Free and Enzymatically Hydrolysed Volatile Compounds of Sweet Wines from Malvasia and Muscat Grapes (*Vitis vinifera L.*) Grown in Sardinia

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The aroma of Muscat of Sorso-Sennori and Malvasia di Bosa wines obtained from grapes grown in Sardinia was evaluated by instrumental analysis. Gas chromatography/mass spectrometry was used to identify and quantify the content of free and bound volatile compounds. The odour activity value (OAV) was also calculated. Higher alcohols and esters were quantitatively the largest group of free volatile compounds in both wines, while terpenes were the main class of bound volatiles. A total of 52 free and 26 bound volatiles were detected. Malvasia di Bosa sweet wine had a higher content of alcohols, esters and acids in comparison to Muscat of Sorso-Sennori, which was richer in some terpenes, like nerol, geraniol and geranic acid, and also in bound volatile compounds. A total of 12 compounds were above the OAV. The main aroma-active compounds of Muscat were 3-methylbutyl acetate (banana), ethyl octanoate and hexanoate (fruity), and linalool (flowery), Malvasia wine was characterised particularly by ethyl octanoate and by 3-methylbutyl acetate.

INTRODUCTION

Among all the aroma constituents, volatiles coming from grapes play an important role in the quality and typicality of wines. In this context, grape varieties can be divided into aromatic and non-aromatic: aromatic grapes have free and glycosylated volatiles (terpenes, C_{13}-norisoprenoids), which, through hydrolysis, may generate precursors of the aromatic compounds that give the typical flavour to the wine, as in Muscat; non-aromatic grapes possess both free and glycosylated volatiles, but the free forms are at a concentration lower than their odour thresholds, thus they make a negligible contribution to the aroma characteristics of wines such as Riesling, Chardonnay, Pinot and Merlot, among others (Sefton *et al*., 1993; Winterhalter, 1993; Kotseridis *et al*., 1998; Di Stefano *et al*., 2000). Moreover, it is well known that, while the cultivar qualitative profile depends strictly on the cultivar, the relative amounts of each compound and thus the sensory properties are also influenced strongly by the terroir, which includes all the regional parameters such as soil, climate, viticulture managements and crop level (Fischer *et al*., 1999).

Sardinia has a old tradition in the wine industry and produces high-value wines from red and white grapes. Sardinia currently has 19 defined DOC areas (Denomination of Controlled Origin), one DOCG (Denomination of Controlled and Guaranteed Origin), and 15 areas of IGT (Typical Geographical Indication). The production of white wines is concentrated largely in the central and northern part of the island, while the production of red wines is concentrated mainly in the south. Two very important aromatic grapes of Sardinia are Malvasia di Bosa (MV) and Muscat of Sorso-Sennori (MS). The MV is a synonym for Malvasia di Sardegna (number 7266 in the Vitis International Variety Catalogue) and the MS is a synonym for Moscato Bianco (number 8193 in the Vitis International Variety Catalogue). These grapes are used to make sweet wines that are sold on the world market every year. Sweet wine production requires harvesting of the grapes at an overripe stage, and this results in particular sensory descriptors such as floral, thyme flower, tropical fruit, passion fruit, mango, citrus, orange peel, apricot, dried apricot, peach, marmalade, honey and caramel (Croser, 1989). MS grapes are grown in the north-west part of Sardinia, in the district of Sorso and Sennori, and their vinification gives rise to a DOC sweet wine (Moscato di Sorso-Sennori). MV grapes are grown in the central-west part of Sardinia, in the territories of Bosa, Suni, Tinnura, Flussio, Modolo and Magomadas. Dry and sweet wines are

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produced from MV grapes. To our knowledge, no data are available in the literature on the aromatic composition of sweet wines obtained from these grapes grown in Sardinia.

This work therefore was aimed at characterising the free and bound volatile composition of two commercial sweet wines deriving from Muscat of Sorso-Sennori and Malvasia di Bosa.

MATERIALS AND METHODS

Wine samples

Muscat (MS) was supplied by a north Sardinian cooperative wine growers' association, while Malvasia (MV) was supplied by an important Sardinian winery. The MS and MV grapes were harvested in the second half of October 2008, at 28 and 25.5 °Brix respectively. For the MS wine, the harvested grapes were crushed and SO_2 (5 g/100 kg), pectic enzyme (3 g/100 kg), tannins (15 g/100 kg) and ascorbic acid (6 g/100 kg) were added. The must was cooled to 19 °C and inoculation was carried out at 30 g/hL, after rehydration of the yeast (Uva ferm Ghm, Lallemand, Montreal, Canada) in warm water for 30 min, as described by the manufacturer. Fermentation took place in stainless steel tanks at 19 to 20 °C, and skin contact lasted until the initial sugar content had been halved. Racking was done at 8°Brix residual sugar level, and fermentation was stopped by chilling to -3 °C, followed by stabilisation. Wine samples were bottled six months after winemaking.

For the MV wine, the harvested grapes were crushed and SO_2 (5 g/100 kg) was added. After overnight skin contact, the must was drained and inoculation with the selected yeast (US-01, Unistrains SrL, Sassari, Italy) was carried out. Fermentation took place in stainless steel tanks at 18 to 20 °C. Racking was done at 3°Brix residual sugar level, and fermentation was stopped by chilling to -3 °C, followed by stabilisation. Wine samples were bottled six months after winemaking. Samples of both wines were analysed in triplicate at the time of bottling in May 2009.

Extraction and gas chromatography–mass spectrometry (GC-MS) analysis of volatiles

Free and glycosylated volatile compounds were extracted from the wines, following the solid phase extraction methods proposed by different authors (Di Stefano *et al*., 1991; Mateo *et al*., 1997; Moio *et al*., 2004), with some modifications. A total of 25 mL of wine was diluted with an equal amount of water and added to 2-octanol as internal standard (125 µL of a 200 mg/L methanol solution), then loaded into a previously activated 1 g C-18 cartridge (Phenomenex, Torrence, CA) and passed through at 3 mL/min. The cartridge was washed with 10 mL of water. The free volatile compounds were eluted with 5 mL of dichloromethane, then 10 mL of methanol was used for the recovery of the glycoconjugated fraction (bound volatiles). The dichloromethane fraction was concentrated to dryness with Na_2SO_4 and then reduced to a small volume (~ 100 µL) with nitrogen flushing.

The methanol fraction was concentrated to dryness with a rotary evaporator and dissolved again in 5 mL of phosphate-citrate buffer (pH 5.0) containing 40 mg of Novarom™ Blanc β-glucosidase enzyme (Novozymes, Bagsvaerd, Denmark). After 16 h of incubation at 40 ± 2 °C, 125 mL of an alcoholic solution of 2-octanol was added as internal standard, the mixture containing free aglycons was loaded into a C-18 SPE cartridge, and the volatiles were extracted with 5 mL of dichloromethane. The extract, dried over Na_2SO_4, was concentrated under a stream of pure N_2 (1.5 L/min) for GC-MS analysis. Each extraction was carried out in triplicate.

GC-MS analysis was performed using a GC/MS-QP2010 mass spectrometer (Shimadzu, Shimadzu Corp., Kyoto, Japan) equipped with a split/splitless injector and a DB-WAX column (60 m x 0.250 i.d., 0.25 µm film thickness; J&W Scientific Inc., Folsom, CA 95360, USA). The temperature program used was 40 °C for 5 min, increasing by 2 °C/min to 220 °C, and held at maximum temperature for 20 min. The flow of the carrier gas (He) was 1.02 mL/min. Injections of 1 µL were performed in splitless mode while the injector port and the ion source were maintained at 250 °C and 230 °C respectively. Positive electron impact spectra were recorded at 70 eV in the range m/z 33 to 350. Identification of the compounds was confirmed by injection of pure standards and comparison with their retention indices and MS data reported in the literature. Compounds for which pure reference standards were not available were identified only on the basis of their retention times and MS spectra.

The quantification used gave semi-quantitative results, but in this case exact amounts were not that important because of the wide variability of the published odour threshold values (OTV) (Takeoka *et al*., 1989; Etievant, 1991; Guth, 1997; Ferreira *et al*., 2000; Vilanova & Sieiro, 2006), as already reported by Vilanova *et al*. (2010). The literature OTV were used to calculate the odour activity value (OAV) of the most relevant volatiles detected by dividing the concentration detected by the OTV.

Statistical analysis

The data on the volatiles were evaluated by a one-way ANOVA (Statistica) and the wine was used as the group variable.

RESULTS AND DISCUSSION

Free volatiles

GC-MS allowed us to detect 52 volatile compounds, although two only in traces. We found fifteen higher alcohols, three C-6 alcohols, thirteen terpenoids, thirteen esters, three acids, two lactones, one aldehyde, one volatile phenol and one other compound (Table 1; Fig. 1). Alcohols, esters and acids were the main compounds in both wines, and are fermentative products produced by yeast metabolism during fermentation.

Terpenes are responsible for the characteristic varietal aroma of Muscat and other aromatic wines (Marais, 1983; Rapp *et al*., 1986; Pisarnitskii, 2001; Selli *et al*., 2006; Zalacain *et al*., 2007). Geranic acid, linalool, nerol, geraniol and β-citronellol were the most abundant terpenes in MS; terpinen 4-ol, with an OTV of 15 (Vilanova & Sieiro, 2006) (Table 2), and 2,6-dimethyl-3,7-octadien-2,6-diol accounted for about 80% of the terpenes in MV, which completely lacked β-citronellol and *trans* and *cis* linalool oxide. It should be highlighted that geranic acid was the main terpenoid compound found in MS, accounting for 35% of the total terpenoid content, and as has already been found in Muscat of Frontignan grapes (Bureau *et al*., 2000) and,

TABLE 1
Free volatiles (µg/L± SD) detected in Muscat of Sorso-Sennori and Malvasia di Bosa sweet wines.

Volatile compound	Wine		Volatile compound	Wine	
	Muscat	**Malvasia**		**Muscat**	**Malvasia**
C-6 Alcohols			***Terpenes***		
(Z)-3-Hexen-1-ol	13 ± 1b*	45 ± 3a	(E) Linalool oxide	30 ± 2a	NPb
1-Hexanol	1271 ± 21a	1_098 ± 47b	(Z) Linalool oxide	56 ± 2a	NPb
(E)-3 Hexen-1-ol	12 ± 1b	170 ± 3a	Linalool	326 ± 13a	42 ± 1b
Total	**1296 ± 22**	**1313 ± 59**	Terpinen 4-ol	11 ± 1b	599 ± 13a
			Hotrienol	12 ± 2b	26 ± 2a
Alcohols			α-Terpineol	114 ± 7a	52 ± 2b
2-Methyl-1-propanol	1916 ± 175b	2652 ± 162a	2,6-Dimethyl-3,7-octadien-2,6-diol	108 ± 1b	366 ± 14a
1-Butanol	99 ± 7a	50 ± 5b	Epoxylinalool I	NPb	57 ± 2a
3+2-Methyl-1-butanol	45602 ± 3056a	52966 ± 2250a	β-Citronellol	185 ± 1a	NPb
2-Methyl-3-buten-1-ol	14 ± 1a	6 ± 1b	Nerol	249 ± 12a	25 ± 2b
1-Pentanol	164 ± 1a	47 ± 2b	Geraniol	229 ± 2a	25 ± 2b
4-Methyl-1-pentanol	17 ± 1b	47 ± 1a	2,6-Dimethyl-1,7-octadien-3,6-diol	49 ± 6a	trb
3-Methyl-1-pentanol	33 ± 1b	45 ± 1a	Geranic acid	689 ± 40a	23 ± 3b
2-Octanol	17 ± 2a	17 ± 1a	**Total**	**2067 ± 102**	**1227 ± 32**
1-Octen-3-ol	79 ± 4a	7 ± 1b			
1-Heptanol	338 ± 50a	40 ± 9b	***Acids***		
2-Ethyl-1-hexanol	17 ± 2a	17 ± 1a	Hexanoic acid	614 ± 93b	1_349 ± 17a
1-Octanol	51 ± 1a	23 ± 0b	Octanoic acid	429 ± 15b	2_273 ± 90a
3-Methyl-1-propanol	30 ± 1b	154 ± 10a	Decanoic acid	157 ± 31b	1_121 ± 113a
Benzyl alcohol	119 ± 20a	91 ± 15a	**Total**	**1200 ± 70**	**4743 ± 178**
2-Phenylethanol	14256 ± 978b	22696 ± 2399a			
Total	**62318 ± 4164**	**78858 ± 4348**	***Lactones***		
			γ-Butyrolactone	128 ± 13a	42 ± 6b
Esters			Dihydro-5-pentyl-2(3H)-furanone	241 ± 12a	36 ± 1b
Ethyl 2 –methylpropanoate	10 ± 1a	NPb	**Total**	**369 ± 10**	**78 ± 6**
Ethyl butanoate	148 ± 11a	NPb			
Ethyl 2-methylbutanoate	Tr	NP	***Volatile phenols***		
Ethyl 3-methylbutanoate	Tr	NP	4-Vinyl guaiacol	61 ± 4b	101 ± 11a
3-Methylbutyl acetate	178 ± 1b	522 ± 54a	**Total**	**61 ± 4**	**101 ± 11**
Ethyl hexanoate	206 ± 3b	420 ± 18a			
Ethyl heptanoate	16 ± 1a	Trb	***Aldehydes***		
Ethyl lactate	226 ± 3b	600 ± 31a	Benzaldehyde	240 ± 4a	NPb
Ethyl octanoate	161 ± 9b	727 ± 10a	**Total**	**240 ± 4**	
Ethyl decanoate	63 ± 12b	389 ± 14a			
Diethyl succinate	1192 ± 163b	2149 ± 16a	***Others***		
Ethyl vanillate	106 ± 14a	34 ± 5b	N-3-Methylbutil acetamide	510 ± 49a	83 ± 14b
2-Phenylethyl acetate	21 ± 2b	78 ± 4a	**Total**	**510 ± 49**	**83 ± 14**
Total	**2327 ± 187**	**5099 ± 85**			

NP, Tr Not present, traces.
* Data followed by different letters within each compound are significantly different at $P < 0.01$.

to a lesser extent, in Moscato bianco grapes (Mazza *et al*., 2003). To our knowledge, this is the first time that geranic acid has been found at a higher concentration than linalool, which generally is the most abundant terpene compound. The terpenoid composition of MS is quantitatively and qualitatively different from that reported by Selli *et al*. (2003) on Muscat of Bornova, and quantitatively was more similar to Muscat, "a petit grain" vintage 2002 wine studied by Sánchez Palomo *et al*. (2007). In fact, we found higher amounts of geranic acid, linalool, β-citronellol, nerol and geraniol in comparison to that in Muscat of Bornova wine. Moreover, the terpenoid content of MS, in general, was higher than that in aromatic wines other than Muscat (Versini *et al*., 2000). The concentration of linalool, geraniol and β-citronellol in MS was higher than their OTV (see Table 2) (Etievant, 1991; Guth, 1997; Ferreira *et al*., 2000). From the analysis of terpenoids it is possible to clearly differentiate the MS from the MV wine. The MV terpenoid content, on the other hand, was higher than that reported in other Malvasia wines (Camara *et al*., 2004; Muratore *et al*., 2007). Moreover, in a previous study on Malvasia of Bosa grapes cultivated in the North of Italy, the terpenoid concentration was found to be very low and the authors did not reveal it (Borsa *et al*., 2005).

Regarding the fermentative compounds, the main compounds in both wines were the alcohols 3 and 2-methyl-

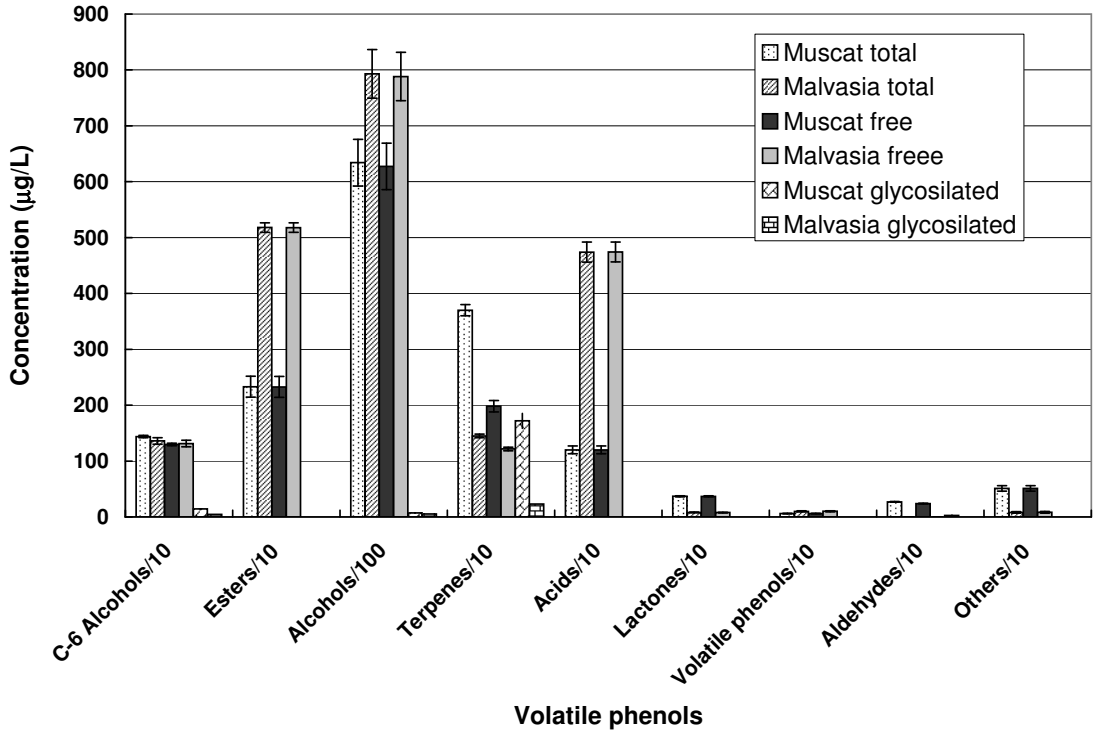

FIGURE 1
Mean and standard deviation of total, free and glycosylated volatile compound classes detected in Muscat of Sorso-Sennori and Malvasia di Bosa sweet wines.

1-butanol, and 2-phenylethanol. Similar amounts of these compounds have been found in Muscat of Bornova (Selli *et al*., 2006), while Muratore *et al*. (2007) found higher amounts in Malvasia delle Lipari wines. This class of compounds has a positive effect on the aromatic quality of wine when the concentration is not more than 300 mg/L (Rapp & Versini, 1996), while concentrations higher than 400 mg/L may act negatively (Mateo *et al*., 2001). In both wines we found a total amount less than 300 mg/L (Table 1). We have to highlight the presence of 2-phenylethanol, characterised by a pleasant rose aroma (Swiegers & Pretorius, 2005), which ranged from 14.2 to 22.6 mg/L in the MS and MV respectively, thus concentrations slightly higher than the OTV (Table 2) (Ferreira *et al*., 2000). The level of 2-phenylethanol has been reported to be related both to grape variety and yeast metabolism (Gomez-Plaza *et al*., 1999). MS wine has a higher content than MV of 1-octen-3-ol, which may confer a mushroom odour that is a by-product of the metabolic activity of *Botrytis cinerea* (Yunome *et al*., 1981). C-6 alcohols that derive from lipoxygenase activity and that are unfavourable to wine quality, due to the fact that they convey herbaceous and leafy notes (Joslin & Ough, 1978), were found in very low amounts, and 1-hexanol was the most abundant in both wines. All C-6 alcohols were found in lower amounts with respect to their OTV (Etievant, 1991).

Esters, which contribute to the fruity flavour of young wines, were observed at lower levels than those reported in Muscat of Bornova (Selli *et al*., 2006) and Muscat of Alexandria (Cabaroglu *et al*., 2002). We found mainly ethyl fatty acid esters, also thanks to fermentation conducted at a low temperature (Molina *et al*., 2007), and two acetates. Ethyl fatty acid esters provide a sweet and/or soap odour to wine (Etievant, 1991). Some of them have a very low OTV (Ferreira *et al*., 2000), thus both wines and, in particular the Malvasia wine, can be characterised by ethyl hexanoate (green apple flavour), which has a calculated OAV of 84, and by ethyl octanoate (sweet, soap), with an OAV of 363.5 (Table 2). Muscat can be also characterised by ethyl butanoate, which was not found in Malvasia. Diethyl succinate, which gives a sweet, fruity flavour, was the most abundant ester in both wines. MV has a higher content of esters than MS, in particular of ethyl lactate, ethyl octanoate and 3-methylbutyl acetate. Ester development depends on amino acid metabolism, thus the higher content in MV may be due to a different amino-acidic composition of the must, which in turn depends on grape composition, yeast density and environmental conditions (Spranger *et al*., 2004).

Volatile acids, which are yeast by-products in the form of long-chain fatty acids, were found in higher amount in the MV wine. In particular, we detected hexanoic, octanoic and decanoic acids. These C6 to C10 fatty acids may impart mild and pleasant aromas to wine when found at concentrations of 4 to 10 mg/L (Shinohara, 1985). The ferulic acid deriving phenol, 4-vinyl guaiacol, was the unique volatile phenol detected in both wines. This compound has been reported to play an important role in white wines, as reported in the case of Gewürztraminer wine from the north of Italy (Versini, 1985). In general it has a negative effect on wine aroma, but in our case its level was much lower than the reported OTV (Ferreira *et al*., 2000). Among the carbonyl compounds we found very low levels of two lactones, γ-butyrolactone and dihydro-5-pentyl-2(3H)-furanone, and of benzaldehyde. The γ-butyrolactone can be found in every fermented product and may occur through chemical or enzymatic formation, presumably from glutamic acid (Wurz *et al*., 1988).

Bound volatile compounds

A total of 26 volatile compounds, one only in traces, were found in the MS and MV wines (Table 3; Fig. 1). We detected three *C-6* alcohols, nine higher alcohols, 13 terpenes and two aldehydes. Bound compounds are flavourless precursor compounds, thus are a reservoir of flavour. MS was characterised by a high content of all bound volatiles in comparison to MV. The terpenes in MS accounted for 45.5% of the total bound volatiles, while in MV there were only 15.7%. In particular, bound nerol and geraniol were present at more than twice the concentration of the free fraction in MS, and this confirm the results found for Muscat of Alexandria (Gunata *et al*., 1986; Selli *et al*., 2003). MS can be differentiated clearly from MV on the basis of its higher content of terpenes and the absence of terpinen 4-ol, 2,6-dimethyl-3,7-octadien-2,6-diol and 2,6-dimethyl-1,7-octadien-3,6-diol, while MV completely lacked any *trans* and *cis* linalool oxides and epoxylinalool I. Bound C-6 alcohols and higher alcohols were at a very low level. 2-Phenylethanol was the main bound alcohol in both wines. We found two aldehydes, namely benzaldehyde and neral, but only in MS.

CONCLUSIONS

In the present work, aroma compounds of sweet wines obtained from Muscat and Malvasia grown in two specific regions of Sardinia were characterised for the first time and can be very helpful to the producers. Varietal and fermentative aroma compounds were identified and quantified in the free and glycosylated form. A total of 52

TABLE 2

Odour activity values (OAVs) of volatile compounds with more influence on the aroma of Muscat of Sorso-Sennori and Malvasia di Bosa wines.

Compounds	Sensory descriptor	Odour threshold (µg/L)	Muscat	Malvasia
Linalool	Flowery	15[a]	21.73	2.8
Geraniol	Citric	30[a]	7.63	UT*
2-Phenylethanol	Roses, sweet	10000[a]	1.42	2.27
Terpinen 4-ol	Flowery	15[d]	UT	39.93
β-Citronellol	Lemon, lime	100[a]	1.85	UT
3-Methylbutyl acetate	Banana	2[c]	89	261
Ethyl butanoate	Kiwi	20	7.4	-
Ethyl hexanoate	Fruity, green, apple, banana	5[a]	41.2	84
Ethyl octanoate	Fruity, banana, pineapple, peach, sweet	2[a]	80.5	363.5
Ethyl decanoate	Sweet, grass	200[b]	UT	1.95
Hexanoic acid	Cheese	300[a]	2.05	4.50
Octanoic acid	Grass acid	500[b]	UT	4.55

[a] Guth (1997)
[b] Ferreira *et al*. (2000)
[c] Takeoka *et al*. (1989)
[d] Vilanova *et al*. (2006)
[*] Below threshold

TABLE 3

Bound volatiles (µg/L ± SD) detected in Muscat of Sorso-Sennori and Malvasia di Bosa sweet wines.

Volatile Compounds	**Wine**	
	Muscat	***Malvasia***
C-6 Alcohols		
1-Hexanol	121.8 ± 2.8a*	NPb
(E)-2- Hexen-1-ol	16.7 ± 0.5a	13.9 ± 0.7a
(E)-3 Hexen-1-ol	3.8 ± 0.5b	30.6 ± 1.9a
Total	**142.3 ± 3**	**44.5 ± 2**
Alcohols		
2-Methyl-1-propanol	6.3 ± 0.9a	9.5 ± 1.1a
1-Butanol	16.6 ± 2.0b	38.5 ± 4.0a
3-Methyl-1-butanol	176.0 ± 17.6a	134.8 ± 2.5a
1-Pentanol	27.7 ± 2.1b	44.2 ± 4.1a
1-Octen-3-ol	10.4 ± 1.4a	10.7 ± 0.8a
1-Heptanol	11.8 ± 1a	12.9 ± 0.4a
1-Octanol	5.0 ± 0.6a	NPb
Benzyl alcohol	182.7 ± 16.2a	109.2 ± 7.5b
2-Phenylethanol	287.2 ± 27.0a	169.6 ± 10.4b
Total	**723.7 ± 37**	**529.4 ± 20**

TABLE 3 CONTINUED

Volatile Compounds	Wine	
	Muscat	*Malvasia*
Terpenes		
(E) Linalool oxide	19.2 ± 3.5a	NPb
(Z) Linalool oxide	58.5 ± 11.8a	NPb
Linalool	307.4 ± 35.2a	33.7 ± 5.1b
Terpinen 4-ol	NPb	35.0 ± 3.8a
Hotrienol	Tr	NP
α-Terpineol	22.5 ± 3.1a	2.9 ± 0.3b
2,6-Dimethyl-3,7-octadien-2,6-diol	NPb	27.3 ± 4.4a
Epoxylinalool I Epossilinaloolo I	120.2 ± 22.6a	NPb
Epoxylinalool II	9.2 ± 2.0b	48.8 ± 6.9a
β-Citronellol	26.6 ± 1.9a	trb
Nerol	570.4 ± 54.3a	5.6 ± 0.7b
Geraniol	589.1 ± 44.3a	33.6 ± 1.0b
2,6-Dimethyl-1,7-octadien-3,6-diol	NPb	41.8 ± 3.7a
Totals	**1723.1 ± 134**	**229.0 ± 26**
Aldehydes		
Benzaldehyde	12.1 ± 2.0a	NPb
Neral	12.5 ± 1.6a	NPb
Totals	**24.6 ± 2**	

NP Not present

* Data followed by different letters within each compound are significantly different at $P < 0.01$.

free and 26 bound volatile compounds were identified and quantified. MS has a higher content of both free and bound terpenes in comparison to MV wine, which was richer in free esters and acids. Bound compounds were present in greater quantities in MS.

According to their OAVs, 3-methylbutyl acetate, ethyl octanoate, ethyl hexanoate and linalool were the main characteristic aroma-active compounds of Muscat wine. Malvasia wine, on the other hand, was characterised particularly by ethyl octanoate, which may confer fruity, banana, pineapple, peach and sweet notes, and by 3-methylbutyl acetate, which may give banana flavour.

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