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SciVerse ScienceDirect

Food Research International 53 (2013) 464–475

Contents lists available at SciVerse ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Association of selected viniviticultural factors with sensory and chemical characteristics of New Zealand Sauvignon blanc wines

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ARTICLE INFO

Article history:
Received 22 March 2013
Accepted 25 May 2013
Available online 4 June 2013

Keywords:
3MH
3MHA
Grape harvesting
Sauvignon blanc
Sensory

ABSTRACT

The major aim of this study was to investigate associations between selected grape-growing and winemaking factors and sensory and chemical characterisation of Sauvignon blanc wines from New Zealand. Thirteen commercial Sauvignon blanc wines produced by the same wine-making team were assessed. The 13 wines included several produced under 'standard' Marlborough wine-production conditions from machine-harvested fruit, whilst other wines were produced from hand-harvested fruit, each exemplifying a particular viticultural (e.g., location) or oenological (use of oak) factor assumed to influence wine composition and sensory profile. The wines were evaluated organoleptically via several sensory methods (sorting; descriptive rating) by 28 New Zealand wine professionals. Varietal impact compounds, 3-mercaptohexan-1-ol (3MH), 3-mercaptohexyl acetate (3MHA), 4-mercapto-4-methylpentan-2-one (4MMP), and 3-isobutyl-2-methoxypyrazine (IBMP) were quantified in each wine. We show that machine-harvested-fruit wines had significantly elevated concentrations of 3MH and 3MHA, and were perceived overall as fruitier, less acidic, and as having better concentration, balance and persistence in mouth than the Sauvignon wines made from hand-harvested fruit. The Sauvignon blanc wine produced by indigenous fermentation in older oak was rated significantly higher in perceived intensity, length, palate weight, and balance than most of the other wines. The study demonstrated that vineyard location, row orientation, type of grape processing at harvest, and oenological manipulations provide means for influencing sensory profile and chemical composition of Sauvignon wines.

1. Introduction

Sauvignon blanc has been described as a relatively simple white wine (Masneuf-Pomarede, Mansour, Murat, Tominaga, & Dubourdieu, 2006), its characteristic varietal aroma due to relatively few volatile compounds. The sensory qualities and chemical compounds that contribute significantly to the perceived varietal character of Sauvignon blanc, *Vitis vinifera* L. var. Sauvignon blanc, have been the subject of much recent research (e.g., Benkwitz et al., 2012a,b; Capone & Jeffery, 2011; King et al., 2010; Marais & Swart, 1999; Parr, Green, & White, 2006; Parr, Green, White, & Sherlock, 2007, Parr, Valentin, Green, & Dacremont, 2010; Pena-Gallego, Hernandez-Orte, Cacho, & Ferreira, 2012; Tominaga, Baltenweck-Guyot, Peyrot des Gachons, & Dubourdieu, 2000; Tominaga, Furrer, Henry, & Dubourdieu, 1998).

Research quantifying the chemical compounds in Sauvignon wines that are considered to contribute the specific fruity and green characters reported as salient to varietal Sauvignon's flavour profile has focused on several thiol (e.g., Tominaga et al., 2000) and methoxypyrazine (e.g., Allen, Lacey, Harris, & Brown, 1991) compounds. Two thiol compounds in particular, 3-mercaptohexan-1-ol (3MH) and 3-mercaptohexyl acetate (3MHA), have been argued as important to the aroma profiles of Sauvignon blanc wine (Benkwitz, Tominaga, et al., 2012; Lund et al., 2009; Mateo-Vivaracho, Zapata, Cacho, & Ferreira, 2010; Tominaga et al., 2000). With respect to wine source-of-origin, Lund et al. (2009), Mateo-Vivaracho et al. (2010), and Green, Parr, Breitmeyer, Valentin, and Sherlock (2011) all reported high concentrations of these compounds in New Zealand Sauvignon wines relative to Sauvignons from other locations. Another thiol compound, 4-mercapto-4-methylpentan-2-one (4MMP), has also been reported as contributing boxwood and/or fruity notes to Sauvignon wines (Green et al., 2011). The methoxypyrazine compounds that are considered important in contributing perceived, green characteristics to wines, notably Sauvignon blanc and Cabernet Sauvignon, are 3-isobutyl-2-methoxypyrazine (IBMP) and 3-isopropyl-2-methoxypyrazine (IPMP). Green capsicum notes are regularly attributed to IBMP (e.g., Allen et al., 1991; Parr et al., 2007), while other vegetal characteristics (e.g., asparagus) are more

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http://dx.doi.org/10.1016/j.foodres.2013.05.028

often attributed to IPMP (Allen et al., 1991; Parr et al., 2007). However, these compounds occur in wine in trace concentrations, have extremely low detection thresholds (Allen & Lacey, 1999; Allen et al., 1991) and are difficult to measure accurately. In the present study we measured concentrations of IBMP only as IPMP concentrations are often too low for valid comparisons between wines to be made.

Other researchers have focused on the sensory characteristics of Sauvignon blanc wines, providing data that show both northern hemisphere and southern hemisphere Sauvignon wines' varietal character to be dominated by fruity notes and 'green' (green capsicum; grassy; vegetal) characters. The exact perceived flavour notes and chemical composition of the wines studied appears to be influenced by wine source-of-origin (Green et al., 2011; Mateo-Vivaracho et al., 2010). The fruity characters most often reported include passionfruit, grapefruit/citrus notes, gooseberry, stone-fruits (e.g., peach; nectarine), and tropical fruits (e.g., guava; pineapple). As well as fruity notes, 'green' characteristics appear essential to Sauvignon wines judged as typical of some locations. These include green capsicum characters in high-typicality New Zealand Sauvignon (Green et al., 2011; Parr et al., 2007), grassy notes in Sauvignons from Sancerre, France (Parr et al., 2010), and herbaceous notes in Sauvignons from Saint Bris in Burgundy, France (Parr et al., 2010).

The sensory profile and chemical composition of a wine can be altered by both viticultural (i.e., grape-growing) and oenological (i.e., wine-making) manipulations (e.g., Jones, Gawel, Francis, & Waters, 2008). Grape and wine processing operations have been shown to influence chemical composition of wines, including Sauvignon blanc (Baiano et al., 2012; Capone & Jeffery, 2011; Murat, Tominaga, & Dubourdieu, 2001). The literature is less clear however as to the way(s) in which grape and wine processing operations influence the sensory profile of Sauvignon wines. In the current study, several viticultural and oenological factors relevant to production of New Zealand Sauvignon blanc wines were associated statistically with sensory qualities and impact chemical compounds. Selection of the vitivinicultural factors to include in the present study had its basis in both current practices in Marlborough wine production and from results of a recent study (Parr, Mouret, Blackmore, Pelquest-Hunt, & Urdapilleta, 2011) that was aimed at understanding the nature of complexity in wine. Results demonstrated that wine professionals' conceptualisations of complexity in wine were dominated by reference to oenological processing operations (e.g., use of oak barrels; type of yeast used to ferment the juice), and viticultural factors (e.g., vineyard site; fruit ripeness) several of which were investigated in the current study.

Sauvignon blanc wine in Marlborough, New Zealand is most often produced in a style considered fruit-driven and relatively free from winemaker influence. That is, Marlborough Sauvignon wine is typically produced in the following way: grapes are grown on vines planted in north–south oriented rows to encourage even ripening of fruit on both sides of the row; the grapes are machine harvested and then processed relatively reductively (i.e., little opportunity for contact with oxygen during crushing and pressing operations); the musts are inoculated with commercial yeasts and fermented in stainless steel vats at temperatures between 12 °C and 18 °C. On the contrary, hand-harvesting of fruit, use of older oak barrels for fermentation or maturation of Sauvignon musts and wines, and other oenological manipulations aimed at increasing complexity or aging ability in the finished wines (e.g., use of indigenous yeasts; batonnage or lees stirring) are practised by a small number of producers only.

The present study involved sensory and chemical characterisation of thirteen Sauvignon blanc wines. All wines were produced in Marlborough in commercial quantities by the same commercial wine producer and were made by the same winemaking team. Three of the wines were produced in the 'standard' way described above, whilst ten wines exemplified a specific viticultural and/or oenological factor of interest. These ten wines were each produced by selecting and controlling a range of viticultural and oenological factors considered as possible sources of enhanced complexity in Sauvignon wines. The factors are summarised in Table 1.

Viticultural factors included (i) harvesting all fruit, or just the shaded fruit (south side of a vineyard row), from vines planted in east–west oriented rows; (ii) fruit from 'old' vines (27 years); and (iii) all fruit from the Awatere Valley, a sub-region of Marlborough known for producing Sauvignon wines with relatively high levels of IBMP (Parr et al., 2007) and a distinctive sensory profile (Trought et al., 2010). Finally, a fourth viticultural manipulation considered was hand-harvesting of fruit (9 wines) versus machine-harvesting (4 wines). This type of processing operation, along with skin contact time and must temperature, recently has been shown to influence chemical composition of Sauvignon blanc grape musts (Capone & Jeffery, 2011). Capone and Jeffery investigated concentration of thiol precursors in Sauvignon blanc grapes that were hand- versus machine-harvested and reported approximately 70% less precursor 3-S-glutathionylhexan-1-ol and 65% less 3-S-cysteinylhexan-1-ol in the hand-harvested fruit compared to machine-harvested fruit. The authors suggested increased berry damage from the latter type of harvesting relative to hand-harvesting as the likely source of the result. In the present study we extended this recent work on the influence of grape processing operations by investigating sensorial as well as chemical aspects of the wines.

Oenological factors considered in the study included (i) natural fermentation of the must in a 3-year-old, 228-litre, oak barrique; (ii) 4.5% of the wine subjected to French oak (228-L barrels) for 150 days; (iii) inoculation of the must with a specific, commercial

Table 1
Sauvignon wines employed in the study. All wines were Marlborough, New Zealand, Sauvignon wines from the 2009 vintage. TA = total acidity expressed as g/L tartaric acid equivalent; RS = residual sugars; SO_2 = sulphur dioxide.

Wines ID	Description	Ethanol % v/v	TA g/L	pH	RS	Dry extract g/L	Free SO_2 mg/L	Total SO_2 mg/L
WF3yob	Hand harvested fruit; wild ferment in 3 year old, 228-L Vicard barrel, Awatere Valley fruit	13.7	9.56	3.16	5.5	24.5	28	146
X5Yst	Hand harvested fruit; yeast X5	14.8	8.48	3.18	4	19.8	24	109
AwatereF	Hand harvested fruit; Awatere Valley fruit	14.1	7.89	3.19	1.5	15.7	27	128
Oldvines	Hand harvested fruit; old vines (planted 1982)	12.3	10.63	3.07	5.5	23.5	21	129
LgWoodFe	Hand harvested fruit; large wooden ferment: Vicard cuve	14	10.29	3.13	2.3	20.1	23	124
StainLSt	Hand harvested fruit; stainless steel tank	14.3	9.71	3.12	3.5	20.1	22	133
ShadEWV	Hand harvested fruit; shaded-side fruit of east–west vine	14.7	8.38	3.19	2.7	18.3	24	106
EWVCoqP	Hand harvested fruit; all fruit east–west vines, Coquard press	14.5	9.81	3.07	3.3	20.1	27	127
PichiYst	Hand harvested fruit; *Pichia kluyveri* yeast	14.6	8.24	3.16	5.8	20.3	22	118
MES	Machine harvested fruit; 4.5% in French oak for 150 days	13.9	7.43	3.3	3.1	17.2	18	106
MVS	Machine harvested fruit; standard wine production	12.8	7.1	3.39	4.2	18.3	21	109
MRS	Machine harvested fruit; standard wine production	13.6	6.97	3.35	2.8	18.3	23	118
STS	Machine harvested fruit; standard wine production	13.2	7.32	3.36	3.4	16.7	23	125

yeast, X5 (Zymaflore, Laffort, France); (iv) inoculation of the must with *Pichia kluyveri* yeast (non-commercial preparation: see Anfang, Brajkovich, & Goddard, 2008); (v) fermentation in a standard, stainless steel vat; and (vi) fermentation of the must in a large oak vessel, namely a 7-year-old, 10,000 l, Vicard oak cuve, the tapering shape of which gives a lower surface area to volume ratio than does a barrique and therefore an assumed more subtle oak impact. Three of the wines were produced entirely in the standard way; i.e., by inoculation of musts with commercial yeast, followed by fermentation and subsequent wine maturation taking place in stainless steel tanks.

1.1. Sensory methodologies

A range of sensory procedures was employed for purposes of sensory evaluation of the thirteen wines in the study. Our aim was to provide a breadth of data concerning the wines' perceived qualities via both analytical (descriptor intensity ratings) and global (sorting; typicality rating: see Parr et al., 2007, 2010) evaluations, rather than by employing a single methodology (e.g., descriptive rating of pre-selected sensory characters) with subsequent replication. The purpose of employing a range of sensory evaluation tasks for participants was aimed at providing evaluation methodologies that have been argued previously as evoking different types of cognitive processing (see Parr et al., 2007), and therefore different perspectives on the stimuli (i.e., the wines). For example, Manetta, Sales-Wuillemin, Gaillard, and Urdapilleta (2011), in a study investigating perception and representation of fragrances, demonstrated that the type of sensory task (triadic task or sorting task) influenced participants' representations of the fragrances. Collectively, data from a range of tasks can therefore provide a broad or wide view of the products of interest.

The descriptive rating task involved participants rating intensity of selected, specific Sauvignon characteristics. Analytical tasks such as rating intensity of specific characteristics (e.g., passionfruit aroma; astringency) are considered relatively data-driven (e.g., Dalton, 2000), encouraging a participant to focus on a specific property of the wine. An assumption underlying the method is that a wine's bouquet or taste is composed of separate, analysable sensory characteristics that participants can perceive separately. On the other hand, global evaluation tasks such as sorting or classifying wines into groups require a participant to employ an overall evaluation of the wine and are assumed to include top-down cognitive processing (e.g., memorial and decision-making processes involving previously-stored knowledge and experience) that are assumed to be less-involved in analytical, descriptor rating. This makes sorting tasks particularly suited to studies that employ domain-specific 'expert' participants (see Parr et al., 2011) such as wine professionals. Classification of wines is likely to involve some type of pattern-recognition cognitive process (Lawless, 1997) such that experience with the product of interest is an important factor influencing ability to undertake the task. Further, the free-sorting task, in requiring participants to organise the wines in keeping with criteria that they select, allows participants to favour some criteria and neglect others (Manetta et al., 2011), meaning that a person's experience with the products of interest is an important influence in their sorting behaviour. In the current study, we limited the participant group to wine professionals only. However, in a related study (Schlich, Medel, Parr, Urbano, & O'Connell, in preparation) we considered familiarity of the thirteen wines reported in this study by employing participants of another culture (French) and with a more diverse range of experience (wine consumers; wine connoisseurs; oenologists). Finally, global evaluation tasks such as typicality ratings and sorting tasks allow for the influence of low-impact compounds, and even sub-threshold odorants and taste stimuli, in the overall perception of a wine in a way that descriptive ratings to selected key characteristics (usually high-impact odorants or tastants) of a wine do not.

Recently, sorting task methodologies have been extended beyond merely asking participants to classify products (e.g., classification based on perceived similarities and/or differences) to also provide qualitative data. This typically involves asking participants to provide sensory descriptors that reflect the criteria the participants used to undertake their sorting (see Parr et al., 2010; Santosa, Abdi, & Guinard, 2010). The descriptors can then be quantified and employed to help interpret the underlying dimensions that result from any quantitative analysis of the sorting data.

To summarise, the aim of the present study was to investigate several of the major viticultural and oenological factors implicated in prior research as important to (i) sensory qualities of Sauvignon wines, and (ii) concentrations of selected chemical compounds considered important to the characteristic varietal expression of New Zealand Sauvignon wines. A feature of the sensory component of the study was employment of a range of sensory methodologies for participants to use to assess the wines.

Several hypotheses were elaborated. These had their basis in (i) factors reported as relevant to complexity in wine by Parr et al. (2011) and (ii) in relation to prior research concerning Sauvignon wine production (e.g., Anfang et al., 2008; Capone & Jeffery, 2011). First, we predicted that wines produced from fruit that were machine-harvested would be perceived as more intense and "typical" with respect to key flavours than wines made from hand-harvested fruit and would show higher concentrations of thiol compounds previously reported as important to Sauvignon blanc aroma and flavour. Second, we predicted that wines produced from fruit grown in a specific location, namely the Awatere Valley, or from vines in rows oriented east–west, would show higher levels of IBMP and be reported as having 'greener' flavour profiles than would the other wines in the study. Finally, we predicted that Sauvignon wines subjected to oenological processing operations of oak treatment, indigenous fermentation, and fermentation with *P. kluyveri* yeast would be perceived as "less typical" of New Zealand Sauvignon wine than would wines made using more standard oenological processing (i.e., where fermentation was initiated by inoculation with commercially available yeast and carried out in inert vessels such as large stainless steel tanks).

2. Materials and methods

2.1. Sensory methods

2.1.1. Participants

Twenty-eight wine professionals with extensive experience of New Zealand Sauvignon wines served as participants. Mean age of the 28 participants was 38.29 years (age range = 27–59 years), and there were 10 females and 18 males. Participants included oenologists and winemakers (N = 23), wine producers, and winery analytical (laboratory) staff. Nine participants were also formally designated wine judges. Three participants reported that they were smokers. Mean number of years of wine industry experience was 13.8 years (range = 5–30 years).

2.1.2. Wines

Thirteen commercial Marlborough Sauvignon blanc wines from the 2009 New Zealand vintage were employed in the experiment. The wines, listed in Table 1, comprised three standard-production wines, and ten non-standard wines. The wines were selected by senior wine professionals not participating in the study as spanning a range in terms of price points and wine styles. The non-standard wines included those where the wine making included oenological processes not typically practised in Marlborough Sauvignon wine production (e.g., older oak maturation; indigenous yeast fermentation) along with wines produced from fruit classified in terms of specific viticultural factors (e.g., specific location; fruit from the shaded side of east–west planted rows). These details can be seen in Table 1. A decision to not adjust acidity in the wines in the study was made to minimise wine processing operations that had potential to introduce confounding factors.

2.2. Design and procedure

The study was conducted at the sensory facilities of the Marlborough Wine Research Centre, Blenheim, New Zealand, in a session that lasted approximately 2 h. All sensory data were collected on the one day to avoid the likely attrition of participants that could occur if the wine professionals were required to undertake the tasks across more than a single visit to the facilities. The experimental design was a fully within-subject design where every participant evaluated every wine via every task. The order of the tasks was the same for each participant. Three to six people participated at any particular time. Participants were welcomed to the sensory facilities and seated in separate booths. The environment of the sensory facilities was controlled as advised for sensory experimentation (ASTM, 1986). Participants were provided with basic information about the study, following which they signed a consent form in keeping with ethical requirements. They were advised that they would taste and make judgments about thirteen wines and that all wines were Sauvignon blanc. They were not given any other information about the study.

The wines were served at an ambient temperature, and were first checked for faults by at least two experienced wine professionals. Fifty-millilitre samples were then poured into standardised tasting glasses (ISO, 1977) that were opaque (black) to eliminate visual cues as sources of information. The glasses were coded with 3-digit numbers and were covered with plastic Petri dishes. In order to limit carry over effects and memory biases, all wine samples were presented in a different order specific to each participant according to a Williams Latin square arrangement generated by FIZZ software (Biosystemes, Courtenon, France). Water was available throughout each session.

Each participant was presented with their unique order of the 13 wines, plus a warm-up wine positioned to the left of the flight of 13 wines. Participants were advised that they were to smell and taste each wine in the order presented, and that all wine was to be expectorated (i.e., not swallowed). Participants were first asked to sample and expectorate the warm-up wine but to not make any written responses to this wine. The warm-up wine was a Marlborough Sauvignon wine from the same vintage as the experimental wines and was employed for the purposes of coating a participant's oral mucosa with wine prior to the sampling of wines on which data would be collected. Participants then undertook four tasks, a descriptive rating task, a typicality rating, a liking rating, and a sorting task, in that order. Participants were advised that they were to proceed with the tasks at their own pace, and that they were welcome to take a short (e.g., 10-minute) break between tasks or at any other time should they so choose.

For the descriptive task, participants rated each wine on intensity of eleven specific flavour descriptors that had been employed in our previous studies (Green et al., 2011; Parr et al., 2007, 2010) and nine other wine characteristics considered relevant (see Table 2). There were two orders of the eleven flavour descriptors in Table 2: odd numbered participants rated the descriptors in a random order (Order 1), whilst even-numbered participants rated the eleven descriptors in Order 2 (the reverse order of Order 1). The descriptors had been selected on the basis of their reported salience to Sauvignon blanc wine in our prior studies, and their importance from a chemical perspective (e.g., Tominaga et al., 2000). The other 9 wine characteristics were rated in the same order by all participants. Flavour intensity was rated via a 100 mm, horizontal visual analogue scale (VAS: see Parr et al., 2007) anchored by the word "absent" on the left-hand side and the word "extreme" on the right-hand side. The nine other wine characteristics (intensity and persistence of bouquet, sweetness, sourness, bitterness, heat (alcoholic sensation), astringency, acid/flavour balance, and palate weight) were rated via a similar VAS scale with "weak" at the left-hand end and "very strong" at the right-hand end.

Table 2
Characteristics evaluated in the descriptive rating task.

Gooseberry	Intensity of bouquet (nose only)
Mineral/smoky/flinty	Persistence of bouquet (nose only)
Leafy/stalky/vegetal	Sweetness
Grassy	Sourness
Herbaceous	Bitterness
Green capsicum	Heat (alcoholic sensation)
Grapefruit/citrus	Astringency
Boxwood/broom/sweaty/cat's pee	Palate weight
Tropical	Acid/flavour balance
Stone-fruit	
Passionfruit	

Participants then rated each wine on a typicality scale and on a liking scale. The typicality rating scale was employed as in Parr et al. (2007), where instructions were given as follows: "Please now rate the wine as to how good you think it is as an example of Marlborough Sauvignon blanc wine". The typicality scale comprised a 100 mm VAS scale with the words "poor example" to the left-hand end and "very good example" to the right-hand end. The liking scale was a 100 mm VAS scale with the words "strongly dislike" to the left and "strongly like" to the right.

Finally, participants were asked to categorise the 13 wines, using a non-directed sorting task. They were asked to again smell and taste each wine in the order presented and then to sort the wines into groups using any criteria that were meaningful to the participant. The experimenters did not specify the number of groups or categories that the wines could be sorted into. Participants were asked to draw a box on their data sheet for each category they defined, and to insert the code numbers of the wines into the relevant box. Participants were also asked that once they had sorted the wines into groups, they provide 3–4 descriptors alongside the relevant box of wine-code numbers to explain the criteria on which their sorting was based. For example, participants were asked the following: "Now, can you please provide 3 or 4 words to tell us why you have put the wines into these groups. For example, what do the wines within a group have in common, or what do they have that the wines in other groups don't have?".

2.3. Physico-chemical analyses

Wine samples (40 mL in 2 × 20-mL sample bottles) from each of the 13 wines were collected in triplicate at the time of the sensory study. They were immediately frozen for subsequent chemical analyses. An additional 500 mL per wine was used for the determination of standard wine parameters.

2.3.1. Analysis of standard wine parameters

Standard wine laboratory parameters of total acidity, residual sugars, pH, ethanol, and volatile acidity were measured using a WineScan FT 120 Fourier Transform Infrared Spectrophotometer (Foss, Hillerød, Denmark). Samples were analysed in quadruplicate and parameters were quantified using a high-input calibration file, which was routinely used for the assessment of commercially produced wines at the Pernod Ricard New Zealand winery in Blenheim, New Zealand. Relative standard deviations (RSD) were exclusively lower than 10%. The total dry extract was calculated using the concentration of ethanol as well as the specific gravity of the sample (method OIV-MA-AS2-03B:2009 in OIV, 2012 and based on Wagstaffe, 1974), specific gravity of samples being determined using an Anton Paar DMA 4500 density meter. Free and total SO_2

were determined by flow injection analysis using a FIAStar 5000 analyser (Foss) fitted with free and total SO_2 method cassettes (5000-070 and 5000-080 respectively). The procedure followed that described in the manufacturer's Application Note AN5270 (based on Dubernet & Grasset, 1998), where total SO_2 was determined by injection of samples into a phosphate buffer solution (pH 8.4), reaction with 5,5′-dithio-bis(2-nitrobenzoic acid) (DTNB) at 50 °C, and then the intensity of the yellow reaction product formed measured at 420 nm using a digital dual wavelength detector. The same procedure was used for determining free SO_2, except that the sample was first injected into a water carrier, acidified with 1 N HCl to liberate gaseous SO_2, this then diffusing through a gas permeable membrane to be likewise dissolved in phosphate buffer (pH 8.4) and analysed accordingly.

2.3.2. Chemicals and gas chromatography–mass spectrometry (GC–MS) consumables

GC–MS columns and consumables were purchased from Agilent Technologies (Santa Clara, CA, USA) unless otherwise stated. All standard chemicals were purchased from Sigma Aldrich (St. Louis, Missouri, USA) as were the natural methoxypyrazine standard 3-isobutyl-2-methoxypyrazine (IBMP) and its deuterated analogue 3-($^2H_3$)-isobutyl-2-methoxypyrazine (IBMP-d3). Volatile thiol 4-mercapto-4-methylpentan-2-one (4MMP) was purchased from Interchim (France), 3-mercaptohexan-1-ol (3MH) from Acros Organics (Geel, Belgium), and 3-mercapthexyl acetate (3MHA) from Oxford Chemicals (Hartlepool, UK). The 4MMP internal standard 4-methoxy-2-methyl-2-mercaptobutane (4M2M2MB) was supplied by Frutarom (Wellingborough, UK), whereas the deuterated internal standards, 3-mercapto-1-$^2H_2$-hexan-1-ol (3MH-d2) and 3-mercapto-1-$^2H_2$-hexyl acetate (3MHA-d2) respectively, were synthesised at the University of Auckland (Hebditch, Nicolau, & Brimble, 2007). 4-Hydroxymercuribenzoic acid sodium salt (pHMB, 95%), butylated hydroxyanisole (BHA), L-cysteine hydrochloride hydrate (99%) and DOWEX (1X2, Cl^--form, strongly basic, 50–100 mesh) were purchased from Sigma Aldrich (St. Louis, Missouri, USA). Ethyl acetate (≥99.7, Fluka, Castle Hill, NSW, Australia) and dichloromethane (for gas chromatography, SupraSolv, Merck, Darmstadt, Germany) were used as solvents. 5,5′-Dithiobis(2-nitrobenzoic acid) (99%) was sourced from Acros Organics (Geel, Belgium). Helium (instrument grade) and nitrogen (food grade) were supplied by BOC Gases NZ Ltd. (Blenheim, New Zealand). All water used for the analysis of compounds on the GC–MS was of ultrapure quality generated by a Millipore water purification system (Merck Millipore, Billerica, MA, USA).

2.3.3. 3-Isobutyl-2-methoxypyrazine (IBMP) analysis

IBMP was quantified by using a stable isotope dilution assay (SIDA) approach which made use of Head Space-Solid Phase Micro Extraction (HS-SPME) GC–MS technology. Sample preparation involved pipetting 2 mL of wine and 6 mL of de-ionised water into a 20-mL SPME sample vial followed by the addition of 3 g sodium chloride and 50 μL internal standard solution, which resulted in a final concentration of 35 ng/L IBMP-d3. Samples were then adjusted with 2 mL sodium hydroxide (4 M) before they were capped and vortexed vigorously. Adsorption of the headspace volatiles, including IBMP, to the SPME fibre (Supelco DVB/CAR/PDMS, 2 cm, 50/30 μm) was achieved by sample pre-incubation at 40 °C for 5 min followed by fibre exposure to the sample. After 40 min of adsorption, the fibre was transferred by a COMBI PAL autosampler (CTC Analytics AG, Zwingen, Switzerland) to the injection port of the GC (Agilent 7890A) ready for desorption of the volatiles onto a polar Supelcowax-10 (30 m × 250 μm × 0.25 μm) and a non-polar Equity-1 (15 m × 320 μm × 0.25 μm) bi-column. The injector was operated at 250 °C with helium as carrier gas at 112 kPa and a flow rate of 17.12 mL/min. Samples were injected in splitless mode for 1 min and the split vent was set up to 12 mL/min for 5 min whilst the air flow was fixed at 1.0 mL/min. SPME fibres were thermally cleaned for 10 min after each injection by using a PAL SPME Fiber Conditioning Station, which was operated at 250 °C under constant N_2 flow (6 mL/min). The GC oven program started at 35 °C for 3 min, increased to 100 °C at a rate of 8 °C/min and was finally ramped up to 250 °C at 10 °C/min and held for 9 min resulting in a total run time of 60.63 min. The mass spectrometer conditions (Agilent 5975C) were set to 250 °C with the ion source working in electron impact mode (70 eV, 230 °C) and a quadrupole temperature of 150 °C. IBMP was analysed in selected ion monitoring mode and set to register values for ions 127 and 154 (IBMP-d3) as well as for ions 124 and 151 (IBMP). Calibrations were undertaken at a range between 0 and 50 ng/L for IBMP and showed good linear correlations resulting in r^2 values in the 0.99-ranges. The m/z ratio of 124/127 was used to quantify IBMP in wine.

2.3.4. Volatile thiol extraction and quantification

For the quantification of volatile thiols the reversible thiol-binding properties of a mercury salt combined with dichloromethane extraction and subsequent quantification via GC–MS were utilised. This method was originally developed by Tominaga, Murat and Dubourdieu (1998) and was developed further as follows. Five millilitres of 1 mM pHMB and 0.5 mL of 2 mM BHA were added to 50 mL of wine together with an internal standard mixture (75 μL) resulting in 1670 ng/L of 3MH-d2 and 170 ng/L of 3MHA-d2 as well as 70 ng/L of the non-wine thiol 4M2M2MB in the wine sample. After pH adjustment to 7 with NaOH, the sample was loaded onto an activated (0.1 M HCl) and pre-rinsed (ultrapure water) strongly basic anion exchange column (DOWEX resin). Samples were then slowly passed through the resin (one drop/5 s), the column washed with 0.1 M sodium acetate buffer (pH 6) before the bound thiols were released from the resin by eluting them (one drop/7 s) with 50-mM L-cysteine–HCl solution (400 mg in 50 mL 0.1-M sodium acetate buffer) adjusted to pH 6. The eluate was extracted twice with 4 and 2 mL of dichloromethane after addition of 0.5 mL of ethyl acetate. Each time, the lower organic phase was recovered and then dried over anhydrous sodium sulphate, filtered through silanised glass wool and then concentrated under a flow of nitrogen to ~50 μL prior to GC–MS analysis.

The same GC–MS hardware was used as described in the IBMP analysis section but the GC was equipped with a HP-Innowax capillary column (60 m × 250 μm × 0.25 μm) and was setup for liquid injection. The injector was operated at 240 °C with helium as carrier gas at 112 kPa and a flow of 14.8 mL/min with the split vent set to 12 mL/min 1.5 min after injection. One microlitre of sample was injected in pulsed splitless mode and was delivered onto the column with a constant helium flow rate of 0.8 mL/min. The initial oven temperature (50 °C for 5 min) was ramped to 115 °C at a rate of 3 °C/min, was then raised to 150 °C at 40 °C/min, held for 3 min, further raised to 173 °C/min at 3 °C/min, and then finally reaching an end temperature of 250 °C (70 °C/min) where it was held for 20 min to bake out the column. The mass spectrometer interface was set to 250 °C, with the ion source working in electron impact mode (70 eV at 230 °C) and the quadrupole operating at 150 °C. Thiols were analysed in selected ion monitoring mode and quantified by comparing the area of the quantifier ions (75, 116 and 134 for 4MMP, 3MHA and 3MH, respectively) with the concentration of the respective internal standards 4M2M2MB, 3MHA-d2 and 3MH-d2 (134, 118 and 136). 5,5′-Dithiobis(2-nitrobenzoic acid) was used to determine the concentration of the thiol standards needed to generate calibrations curves (Riddles, Blakeley, & Zerner, 1979). Standard curves were obtained with 10 calibration points by adding increasing quantities of the reference standards to 50 mL of low-thiol Sauvignon blanc wine (10–100 ng/L for 4MMP; 40–2200 ng/L for 3MHA; 200–12,000 ng/L for 3MH). The linear regressions for all thiols were found to be very good (r^2-values in the 0.99 range) with recoveries around 100%. RSDs lower than 10% were generally achieved for all three quantified thiols.

2.4. Data analysis

2.4.1. Sorting task quantitative data

The sorting task data were converted to define a square matrix containing in cell (i,j) the number of subjects having grouped both wines i and j into the same group; the larger this number, the more similar wines i and j were perceived to be. This similarity matrix was analysed by ordinal multidimensional scaling (MDS: Proc MDS, SAS/STATS 9.3), a multivariate technique defining Euclidean optimal representations of the wines in a low-dimensional space (most often bi-dimensional).

2.4.2. Sorting task qualitative data: category descriptors

The analysis approach to the category descriptors produced by participants to explain their sorting rationale was modelled on that described by Santosa et al. (2010) in their study investigating consumer perceptions of extra virgin olive oils. First, key themes were identified from the terms produced by all 28 participants. The themes were consistent with wine-description categories produced in a prior study that investigated how wine consumers and wine professionals mentally represent the concept of complexity in wine (Parr et al., 2011). Second, similar words and phrases were grouped into the key categorical themes in order to reduce the data and a table was produced (Table 3). Themes with four or less terms were omitted from the table and the specific terms reclassified into the most appropriate remaining categorical theme. This resulted in 25 categorical themes as per Table 3.

From these qualitative data (i.e., the grouped descriptors provided by participants to explain their sorting criteria), a matrix containing wines as rows and categories as columns was constructed with the numbers of participants having described each wine (through their grouping) by each verbal category. This matrix was analysed by correspondence analysis (CA), a multivariate technique producing a low-dimensional representation of both wines and verbal categories in which proximities between wines and verbal categories can be interpreted as preferential associations between them.

2.4.3. Descriptive data

Ratings to VAS scales for each experimenter-provided descriptor were quantified in terms of a number between zero and 100, with 0.5 gradations. For each sensory attribute a two-way analysis of variance (ANOVA) was conducted and, for those having a significant wine effect, each mean was compared to the grand mean. The significant attributes were also grouped according to their correlations. The results of these analyses are presented (see Table 5) as a Flash table (Porcherot & Schlich, 2000). In order to get a map of the product drawn from these significant attributes, a canonical variate analysis (CVA) of the product effect in the two-way MANOVA model was run.

Table 3
Qualitative analysis of participants' words and phrases used to describe sorted categories in the free sorting task employing the 13 wines.

Key themes	V. code	Words or phrases used to describe the sorted categories
Well balanced; well structured	wellbal	Well balanced, good balance, good acid balance, balanced acidity, good length, more length, good structure, good palate, like palate structure, broad, greater length
Poor balance; lacks structure	poorbal	Poor balance, poor acid balance, unbalanced, flat palate, light acid, flat, out of balance
Intense; concentrated	intense	Intense, intense nose, intense fruit, very rich palate, good intensity, intensity on nose, concentrated, full body, big body & structure, moderate weight, moderate concentration, moderate/good weight, good intensity, more alcoholic
Lacks intensity	lackint	Lacks intensity, lacks concentration, light, lean wine, thin palate, lighter weight, dilute, poor palate weight, not much palate weight, complex but dilute, thin, low pungency, less pungent, subtle
Low quality; simple	lowqual	Bulk wine, basic, simple
Good varietal character; high typicality	varietal	Good varietal character, varietal definition, varietal characters on nose, primary aromas and flavours, high typicality, good example Marlborough, typical Marlborough Sauvignon on nose & palate, Marlborough style, more classical style, medium typicality, average example, good flavour profile, good flavour
Green & ripe	Gr&ripe	Green & ripe, combination of tropical & herbal spectrums, balance of green & tropical, balance of ripe/unripe, middle ground between categories 1 & 3, ripe-green balance of aroma & flavour, green characters but ripe fruit, middle ground between 1 & 3
Low varietal character, low typicality, not ripe	atypical	Low varietal character, not very varietal, low in thiols, not so boxwood/passionfruit, not typical Marlborough, lack varietal definition, not typical, alternative style, foreign looking, not Marlborough, different, not very typical, not aromatic, down on aroma, low flavour profile, lacks flavour, more alternative style, not so thiol boxwood, passionfruit; unripe; not tropical; less ripe.
Phenolic, bitter	phenolic	Bitter, phenolic textures, bitterness, astringent
Green characters	green	Green, green spectrum, greener, green characters, green stalky aromas & flavours, greenness, green back palate, tinned peas/asparagus, minty, fresh herbs, grass, grassy style, strong green capsicum, vegetal, tight green
Sweet	sweet	Sweet long finish, sweet nose, sweet, sweeter, sweetness, sweet fruit
Fruit; ripe; not herbaceous	fruity	Passionfruit, thiols, high thiols, more passionfruit, stone-fruit, ripe stone-fruit, apricot, citrus, orange, lemon, citrusy, citrus dominant, some citrus, tropical, ripe, guava, ripe spectrum notes on nose, riper styles, tropical fruit, more tropical, riper wines, not herbaceous, stewed/stewed fruit, gooseberry, pungent fruit, juicier palate, juicy, some fruit but more citrus
Oak, wood, barrel	oak	Oak, oaky, oak dominant nose & palate, wooded style, burnt, smoky, toasty, barrel ferment, partial barrel fermentation
Floral; confectionary	floral	Floral, high floral similar to Gewurztraminer, very floral and Muscat-like, perfumed, confectionary notes, lolly
Sweaty/boxwood	sweaty	Sweaty, sweat bomb, strong sweaty characters, more sweaty, overly sweaty, boxwood/cat urine
Mineral, flinty	mineral	Flinty, mineral, chalky, mineral characters on nose, some minerality
Wine production characters	MLFyst	Wild yeast, MLF (malo-lactic fermentation), toffee/caramel, hot fermentation characters, lees contact aging, yeasty, more yeasty, lees, winemaker influenced, extractive skin aromas & flavours, possible MLF, hot ferment character
Overall quality; textural; complex	quality	Good, premium wine, Ok wine, interest factor, complex, textural, good wines
Acidic, tight palate	acid	Acid, sour, aggressive, malic acid, broad acid, high acid, linear acidity, searing, broader acid style, acidic, more acid, high acidity, too acidic, acid driven, higher acid, tight palate, light acid
Sulphide, high SO_2	pungent	High SO_2, higher SO_2, good sulphide, sulphide, reduced, smells like onion, garlic, reductive, gassy nose, aged characters, aged, aged Sauvignon blanc
Dusty, cardboard	dusty	Cardboard/pulp, strong dusty aroma, dirty, not clean, slightly dusty aroma, slight chemical
Herbal	herbal	Very herbaceous, pungent herbal, herbaceous, herbal
Soft/easy to drink	soft	Soft, soft mouth-feel, soft acid, not astringent, softer, soft easy palate, food friendly, not always astringent
Vibrant, fresh	fresh	Vibrant, up-front, fresh, zingy, more zingy, young
Terroir, location	terroir	Austrian Sauvignon, Awatere sub-region, Wairau sub-region, warmer site, cooler site, less leaf plucking, clay soil, not New Zealand

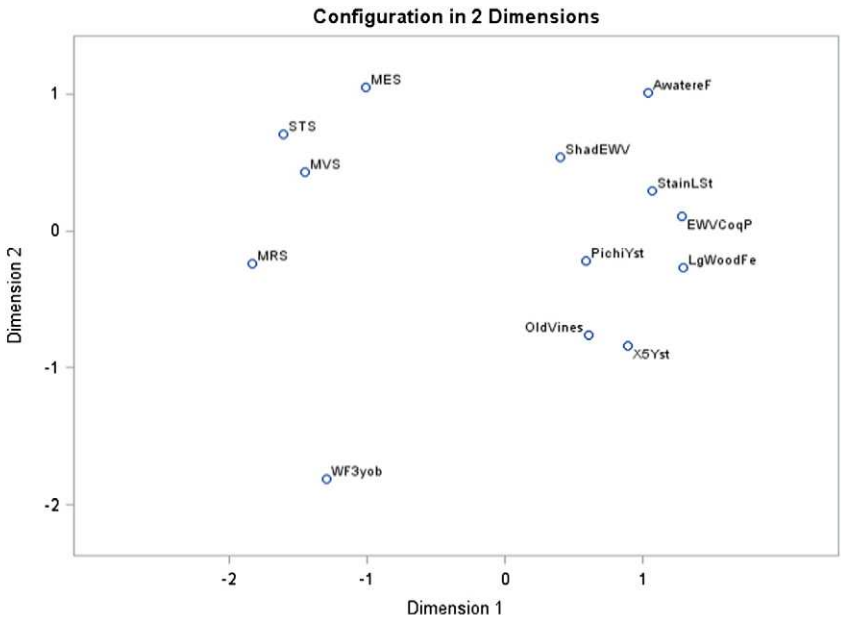

Fig. 1. Wine perceptual map obtained by multidimensional scaling of free-sorting task data obtained from a panel of New Zealand wine professionals.

3. Results

3.1. Sensory characterisation

3.1.1. Sorting task

The data from the sorting task were subjected to multidimensional scaling (MDS). A bi-dimensional MDS solution was selected since it provided a STRESS value of 0.1315, a value generally considered to be a good fit of the original similarities by the Euclidean distances in the map. It is clear from Fig. 1 that the wine professionals perceived differences amongst the wines, on average sorting the 13 wines into three groups. The three standard-production wines (MRS, MVS, STS) were grouped together along with the fourth wine produced from machine-harvested fruit (MES). The other nine wines comprised two groupings, one with wine WF3yob (natural fermentation in older oak) in a group on its own and the other eight wines comprising the third grouping. To understand what factor(s) led to this perceptual separability of the wines, the sorting-task category descriptors (participant-provided descriptors) and the experimenter-provided, descriptive rating data were each considered.

3.1.1.1. Sorting task category descriptors. The descriptors provided by participants to describe the characteristics defining each category they had formed in the free-sorting task were tabulated (Table 3) and analysed qualitatively and quantitatively to assist in understanding the sorting task results. CA was performed on the data in Table 3, with the 25 category descriptors associated with the 13 wines. The first two axes of the correspondence analysis, accounting for 55% of the total information, produced a wine by verbal category map which is depicted in Fig. 2. Fig. 2 demonstrates that several

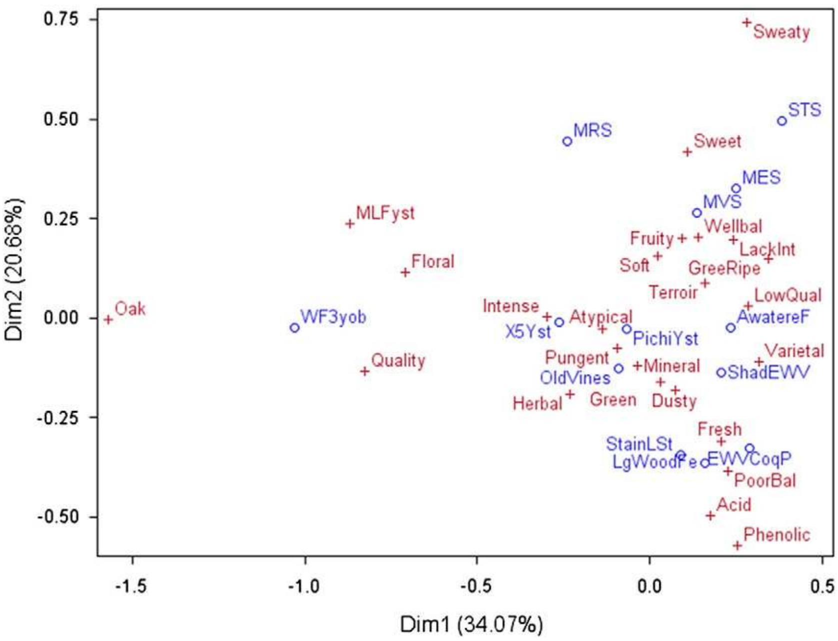

Fig. 2. Correspondence analysis associating participant-generated descriptors to their sorted categories with the 13 wines.

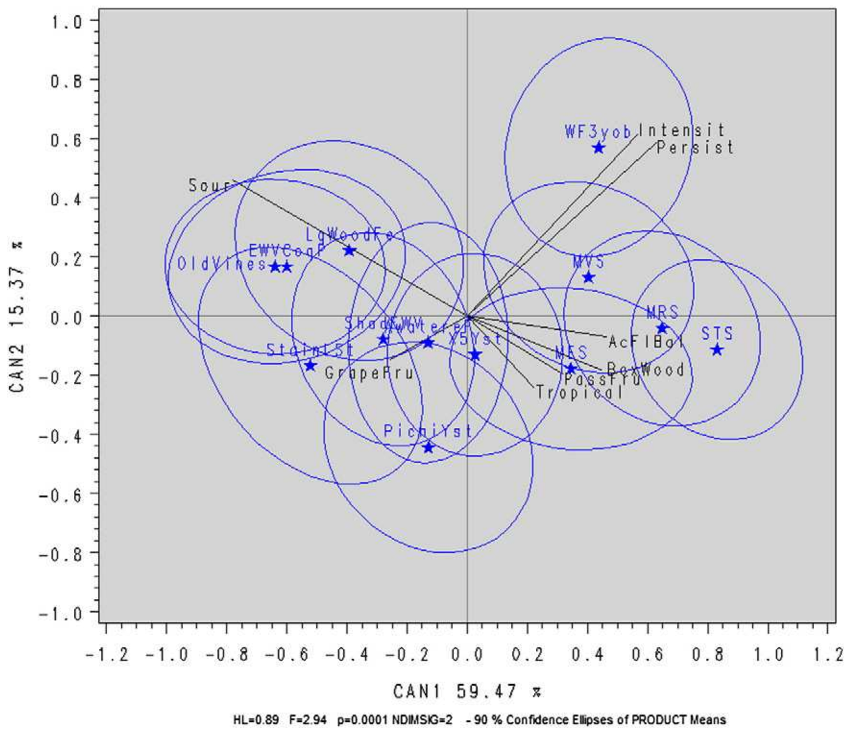

Fig. 3. Wine map from canonical variate analysis (CVA) of the 8 sensory descriptors discriminating significantly ($p = 0.05$) the 13 wines, superimposition of these descriptors by their correlation coefficients with the axes, and superimposition of the wine confidence ellipses (areas where each wine could have been located with a probability of 0.90, given the individual variability and a binormal assumption of individual distribution).

descriptors assumed importance in their contribution to the perceptual separability of the wines. Characteristics 'sweaty' and sweet' separated the machine-harvested-fruit wines (MES, MRS, MVS, STS) from the other wines. Horizontally, the machine-harvested-fruit wines separated in the CA plot from the wine in a group on its own, namely WF3yob. This latter wine was characterised by descriptors of 'oak', malolactic and yeasty characters, and the term "quality". In contrast, 'acid', 'phenolic', and 'poor balance' associated with the other eight wines.

3.1.2. Descriptive rating

The data from intensity ratings to the experimenter-provided descriptors including perceived typicality and wine liking were subjected to ANOVAs. Canonical variate analysis (CVA) was then performed on these data and the output in terms of the first two dimensions is presented in Fig. 3 where the eight descriptors that reached statistical significance ($p = 0.05$) are plotted with the 13 wines. The first dimension, accounting for 59.47% of the variance, shows the four machine-harvested-fruit wines opposing the majority of the other wines. The machine-harvested-fruit wines associated with wine qualities perceived to be positive in Sauvignon wines, namely intensity and persistence of bouquet, good acid/flavour balance, and higher intensities of thiol-related flavours of boxwood, passionfruit, and tropical. It is clear that the data support our first hypothesis in that a major factor in perceived separability of the wines was the type of grape processing at time of harvest.

To further support our first hypothesis, the descriptor ratings' data were subjected to a one-way ANOVA where the independent variable comprised machine- versus hand-harvesting of fruit. Table 4 shows the eight descriptors that reached significance in this analysis. The data in Table 4 suggest that passionfruit and boxwood, flavours assumed related to concentration of varietal thiol compounds, were factors contributing to the discriminability of the machine-harvested-fruit wines from the wines that were produced from hand-harvested fruit. A second factor likely to have driven discriminability of the wines was perceived sourness, the hand-harvested, non-standard wines being on average higher in perceived sourness and total acidity (Table 1) than the machine-harvested-fruit, standard-production wines.

To explore perceived differences amongst the nine hand-harvested wines, given that they separated into two categories, a subset of the data comprising descriptive rating data to these nine wines only, was taken for further analysis. Table 5 shows a flash table of the output with the twelve descriptors showing significant effects included. The statistically-significant effects are highlighted in terms of whether a mean was significantly higher or lower than the overall mean. Three clusters of attributes were defined. The first one gathers attributes related to the green and sour characteristics of the wines and distinguishes EWVCoqP, AwatereF and ShadEWV. Table 5 shows that these wines that were considered a priori as likely to have greener sensory profiles, namely those made from Awatere fruit and from fruit of the two east–west orientation vineyard rows, were on average rated significantly higher on herbaceous, grassy, green capsicum, gooseberry and sourness. The second cluster is related to the intensity and the persistency of the wines and distinguishes the indigenous fermentation wine, WF3yob, which was judged

Table 4
Mean descriptive ratings of intensity of wine characteristics as a function of type of fruit harvesting: Hand harvesting (9 wines) versus machine harvesting (4 wines). Ratings to descriptors not reported in the table failed to reach significance ($p = 0.05$).

Flavour	Machine	Hand	F	Prob
Passionfruit	53.5	42.4	26.41	0.0003
Boxwood	57.7	43.9	24.25	0.0005
Sour	38.8	51.6	11.28	0.0064
Tropical	51.8	45.8	8.37	0.0146
Grapefruit/citrus	50.8	56.7	7.75	0.0178
Persistence	58.6	47.4	6.44	0.0276
Intensity	60.9	50.5	6.26	0.0294
Acid/flavour balance	53.4	45.1	6.17	0.0304

Table 5
Mean ratings to the 12 significant descriptors for each of the nine hand-harvested wines. Means significantly ($p = 0.05$) lower or higher than grand mean are highlighted.

Attribute	F	PROB	Grand mean	OldVines	X5Yst	PichiYst	WF3yob	StainLSt	LgWoodFe	AwatereF	ShadEWV	EWVCoqP
Herbace	5.18	0.0000	43.3	31.9	32.4	35.3	42.2	45.9	47.3	50.4	51.0	53.0
Grassy	2.11	0.0360	39.3	36.9	32.4	32.0	35.1	44.2	39.4	48.4	44.4	41.1
GreenCap	3.71	0.0000	38.8	32.3	29.8	29.8	35.7	39.3	44.1	44.6	43.2	50.7
Goosberr	5.31	0.0000	45.6	39.6	38.3	38.2	35.7	50.8	54.1	44.4	54.4	54.6
Sour	7.07	0.0000	51.6	63.3	44.0	43.5	44.0	53.0	57.5	48.1	52.3	58.8
Intensit	5.29	0.0000	50.5	48.1	51.6	43.6	69.7	45.7	49.7	48.7	49.4	48.3
Persist	6.92	0.0000	47.4	42.0	49.9	40.1	67.2	39.9	50.0	47.8	46.1	43.9
PalaWght	5.75	0.0000	48.2	36.9	51.1	48.7	62.1	47.3	46.6	48.2	47.1	46.4
AcFlBal	2.80	0.0060	45.1	34.8	48.4	49.7	55.7	43.0	40.7	47.0	45.6	41.3
Heat	2.39	0.0170	38.0	32.5	41.8	42.4	36.5	37.0	33.5	38.4	45.5	34.7
Sweet	3.35	0.0010	37.6	31.1	41.8	48.8	36.1	37.8	30.5	36.4	39.5	36.7
Mineral	2.84	0.0050	51.7	50.5	58.4	52.1	61.6	47.1	46.2	56.2	46.1	47.1

significantly higher on these attributes. The third cluster is related to sweet and quality-type attributes and again distinguishes WF3yob wine which was rated higher on palate weight, acid/flavour balance, and minerality. Fig. 4 shows the two first axes of the CVA of these 12 attributes and accounts for 69% of the total discrimination among wines. This map suggests that the wines can be considered in terms of four different groups. The most distinctive group is composed of WF3yob wine only, this wine characterised mostly by its intensity, persistency (length), and palate weight. In an orthogonal direction, the remaining wines are split into three groups according to their sweet to sour gradient: the sweetest wines were PichiYst and X5Yst and the sourest wines were LgWood Fe and EWVCoqP, with wines OldVines, StainLst, ShadEWV and AwatereF in between.

3.1.3. Typicality and liking

The data comprising ratings of Marlborough Sauvignon typicality and wine liking were associated and the output presented in Fig. 5 which shows several results. First, two of the three machine-harvested-fruit, standard-production wines, STS and MVS, were perceived as significantly higher in Marlborough typicality. Conversely,

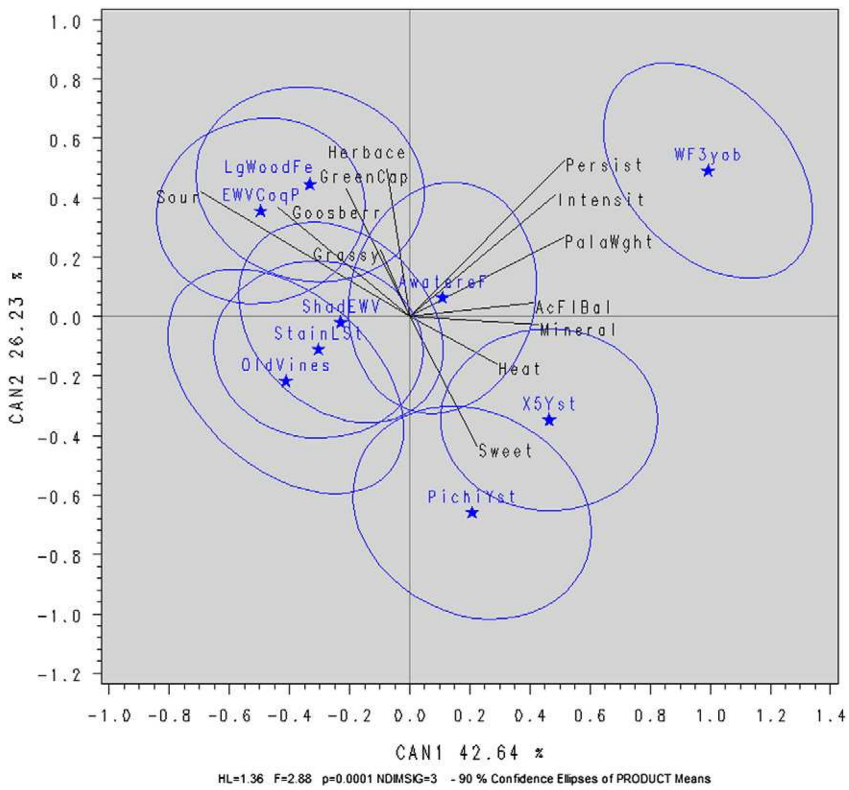

Fig. 4. Wine map from canonical variate analysis of the 12 sensory descriptors discriminating significantly ($p = 0.05$) the 9 non-standard wines, superimposition of these descriptors by their correlation coefficients with the axes, and superimposition of the wine confidence ellipses (areas where each wine could have been located with a probability of 0.90, given the individual variability and a binormal assumption of individual distribution).

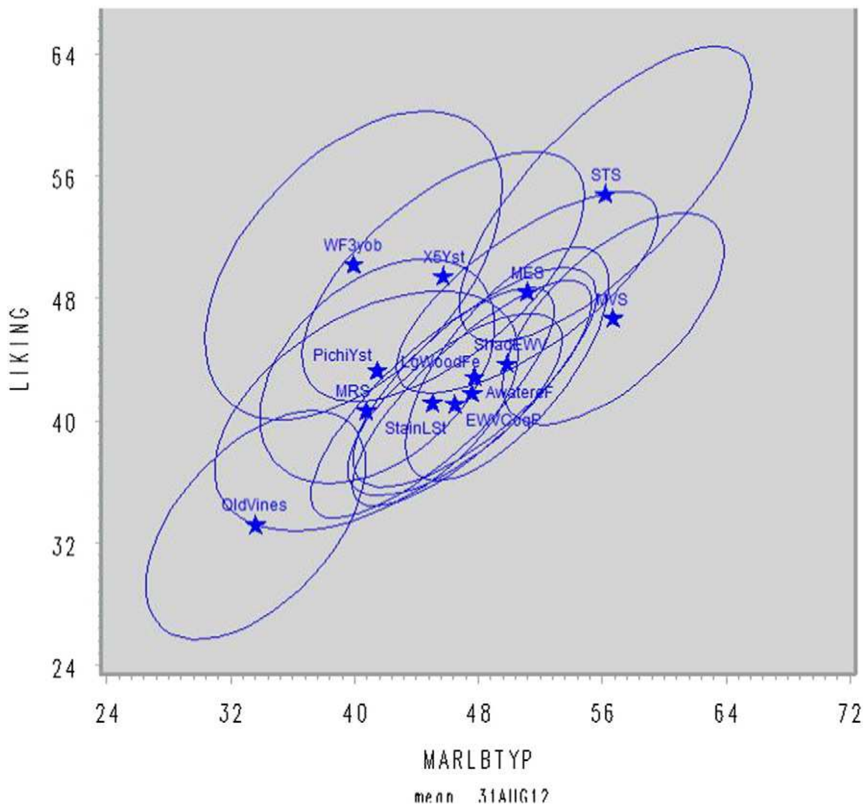

Fig. 5. Wine scatter plot based on the mean scores for Marlborough typicality scale (x-axis) and liking scale (y-axis), and superimposition of the wine confidence ellipses (areas where each wine could have been located with a probability of 0.90, given the individual variability and a binormal assumption of individual distribution).

one of the non-standard wines, 'Old vines', was perceived significantly lower in Marlborough typicality than the other wines. Second, the relatively low ratings show that in general the wines in this study were not considered by the participants as particularly 'typical' of Marlborough Sauvignon blanc. Third, the data in Fig. 5 show some interesting effects concerning the relation between perceived typicality and liking. Specifically, there was a high positive correlation between liking and perceived typicality for several of the wines, in particular those produced by 'standard' Marlborough oenological practices. This result is in keeping with previously-published data demonstrating a positive association between ratings of wine typicality and liking (Parr et al., 2010). On the other hand the association between typicality and liking broke down for 'wild ferment, 3 year-old barrel' wine, the wine that arguably deviated most from current practices of standard, Marlborough Sauvignon production. This latter wine was judged high on liking but relatively low on perceived typicality, suggesting that the wine professionals were able to separate their assessments of wine typicality from those pertaining to their liking of a wine.

3.2. Physical and chemical data

To address the first hypothesis, one-way ANOVAs, with hand versus machine harvesting as the independent variable, were performed on the data comprising twelve physico-chemical measures determined for each of the 13 wines. The twelve factors comprised estimates of pH, TA, ethanol, dry extract, residual sugars, volatile acidity, free and total sulfur dioxide, and concentrations of chemical compounds 3MH, 3MHA, 4MMP, and IBMP. The output from this analysis can be seen in Table 6. In keeping with the sensory data, these results demonstrate that acidity/sourness (TA & pH) and concentrations of varietal thiols 3MH (hand harvesting *mean* = 437; machine-harvesting *mean* = 3367.25) and 3MHA (hand harvesting *mean* = 15.33; machine-harvesting *mean* = 392.50) differed on average between the machine and hand-harvested-fruit wines.

To consider the second hypothesis, a one-way ANOVA was performed on the concentrations of IBMP determined for each wine with perceived 'greenness' as the independent variable. Four wines were designated a priori on the basis of previous research as likely to present with greener flavour profiles and higher levels of IBMP

Table 6
Results from a one-way ANOVA involving the physical and chemical data collected on the 13 wines with type of harvesting as the independent variable: 4 wines were machine harvested; 9 wines were hand harvested. Due to the small number of degrees of freedom, free SO_2 (FSO2), dry extract (DryExtr) and ethanol v/v (Alc) can also be seen as discriminating variables between Hand and Machine harvesting.

One-way ANOVA model of hand/machine harvested				
Variable	*F*	Prob	Hand	Machine
3MHA	84.67	0.0000	15.33	392.50
3MH	70.05	0.0000	437.00	3367.25
pH	60.72	0.0000	3.14	3.35
TA	15.58	0.0023	9.22	7.21
FSO2	3.94	0.0727	24.22	21.25
DryExtr	3.84	0.0758	20.27	17.63
Alc	3.06	0.1081	14.11	13.38
TSO2	2.12	0.1736	124.44	114.50
4MMP	1.59	0.2327	62.67	36.25
RS	0.26	0.6196	3.79	3.38
IBMP	0.23	0.6433	11.23	12.38
VA	0.11	0.7465	0.47	0.46

TSO2 = total SO_2; RS = residual sugar.

than the other five wines. The a priori designated 'green' wines included two wines from east–west planted vines (EWVCoqP; ShadEWV), and two wines from fruit produced in the Awatere Valley (AwatereF; WF3yob). There was a significant effect of 'greenness', $F(1, 8) = 7.59$, $p = 0.0283$, with the a priori designated 'green' wines higher in IBMP ($mean = 14.68$, $SD = 4.09$) than the non-green wines ($mean = 8.48$, $SD = 2.75$).

4. Discussion

The main aim of the study was to investigate statistical association between various, relevant grape-growing and wine-making factors on sensory and selected chemical aspects of Sauvignon blanc wines. The most important outcome of the study is demonstration of significant associations between type of grape harvesting (hand versus machine) and (i) perceived flavour profile and (ii) chemical composition of Sauvignon blanc wines. The result not only supports our first hypothesis and fits with other recently reported, chemical data (e.g., Capone & Jeffery, 2011) demonstrating the importance of considering grape-processing factors as a major influence in the varietal-aroma composition of Sauvignon blanc wine, but extends the research area by inclusion of sensory data.

Several specific results relating to support of our first hypothesis deserve discussion. First, as expected the higher concentration of volatile thiol compounds in the machine-harvested-fruit wines correlated positively with higher intensity ratings to wine descriptors 'passionfruit' (MVS & STS), 'boxwood' (MRS & STS), 'tropical' (STS), 'intensity of bouquet' (MRS, MVS, & STS), 'persistence of bouquet' (MRS, MVS, & STS) and 'Marlborough typicality' (MVS & STS). Second, acidity ('sourness') was perceived to be intense in several of the wines (Old vines; EW all fruit; Large wooden ferment), most likely influencing judgment of other sensory characteristics to these wines. Interestingly, unlike the effect reported by Jones et al. (2008), there is no evidence in the present study that perceived acidity was enhanced by volatile aroma compounds, at least not for the compounds measured. This comment must be qualified however in that total acidities of the wines differed, most notably between those of the four machine-harvested-fruit wines and several of the non-standard wines. Importantly, the higher acidity of several of the hand-harvested fruit wines cannot be allocated to unripe fruit, given the levels of alcohol and residual sugar reported for these wines. As reported earlier, the decision to not adjust acidity in the wines in the study was made within the context of minimising wine processing operations or ameliorations that had potential to introduce confounding factors.

In keeping with our second hypothesis, 'green' flavour notes (e.g., herbaceous, grassy, green capsicum) were dominant in wines made from fruit of east–west rows, both the all-fruit condition and shaded fruit (southern side) only condition, and wines made from Awatere Valley fruit. The latter effect (i.e., green flavour profiles reported in Awatere Valley wines) has been reported previously (Trought et al., 2010). To our knowledge, this is the first empirical demonstration of the influence of fruit from east–west vineyard rows in producing wines that were distinctly greener in sensory profile than wines produced from fruit of vines from the more common planting orientation of north–south vineyard rows. In keeping with the perceived greener flavour profiles, wines from the Awatere Valley location and from vine rows oriented east–west showed significantly higher concentrations of IBMP.

Influence of type of yeast(s) on Sauvignon blanc aroma and chemical composition has been the subject of prior research (e.g., Anfang et al., 2008; King et al., 2010). The present study adds to this body of research in several ways. First, we extend the chemical-composition research of Anfang et al. by providing sensory data that show fermentation with *P. kluyveri* to produce a Sauvignon wine judged to be significantly lower in several 'green' and sour characteristics than the other non-standard wines. Second, the current study provides sensory data that support the commonly-held belief that Sauvignon blanc juice subjected to indigenous yeast fermentation in an oak barrel produced a distinctive wine. Wine WF3yob stood out perceptually from all other wines in the study, and was evaluated positively despite not being perceived as 'typical' or a good example of its wine type, namely Marlborough Sauvignon blanc.

The majority of the wines in the current study were not considered particularly 'typical' of Marlborough Sauvignon blanc by the wine-professional participants. The non-standard wines in particular were assessed as not 'typical' and were also rated relatively low on liking. An exception was wine WF3yob which received a significantly more positive hedonic assessment than the other non-standard wines. The positive ratings of liking by wine professionals toward a wine they clearly judged as not typical of Marlborough Sauvignon blanc provides evidence that the wine professionals could separate their assessments of wine typicality from those pertaining to their liking of a wine, an issue that has been questioned by some sensory professionals who have argued that it is inappropriate to seek hedonic data from those with domain-specific expertise or analytical training (e.g., trained panelists) pertaining to a specific food or beverage.

5. Conclusion

Cultural practices and viticultural conditions can alter perceived qualities and chemical constituents of Sauvignon blanc wines, providing options for wine producers to innovate in response to changes in wine consumers' knowledge and preferences. The present study demonstrates an association between several viticultural and oenological factors and the final expression of Sauvignon wines from New Zealand, in particular the vineyard location (Awatere or Wairau Valley of Marlborough), vineyard row orientation, and the grape processing operation of hand- or machine-fruit harvesting. The next step will be to link such factors causally with specific expressions of Sauvignon blanc wine.

Acknowledgement

The research was funded by the Foundation for Research, Science and Technology, N.Z. (grant UOAX0404); the Royal Society of New Zealand International Science & Technology Linkages Fund award to Wendy Parr; Pernod Ricard NZ; and Pernod Ricard Centre de Recherche, Paris, France. We thank Andy Frost, Patrick Materman, Frank Benkwitz, Mani Naiker, Julia O'Connell, and the wine professionals who participated in the study.

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