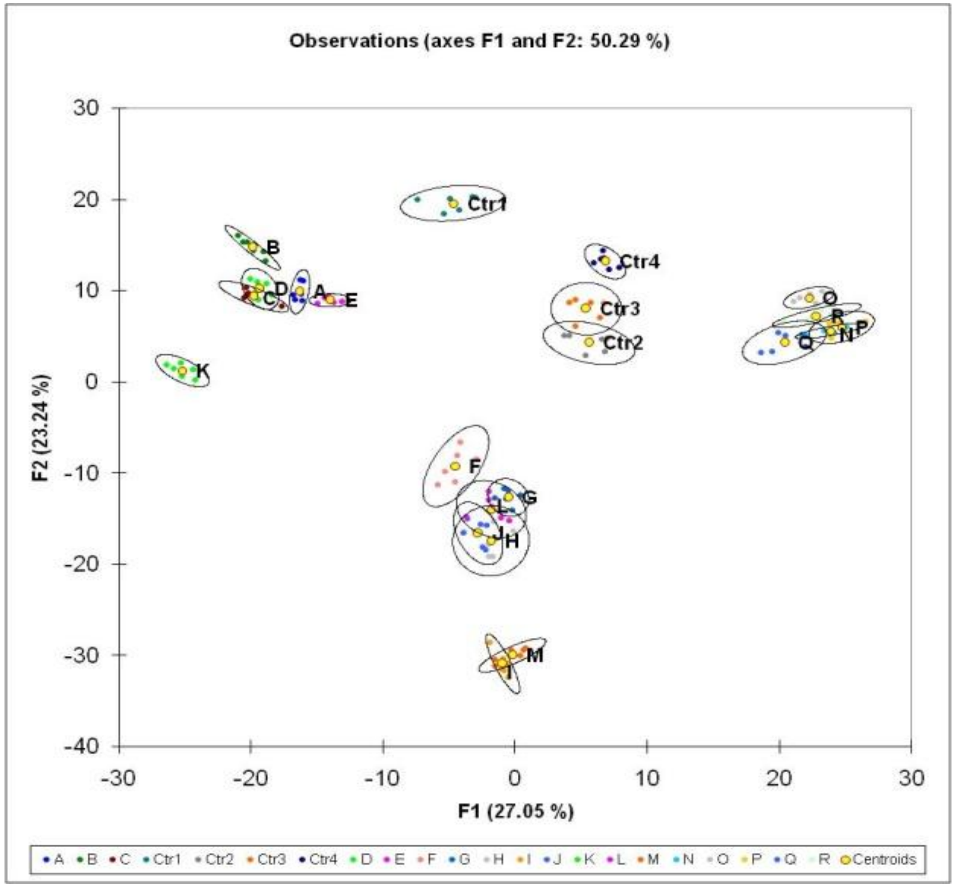

Figure 5 DA plot using data of all 18 wines, as well as the control samples. The wine samples are indicated as A to R, and control samples for Groups 1 to 4 as Ctr1, Ctr2, Ctr3 and Ctr4, respectively.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

Table 3 Orthonasal sensory attributes of all 18 wines (A - R), as well as four control samples (Ctr1, Ctr2, Ctr3 & Ctr4). Samples with different superscripts in the same row differ significantly at the 5% level of significance.

Sensory descriptor	**Samples**																						
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**Ctr1**	**Ctr2**	**Ctr3**	**Ctr4**	**LSD (p=0.05)**
FRUITY	27.31^{jkl}	20.89^{n}	22.67^{mn}	23.03^{mn}	27.63^{ijk}	28.08^{hijk}	28.79^{hijk}	28.50^{hijk}	35.39^{e}	29.50^{ghij}	33.57^{ef}	30.58^{gh}	31.73^{fg}	30.41^{ghi}	38.85^{d}	26.96^{jkl}	24.55^{lm}	26.01^{kl}	49.89^{c}	53.07^{b}	57.58^{a}	54.88^{ab}	2.93
Berry jam	16.28^{de}	11.27^{ghi}	10.02^{hij}	12.36^{fgh}	17.70^{d}	6.73^{k}	8.44^{ijk}	7.97^{jk}	6.02^{k}	15.27^{def}	23.59^{c}	13.51^{efg}	10.06^{hij}	8.58^{ijk}	23.68^{c}	15.98^{de}	12.62^{fgh}	12.13^{gh}	34.40^{a}	23.83^{c}	26.89^{b}	28.71^{b}	2.91
Blackcurrant	2.70^{cd}	2.69^{cd}	3.72^{c}	2.51^{cde}	2.56^{cde}	1.32^{defgh}	1.63^{defg}	0.89^{fgh}	0.19^{gh}	1.80^{def}	1.12^{efgh}	1.82^{def}	1.80^{def}	0.00^{h}	0.00^{h}	0.24^{gh}	0.12^{h}	0.00^{h}	6.08^{a}	11.43^{a}	11.88^{a}	12.72^{a}	1.48
Blackberry	10.58^{cdefgh}	8.21^{hij}	6.52^{ijk}	8.77^{ghi}	11.56^{cdef}	11.90^{cd}	11.54^{cdefg}	11.35^{cdefg}	10.18^{defgh}	11.67^{cde}	5.76^{jkl}	8.91^{efghi}	13.31^{c}	9.68^{defgh}	4.66^{kl}	3.06^{l}	4.42^{kl}	8.87^{fghi}	19.53^{b}	20.44^{ab}	22.33^{a}	23.00^{a}	2.78
Prune	0.39^{e}	0.55^{e}	0.42^{e}	1.01^{e}	0.93^{e}	4.41^{d}	6.05^{e}	7.03^{bc}	17.57^{a}	1.49^{e}	0.59^{e}	0.76^{e}	8.81^{b}	6.94^{e}	1.29^{e}	1.85^{e}	1.61^{e}	0.78^{e}	0.64^{e}	1.52^{e}	0.92^{e}	0.37^{e}	1.84
Raspberry	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.40^{b}	17.69^{a}	0.24^{b}	0.21^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.44^{b}	0.00^{b}	0.45
VEGETATIVE	26.06^{cd}	44.07^{b}	27.86^{c}	27.14^{cd}	27.27^{cd}	23.64^{cde}	17.89^{efg}	16.51^{fg}	8.74^{h}	21.84^{def}	19.84^{efg}	21.62^{def}	16.61^{fg}	9.00^{h}	6.60^{hi}	55.13^{a}	15.46^{g}	18.72^{efg}	6.52^{hij}	0.79^{j}	0.58^{j}	1.02^{j}	6.02
Olive	4.52^{cdef}	6.98^{bcd}	8.24^{bc}	8.67^{cd}	6.88^{bcd}	4.60^{cdef}	7.15^{bcd}	6.40^{bcde}	3.62^{cdef}	6.25^{bcde}	10.74^{b}	8.85^{cd}	3.56^{cdef}	5.33^{bcdef}	2.69^{def}	52.99^{a}	5.75^{bcde}	10.11^{b}	1.32^{ef}	0.00^{f}	0.19^{f}	0.00^{f}	5.45
Green Bean	7.59^{b}	9.99^{a}	6.35^{bcd}	6.22^{bcde}	7.30^{bc}	5.59^{cdef}	5.42^{def}	4.46^{ef}	1.23^{g}	7.28^{bc}	5.46^{def}	4.22^{f}	7.55^{b}	0.00^{g}	0.16^{g}	0.11^{g}	5.32^{def}	0.73^{g}	0.99^{g}	0.00^{g}	0.00^{g}	0.00^{g}	1.81
Asparagus	2.98^{b}	20.91^{a}	3.59^{b}	3.06^{b}	3.03^{b}	2.99^{b}	0.74^{c}	0.89^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.68^{c}	0.21^{c}	0.00^{c}	0.00^{c}	1.33
WOODY	30.24^{e}	27.67^{ef}	36.80^{cd}	35.19^{d}	26.36^{f}	28.53^{ef}	35.14^{d}	41.69^{ab}	41.19^{ab}	39.10^{bc}	9.63^{gh}	36.62^{cd}	44.55^{a}	1.86^{jk}	11.75^{g}	2.55^{ijk}	9.14^{gh}	3.27^{ijk}	5.84^{hi}	5.00^{ij}	1.93^{jk}	0.00^{k}	3.81
Coffee	10.33^{cde}	7.87^{def}	27.08^{a}	21.74^{b}	7.39^{ef}	10.04^{cde}	19.06^{b}	12.89^{c}	10.63^{cd}	0.66^{cd}	5.06^{h}	3.96^{fg}	0.00^{g}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.63^{h}	0.01^{h}	0.36^{h}	0.00^{h}	3.08
Mocha	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.19^{b}	7.07^{a}	0.28^{b}	0.53^{b}	0.57^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.66
Planky	7.39^{bcd}	7.03^{bcde}	5.48^{ef}	5.65^{cdef}	4.68^{fg}	4.93^{f}	7.78^{b}	11.24^{a}	11.99^{a}	1.99^{hi}	1.37^{hij}	2.89^{gh}	7.47^{bc}	1.30^{hij}	5.54^{def}	0.97^{j}	4.67^{fg}	1.73^{hij}	0.98^{j}	0.94^{j}	0.38^{j}	0.00^{j}	1.90
High roast	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	7.23^{d}	6.50^{d}	10.31^{c}	12.19^{c}	25.14^{b}	4.24^{e}	23.31^{b}	34.20^{a}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.93^{f}	0.28^{f}	0.00^{f}	2.17
SWEET ASS.	6.52^{bcd}	4.19^{cdefgh}	6.42^{bcde}	5.73^{bcdef}	6.36^{bcde}	1.78^{ghi}	7.83^{bc}	6.15^{bcdef}	3.08^{defghi}	5.44^{bcdefg}	2.48^{fghi}	$4.94^{bcdefgh}$	3.18^{defghi}	22.90^{a}	6.74	2.74^{efghi}	$4.92^{bcdefgh}$	3.08^{defghi}	8.43^{b}	2.43^{fghi}	1.48^{hi}	0.32^{i}	3.73
Vanilla	1.87^{cde}	1.21^{defg}	2.70^{abc}	3.29^{a}	2.72^{abc}	0.33^{gh}	3.67^{a}	3.57^{a}	1.27^{defg}	3.13^{ab}	0.83^{efgh}	2.23^{bcd}	0.99^{efgh}	0.00^{h}	0.00^{bcd}	0.00^{h}	0.00^{h}	0.00^{h}	1.47^{def}	0.61^{fgh}	0.35^{gh}	0.00^{h}	1.05
Honey	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	$0.\ 00^{c}$	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	16.88^{a}	3.29^{b}	1.81^{bc}	3.70^{b}	1.90^{bc}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.67
FLORAL	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	$0.\ 00^{c}$	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	15.75^{a}	3.22^{b}	2.43^{b}	2.58^{b}	3.11^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.02
Rose	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	$0.\ 00^{c}$	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	14.09^{a}	2.56^{b}	1.71^{bc}	2.30^{b}	2.55^{b}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	1.83
BUTTERY	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	$0.\ 00^{c}$	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	2.01^{b}	1.17^{bc}	0.46^{c}	0.19^{c}	17.38^{a}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	1.54
SPICY	5.92^{de}	4.08^{f}	5.30^{ef}	7.81^{c}	3.57^{f}	3.80^{f}	8.56^{c}	8.54^{c}	25.20^{a}	7.55^{cd}	0.46^{g}	4.25^{ef}	14.05^{b}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{g}	0.47^{g}	0.00^{g}	0.19^{g}	0.00^{g}	1.81
Mixed Spice	3.12^{fg}	2.82^{fg}	2.65^{g}	3.96^{ef}	1.07^{h}	2.42^{g}	5.41^{cd}	5.79^{c}	17.52^{a}	4.54^{de}	0.53^{h}	2.39^{g}	8.38^{b}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}	0.29^{h}	0.01^{h}	0.12^{h}	0.00^{h}	1.20

LSD = Least significant difference at p=0.05; Sweet Ass. – Sweet-associated; 1st tier sensory attributes are indicated in capital letters, 2nd tier attributes are indicated in lower case.

Dry red wine samples: **A**-Nederburg Cabernet Sauvignon; **B**-Nederburg Merlot; **C**-Nederburg Pinotage; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot; **G**-Obikwa Shiraz; **H**-Roodeberg; **I**-Nederburg Ingenuity; **J**-Chateau Libertas; **K**-Namaqua Dry; **L**-Two Oceans Cabernet Sauvignon-Merlot; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet; **Q**-Drostdy Hof Natural Sweet; **R**-Namaqua Johannisberger; **Control** (Ctr1-4)-Tassenberg.

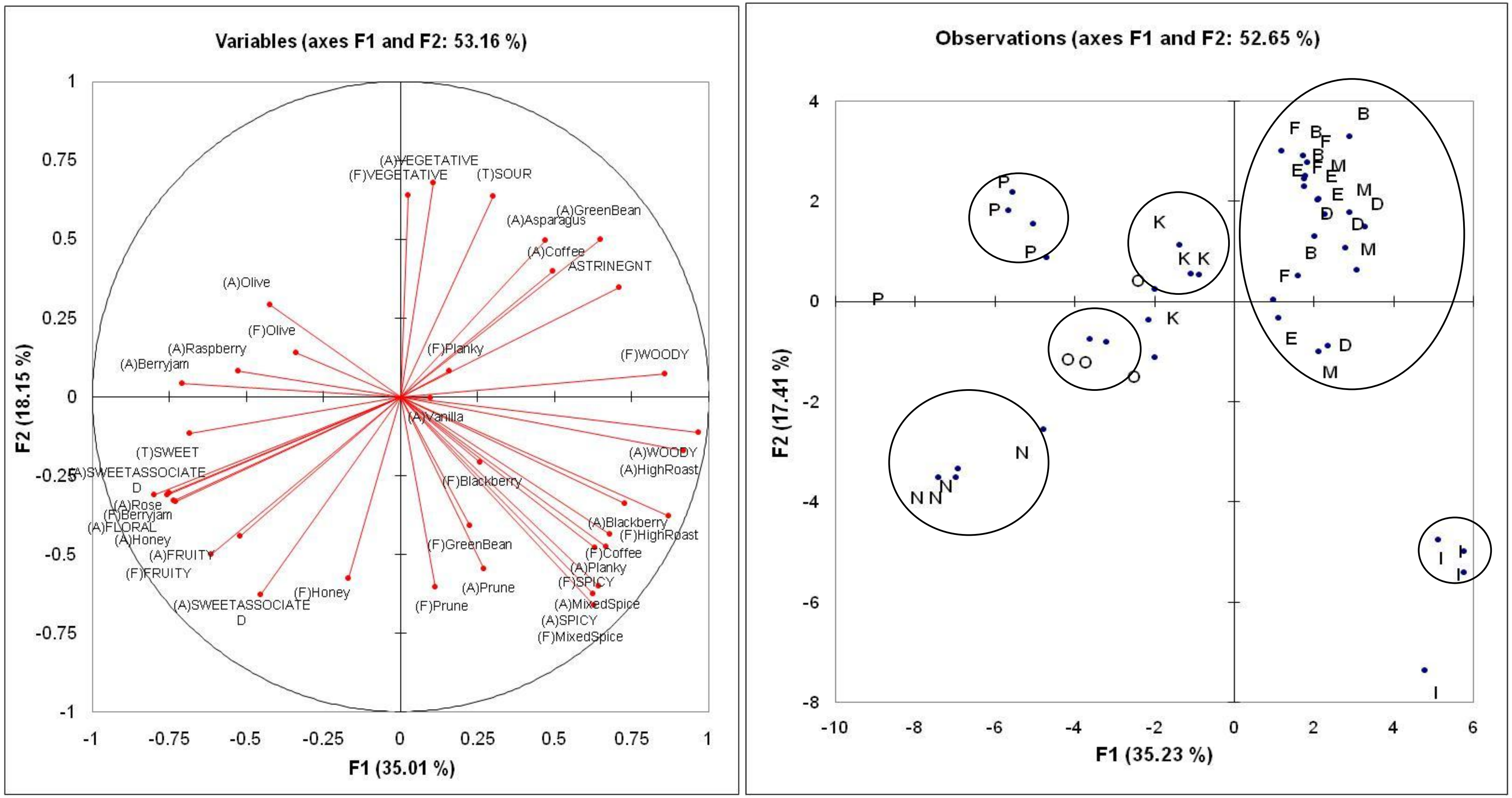

Figure 6 PCA loadings (left) and scores (right) plots for 10 wines. Samples B, D, E, F, I, K, M, N, O and P are indicated as scores; and sensory attributes as loadings. The first two principal components explain 41.86% of the variance. Except for Astringency, the letter 'A' 'F' and 'T' in front of an attribute refer to aroma (orthonasal), flavour or palate aroma (retronasal) and basic taste attributes, respectively.

Dry red wine samples: **B**-Nederburg Merlot; **D**-Nederburg Shiraz; **E**-Nederburg Baronne; **F**-Obikwa Merlot**;** **I**-Nederburg Ingenuity; **K**-Namaqua Dry; **M**-Alto Rouge.

Sweet red wine samples: **N**-Four Cousins Natural Sweet; **O**-Cellar Cask Johannisberger; **P**-Robertson Winery Natural Sweet.

After discussions with statisticians (Personal communication: Prof. Tormod Næs, Nofima, Norway, 2009; Marieta van der Rijst, ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa, 2009) it was deemed important to determine whether the slight shift of the control samples in Figures 4 and 5 actually affected the relative multivariate associations of the 18 wines and their attributes. It was therefore decided to choose a subset of 10 wines (Table 4) from the larger group of 18 wines and repeat the QDA. Samples were chosen from the clusters identified in Figures 4 and 5. For smaller clusters only one sample was identified while two samples were identified from bigger clusters.

After repeating QDA on the ten wines (Table 4) with the same group of sensory panellists, the data were analysed in a similar fashion as described in Chapter 3. The PCA scores and loadings plots (Figure 6), illustrate the association between the *sensory attributes* and the 10 wines. When comparing Figures 4 and 6, similar associations and clustering are illustrated in both PCA plots. This indicates that the above-mentioned shift of the control samples illustrated in Figure 4 did not have a significant effect on the association of the other wine samples, and that both analyses resulted in valid, reliable results.

Table 4 Ten wines illustrating the largest degree of statistical variance, as determined visually from the appropriate PCA and DA plots.

Group	Sample	Brand name	Classification
1	B	Nederburg Merlot	Cultivar wine
1	D	Nederburg Shiraz	Cultivar wine
1	E	Nederburg Baronne	Red blend
2	F	Obikwa Merlot	Cultivar wine
2	I	Nederburg Ingenuity Red	Italian red blend
3	K	Namaqua Dry Red	Dry red blend
3	M	Alto Rouge	Dry red blend
4	N	Four Cousins Natural Sweet Red	Natural sweet red blend
4	P	Robertson Winery Natural Sweet Red	Natural sweet red blend
4	O	Cellar Cask Johannisberger Red	Natural sweet red blend

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CHAPTER 5

General conclusions

This study clearly demonstrated that knowledge of both the intrinsic and extrinsic factors, influencing wine preference are extremely important. It is therefore important for researchers to understand the interplay of intrinsic (sensory) and extrinsic (non-sensory) factors, as both dimensions need to be considered and optimised for a product to be lucrative in the marketplace. The current trend is to explore new wine consumer segments and to develop wine styles that relate to these consumers' specific lifestyles.

The objective of this study was to analyse a range of South African red wines in terms of sensory and chemical attributes, as well as the degree of liking using a target group of black South African consumers consuming wine regularly. According to *Statistics South Africa's* mid-year estimates for 2010, the black consumer constitutes approximately 79.4% of the South African consumer. Potentially they can form a major part of the wine market. Firstly the inherent or intrinsic characteristics of wine, driving preference and secondly, the external or extrinsic factors such as label and price influencing the purchasing decision, were measured. Finally it was determined whether there were segments of consumers that differ in their degree of liking and response to the respective extrinsic cues.

In order to capture as much variation in the sensory profile as possible, the wines selected for this study varied significantly in terms of style. The selection included *dry* and *natural sweet red wines*, as well as low-end inexpensive wines together with high-end, top quality wines. The selection of red wines were industry-selected and consisted of thirteen dry cultivar wines and red blends, as well as five sweet blends.

The sensory attributes of the full range of wines were analysed by characterising the full spectrum of first tier and second tier aroma, flavour, taste and mouthfeel attributes. Data analysis of the sensory profiles of the red wine samples revealed five first tier descriptors for aroma (orthonasal) and flavour (retronasal), which included *fruity*, *vegetative*, *woody*, *sweet-associated* and *spicy*. It seemed that the cultivar specific wines associated with a wider range of sensory descriptors which included *woody*, *vegetative* and *fruity.* The sweet red wines mostly illustrated *fruity* and *sweet-associated* attributes, the latter being mostly *honey* and *floral*.

Regarding the basic tastes (*sweet, sour* and *bitter)* and mouthfeel (*astringency),* the wines were divided by the descriptors *sweet taste* and *astringency*. The sweet red wines predictably scored the highest for *sweet taste*, however, differences were also found between the cultivar specific samples and the dry red blends with the red blends scoring slightly higher for *sweet* taste. As would be expected the mouthfeel attribute *astringency* clearly divided the dry and sweet wines, with the red cultivars and dry red blends scoring 50% more for astringency than the sweet wines.

Chemically there was a significant variance in the alcohol and sugar content of the wines, ranging from the very dry Shiraz with a relatively high percentage of alcohol to the natural sweet red blends with a low alcohol content. Glucose and fructose concentrations showed the inverse pattern, as the sweet red wines had values of up to 30 times higher than that of the dry red wines. For the other principal wine parameters measured, little variation was found across the samples.

GC-FID was used to identify and quantify the major volatile constituents present in the wines. The three main groups, the dominant esters, alcohols and fatty acids, were to a lesser or greater extent present in all the wines. The chemical and sensory profile for only the dry red wine samples were investigated using the odour activity values (OAV) and the odour threshold values (OTH), as obtained from literature. Not all the compounds surpassed the detection threshold and therefore are not likely to have relevance to the global wine aroma as detected by the human nose.

In partial least squares regression (PLS) of the sensory and chemical data it was found that the red blends were driven by the presence of alcohols and esters, and the *woody* sensory descriptors such as *high roast oak,* as well as *coffee* and *mixed spice*, while the red cultivar wines were mostly driven by fatty acids and esters and the vegetative sensory descriptors such as *green bean* and *asparagus*. The sweet red blends were all closely associated with acids, were high in glucose and fructose and illustrated *fruity* and typical *sweet-associated* and *floral* notes such as *honey* and *rose*, being typical sweet wine sensory descriptors. The sweet red wines were characterised by fewer chemical and sensory descriptors compared to that of the dry red wines, the sweet red wines were therefore considered not to have a complex sensory and chemical profile.

The outcome of the above-mentioned results provides a better understanding of the volatile composition and sensory quality of the selected red wines. The results could assist winemakers to optimise winemaking conditions (harvest parameters, juice preparation, fermentation techniques, yeasts used, bacteria and enzymes, etc.) in order to enhance specific wine aromas in the final product, as well as adapt basic taste and mouthfeel attributes. Although the multivariate statistical methods used, indicated associations between chemical and sensory descriptors, more advanced instrumental research is necessary to determine which specific chemical compounds drive orthonasal sensory quality. Further research on a wider range of wine samples is also required to determine the specific chemical drivers of liking, especially to indicate drivers of liking in terms of cultivar.

Consumer analysis was conducted to determine the degree of liking of a subset of the wines, using black consumers from the Western Cape, South Africa. The subset of wines, four dry cultivar wines and blends plus three natural sweet blends were chosen based on sensory results showing the largest degree of variance between them. The consumers evaluated degree of liking of seven red wines in a blind tasting session. In this test the consumers preferred the sweet red wines, illustrating a high glucose and fructose content, as well *fruity, sweet-associated* and *floral* notes, the latter aromas being characteristic of sweet red wines. Sensory results thus indicated that these consumers prefer less complex wines with sensory descriptors that are familiar and easy to recognise.

To determine whether the consumers' degree of liking scores in the blind tasting would result in different clusters or segments of consumers, a clustering technique, discriminant analysis, was applied to the full data set of the degree of liking scores. Four different consumer clusters were identified: Cluster 1, preferred both *dry* and *sweet red wines* equally, Cluster 2 *strongly favoured sweet red wines* and *moderately liked dry red wines*, Cluster 3 *strongly favoured sweet red wines* with little preference for *dry red wines;* and lastly Cluster 4 preferred *dry red wines.* Clusters 2 and 3 contained the larger proportion of the total group of consumers (62%), whereas Cluster 4 only represented 17% of this consumer group.

Purchase intent was also evaluated by viewing actual photographs of the respective wine packaging. The wines were all familiar brands in South Africa, with excellent wine sales nationally and lesser sales in the township areas (Personal communication: D Schmidt, Distell, South Africa, Stellenbosch, 2009). In a test such as this consumers have to indicate the value they ascribe to a specific type or brand of wine. The results were, in a sense, quite opposite to that of the blind tasting. When viewing actual photographs of the wines, the consumers indicated that they preferred the cultivar specific wines with more elegant labels giving a perception of value and style. Even though these samples did not score high in the blind tasting, consumers indicated that they would definitely purchase these wines. When purchasing wines, consumers are not normally able to taste the wines, therefore the appearance and perception of a specific bottle of wine can be regarded as an important driver of choice. Wine marketers should use both the relevant intrinsic and extrinsic factors driving consumer liking when marketing wines. Then consumer will be confronted with a wine that they not only like from a flavour and mouthfeel point of view, but a wine that they value from an appearance point of view.

The socio-demographic data, i.e. gender, age and consumption frequency of wines, were correlated to specific variables and this aided in clustering the consumers into different categories or groups according to their different profiles. Positive interactions where found between consumption and wine sample, gender and wine sample, as well as age and wine sample for most of the consumer concepts tested. This means that degree of liking of the different wines is influenced by the gender, age and frequency of consumption. When viewing the photographs of the respective brands, an association between consumption frequency and purchase intent was also found. This result indicated that there were different attitudes amongst the group of consumers whilst tasting the wines blind versus looking at the outer package and purchasing wines for consumption. Black consumers who drink wine less frequently preferred *Four Cousins Natural Sweet* and *Robertson Winery Natural Sweet*. Both these wines are red blends with a relatively low alcohol content and reasonably high content of glucose and fructose. These brands are also familiar brands within the South African context, known for their *easy drinking* and *affordable price*. It was found that the black consumers that do not drink wine prefer to buy wines that they are familiar with and can relate to, while consumers that drink wine more frequently, enjoy to experiment with more expensive wine brands. It seems that the image of the wine plays an important role, more than actual preference and price.

Consumers were also probed on their general opinions or perceptions on the consumption and purchasing of wines and other alcoholic beverages, as well as the factors that drive these opinions. *Alcohol content*, *label* of the bottle, *vintage*, *price* and *cultivar* were found to be the most important aspects when purchasing red wines, while *awards* and *type of closure* (*screw cap* or cork) are regarded as the least important.

Consumer responses in terms of their opinions and perceptions differed across the four clusters. Cluster 4, who favoured dry red wines strongly, indicated that all the aspects, except *awards* and *screw cap* are important. Cluster 1, who favoured both dry and sweet red wine equally, indicated that all the aspects except *winery, origin, awards*, and *closures* are important when purchasing wines. Clusters 2 and 3 both favoured the sweet red wines. Cluster 2 is of the opinion that *alcohol content, label* and *vintage* are important, whereas Cluster 3 is of the opinion that *alcohol content, label* and *price* are important aspects when purchasing wines. It seems that the discerning wine consumer, who likes high-end wines, takes more aspects into consideration when purchasing wine, whereas the consumer who favours low-end wines only takes a limited number of aspects into consideration.

When comparing the four clusters as a whole, only *label* and *alcohol content* scored reasonably high in all four clusters. This does not indicate that high *alcohol content* is regarded as favourable; it indicates that *alcohol content*, whether high or low is taken into consideration when purchasing wines. From a marketing view point, it seems that it would be beneficial to place more emphasis on the specific alcohol content. This could be done by means of general marketing or by indicating the reduction in alcohol content more prominently on the label. Further investigation should, however, be done on the preferred *alcohol content*, in both blind and informed conditions; among male and female black consumers of different age groups.

The information on these clusters could be of great value to the South African wine industry, especially those wine distributers who are interested in entering the black market as potential point of sale. It is, however, important to note that the results of this study only represent the black consumer residing in the Western Cape. Further research is required to elucidate the degree of liking, wine consumption and purchasing perceptions of black consumers in other areas such as Gauteng.

In conclusion, this study provided an insight into the relative importance of product expectation and actual sensory experience of a selection of South African red wines. Wine marketers should focus on adding value and style to South African sweet red blends. Natural sweet red wines are known for their easy drinking, as well as their relatively low price. Emphasis can also be placed on the alcohol content, and further studies should be conducted in order to determine what consumers prefer when it comes to alcohol content. According to the consumer tasting results, the upper-class black consumer prefers the sweeter red wines. There is thus a major gap for marketing dry style red wines. Focus should be placed on marketing, branding, label, alcohol content and bottle design, all which will aid in the value perception of the final product. This study also indicated that consumers prefer bottled wines significantly more than boxed wines. Currently there is, however, a drive to market wine in a boxed format, it's less expensive and easier to transport. The viability and marketability of this form of packaging amongst consumers therefore needs further research.

A model driving further studies should be developed to understand the role of both intrinsic and extrinsic factors that underline preference, as well as perception of wines. It is also important to ascertain whether there is a *constant change in preference* between wines tested blind, and wines tested in an informed situation. Results pertaining to latter could be used to give an indication to the South African wine industry on how to re-direct the research and development and/or marketing policies, especially with regard to the black consumer in highly populated areas. In the process, consumer demands could be turned into product specifications which are actionable and profitable, a vital requirement for the global wine industry which is hampered by the current economic recession.

ADDENDUM A

Fact sheet data of wines used in this study

Fact sheet data: Aroma, flavour and chemical attributes of eighteen red wines selected for this study using the internet sites as basis.

Brand	Cultivar	Vintage	Aroma attributes	Flavour attributes	Alcohol % Vol	pH	Acidity g/L	RS g/L
Nederburg	Baronne	2008	Prunes Blackcurrant Spicy	Prunes Blackcurrant	13.78	3.6	5.93	3.80
Nederburg	Ingenuity Red	2006	Spice Ripe blackberry Cherry Plum	Ripe Fruit	14.62	3.41	6.13	3.21
Namaqua	Dry Red	2009	ND	Berry fruit	13.0	3.53	5.62	4.22
Namaqua	Johannisberger Red	2009	Strawberry	ND	11.0	3.76	6.07	60.2
Two Oceans	Cabernet Sauvignon-Merlot	2009	Strawberries Cherries	Ripe fruit	13.2	3.63	5.43	5.90
Alto	Alto Rouge	2007	Blackcurrant Plums Dark chocolate Vanilla	Tobacco Chocolate Toast Vanilla	14.48	3.42	6.24	2.60
Chateau Libertas		2008	Ripe berries Spicy	Ripe Berries Plum Oak Spices	13.6	3.49	5.71	1.73
Roodeberg	Red	2007	Smoky Oak	Berries	14.2	3.5	5.62	2.41
Van Loveren	Four Cousins Natural Sweet Red	2009	Rose petal	Ripe plums Strawberries	9.5	3.65	5.3	70.0
Cellar Cask	Johannisberger Red	2009			11.5	3.64	4.9	48.5
Robertson Winery	Natural Sweet Red		Fruit Floral	Cherry Berry	8.32	3.4	6.86	67.2
Drostdy Hof	Natural Sweet Red (Sold as a *Light* wine)	2009	Cherry Plum	Fruity	7.53	3.6	7.53	71.0
Nederburg	Cabernet Sauvignon	2008	Blackberries Blackcurrants Oak	Ripe fruit Oak Spices	14.01	3.68	6.14	2.83
Nederburg	Merlot	2008	Fruit Strawberries Blackcurrant Vanilla	Fruit	14.8	3.53	6.1	3.80
Nederburg	Pinotage	2007	Plum Cherry Oak spices	Rich fruit	13.85	3.57	5.39	4.36
Nederburg	Shiraz	2007	Ripe fruit Berries Oak spice Cloves Dark chocolate	Ripe plum Dark Chocolate	14.05	3.47	5.84	3.64
Obikwa	Merlot	2009	Fruity Plum Red berries Vanilla	Berry Black fruit Red fruit Oak	13.67	3.4	5.67	2.49
Obikwa	Shiraz	2009	Red berries Ripe plums Oak spices	Ripe plums New leather	13.6	3.5	5.70	1.90

RS: Residual sugar, ND: “No Details” available on wine fact sheets.

ADDENDUM B

Questionnaire for QDA training

EXAMPLE OF QUESTIONNAIRE FOR QDA TRAINING

	Control			Sample A			Sample B			Sample C			Sample D			Sample E		
AROMA	Mon	Tue	Wed	Mon	Tue	Wed	Mon	Tue	Wed	Mon	Tue	Wed	Mon	Tue	Wed	Mon	Tue	Wed
Fruity	**60**	**60**		**20**	**20**		**25**	**25**		**30**	**25**		**25**	**25**		**50**	**40**	
Berry jam	30	30		10	10		15	15		20	20					10	10	
Blackcurrant	15	15		5			5			5								
Blackberry	30	30		10	10		10	10		15	15		15	10		25	25	
Prune																40	35	
Raspberry																		
Vegetative				**45**	**45**		**30**	**20**		**30**	**25**		**30**	**30**				
Green Bean				15	15		10	10		10	10		20	15				
Asparagus				20	20													
Olive				10			10			5			0	15				
Woody				**30**	**30**		**35**	**40**		**25**	**25**		**35**	**30**		**30**	**50**	
Coffee				10	10		20	30		10	10		20	20				
Planky				10			5			5						20		
High Roast					20			15			10		20	20		25	30	
Sweet ass.				**10**			**10**	**10**		**10**								
Vanilla							**5**	**10**										
Honey																		
Spicy							**15**	**15**								**40**	**40**	
Mixed Spice							10	10								30	30	
Floral																		
Rose																		
PALATE ATTRIBUTES																		
Fruity	**50**	**50**		**20**	**20**		**15**	**15**		**20**	**20**		**25**	**25**		**50**	**50**	
Berry jam	40	40																
Blackberry	25	25											20	20				
Prune																40	20	
Vegetative				**30**	**30**		**25**	**25**		**20**	**20**							
Olive																		
Woody				**30**	**30**		**35**	**40**		**30**	**30**		**25**	**25**		**60**	**60**	
Planky																		
Coffee													20			30		
High Roast								30						15		40	40	
Spicy																**30**	**30**	
Mixed Spice																25	25	
Sweet ass.																		
Honey																		
Sweet	30	30		20	20		10	20		15	20		20	20		25	25	
Sour	30	30		15	15		10	10		15	15		25	25				
Astringent	20	20		20	20		25	25		20	10		50	40		30	25	

ADDENDUM C

Questionnaire for consumer analysis

NAME OF JUDGE:_______________________________ EMAIL ADRESS:_______________________________ p1.

Questionnaire on red wines - please circle the correct answer

JUDGE NO:________

GENDER:

Male / Female

AGE: 18-23 / 24-29 / 30-35 / 36-40 / 41+

WHAT IS YOUR CURRENT EMPLOYMENT:

Student / Assistant / Administrative / Professional / Retired / Unemployed
Other:

INCOME GROUP: Please give an indication of your MONTHLY or YEARLY income

Monthly: <5,000 / 5,001 – 10,000 / 10,001 - 30,000 / >30,000

Yearly: <60,000 / 60,001 - 120,000 / 120.001 - 360,000 / >360,000

EDUCATION:

Grade 11 (Standard 9) or less / Grade 12 (Matric) / Diploma or Degree

MOTHER TONGUE:

English / IsiXhosa / IsiZulu / Sesotho / Sepedi / Setswana / Other:________

HOW OFTEN TO YOU CONSUME RED WINE:

More than 3 times per week / 1-2 times per week / 2 times per month / Approx 4 times a year / NEVER

HOW OFTEN DO YOU BUY RED WINE:

More than 3 times per week / 1-2 times per week / 2 times per month / Approx 4 times a year / NEVER

HOW DO YOU RATE YOUR KNOWLEDGE OF RED WINE:

No knowledge / Moderate knowledge / Above average / Expert

WINE CONSUMPTION - WHICH OF THE FOLLOWING IS APPROPRIATE?

1. I have never drunk any wine before;
2. I have drunk wine in the past but no longer do so;
3. I will drink wine if there is nothing else available;
4. For me wine is not the first choice but I am open to drinking wine;
5. Quite happy to drink wine

RED WINE CONSUMPTION - WHICH OF THE FOLLOWING IS APPROPRIATE?

- Compared to a year ago, I drink more red wine;
- Compared to a year ago, I drink less red wine;
- Compared to a year ago, I drink the same amount of red wine

LOCATION: Name the Country and City/Town where you have be staying / working over the following time periods:

2010-2005: Country:________________ City/Town: ______________

2004-2000: Country:________________ City/Town: ______________

1999-1995: Country:____________________ City/Town: ______________

1994-1990: Country:____________________ City/Town: ______________

Please turn to page 2

SET 1 - TASTING OF 4 RED WINES

INSTRUCTIONS

- RINSE YOUR MOUTH WITH WATER BEFORE TASTING EACH SAMPLE. TAKE A GENEROUS SIP FROM EACH SAMPLE
- RANK THE SAMPLES ON THE SCALES FOR 1] DEGREE OF LIKING & 2] PURCHASE INTENT. IN EACH CASE, CIRCLE THE CORRESPONDING NUMBER NEXT TO THE PREFERRED ANSWER.

	CODE		CODE		CODE		CODE	
How do you like the TASTE of these wines??	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

	CODE		CODE		CODE		CODE	
Would you BUY these wines??	5	Definitely would buy	5	Definitely would buy	5	Definitely would buy	5	Definitely would buy
	4	Probably would buy	4	Probably would buy	4	Probably would buy	4	Probably would buy
	3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not
	2	Probably would not buy	2	Probably would not buy	2	Probably would not buy	2	Probably would not buy
	1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy

Refresh your mouth with water & Turn to page 3 for more samples

SET 2 - TASTING OF 3 RED WINES

INSTRUCTIONS

- RINSE YOUR MOUTH WITH **WATER** BEFORE TASTING EACH SAMPLE. TAKE A **GENEROUS SIP** FROM EACH SAMPLE
- RANK THE SAMPLES ON THE SCALES FOR 1] **DEGREE OF LIKING** & 2] **PURCHASE INTENT**. IN EACH CASE, **CIRCLE** THE CORRESPONDING NUMBER NEXT TO THE PREFERRED ANSWER.

	CODE		CODE		CODE	
How do you like the TASTE of these wines??	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

	CODE		CODE		CODE	
Would you BUY these wines??	5	Definitely would buy	5	Definitely would buy	5	Definitely would buy
	4	Probably would buy	4	Probably would buy	4	Probably would buy
	3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not
	2	Probably would not buy	2	Probably would not buy	2	Probably would not buy
	1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy

Turn to page 4 for general questions

GENERAL QUESTIONS ON RED WINE

INDICATE HOW APPROPRAITE THE FOLLOWING **OCCASIONS** ARE, WHEN **YOU DRINK** RED WINE

NOT APPROPRIATE 1 2 3 4 5 NOT SURE 6 7 8 9 EXTREMELY APPROPRIATE

Chilling with friends	1___2___3___4___5___6___7___8___9
While having a meal	1___2___3___4___5___6___7___8___9
While watching TV	1___2___3___4___5___6___7___8___9
While watching sports	1___2___3___4___5___6___7___8___9
Pre-dinner drinks	1___2___3___4___5___6___7___8___9
While in a meeting	1___2___3___4___5___6___7___8___9
Entertaining at home	1___2___3___4___5___6___7___8___9
After work	1___2___3___4___5___6___7___8___9
While braaiing	1___2___3___4___5___6___7___8___9
Celebrating, e.g. birthday, wedding etc.	1___2___3___4___5___6___7___8___9

INDICATE HOW APPROPRAITE THE FOLLOWING **VENUES** ARE, WHEN **YOU DRINK** RED WINE

NOT APPROPRIATE 1 2 3 4 5 NOT SURE 6 7 8 9 EXTREMELY APPROPRIATE

At home	1___2___3___4___5___6___7___8___9
At a friend's place	1___2___3___4___5___6___7___8___9
Restaurants / Hotels	1___2___3___4___5___6___7___8___9
Tavern / Shebeen	1___2___3___4___5___6___7___8___9
Bar / Pub	1___2___3___4___5___6___7___8___9
Wine farm	1___2___3___4___5___6___7___8___9
Night Club	1___2___3___4___5___6___7___8___9

INDICATE HOW IMPORTANT THE FOLLOWING **ASPECTS** ARE WHEN **YOU BUY** RED WINE

NOT IMPORTANT 1 2 3 4 5 NOT SURE 6 7 8 9 EXTREMELY IMPORTANT

Price of the wine	1___2___3___4___5___6___7___8___9
Label of the wine	1___2___3___4___5___6___7___8___9
Awards, e.g. Veritas Gold	1___2___3___4___5___6___7___8___9
Vintage / Year of release, e.g. 2009	1___2___3___4___5___6___7___8___9
Cultivar, e.g. Merlot, etc.	1___2___3___4___5___6___7___8___9
Cork as type of closure	1___2___3___4___5___6___7___8___9
Screw cap as type of closure	1___2___3___4___5___6___7___8___9
Origin of production, e.g. Paarl, etc.	1___2___3___4___5___6___7___8___9
Brand or Winery, e.g. Kanonkop	1___2___3___4___5___6___7___8___9
Alcohol level	1___2___3___4___5___6___7___8___9

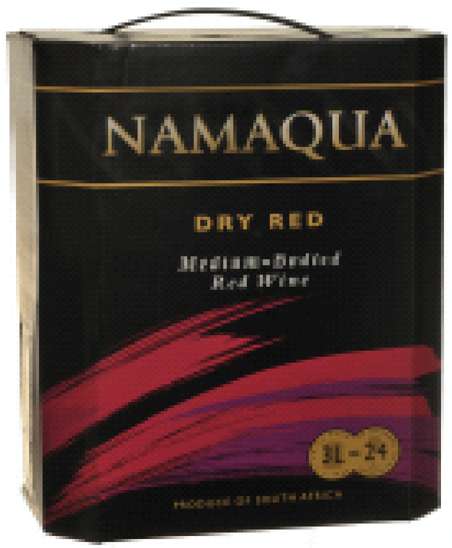
HOW IMPORTANT IS IT FOR YOU TO DRINK WINE WITH THE FOLLOWING **PERSONS**?

NOT IMPORTANT 1 2 3 4 5 NOT SURE 6 7 8 9 EXTREMELY IMPORTANT

With my partner	1___2___3___4___5___6___7___8___9
With my family	1___2___3___4___5___6___7___8___9
With my friends	1___2___3___4___5___6___7___8___9
With business colleagues	1___2___3___4___5___6___7___8___9
Other (Give example): ______	1___2___3___4___5___6___7___8___9

Please turn to page 5 for some further general questions

SET 3: Would you BUY these wines? In each case, CIRCLE the number of your preferred choice.



CODE		CODE		CODE	
5	Definitely would buy	5	Definitely would buy	5	Definitely would buy
4	Probably would buy	4	Probably would buy	4	Probably would buy
3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not
2	Probably would not buy	2	Probably would not buy	2	Probably would not buy
1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy

Please turn to page 7 for the next set of photos

SET 3: Would you <u>BUY</u> these wines? In each case, <u>CIRCLE</u> the number of your preferred choice. p7.

CODE		CODE		CODE		CODE	
5	Definitely would buy	5	Definitely would buy	5	Definitely would buy	5	Definitely would buy
4	Probably would buy	4	Probably would buy	4	Probably would buy	4	Probably would buy
3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not	3	Maybe / Maybe not
2	Probably would not buy	2	Probably would not buy	2	Probably would not buy	2	Probably would not buy
1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy	1	Definitely would not buy

THANK YOU FOR YOUR ASSISTANCE!

HAND YOUR QUESTIONNAIRE IN AT THE DOOR, BEFORE COLLECTING YOU GIFT VOUCHER