Aroma Evaluation of Young Chinese Merlot Wines with Denomination of Origin

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Merlot wines from four premium wine-producing districts in China were analysed for their volatile composition and sensory properties. Fifty-seven aroma compounds were quantified by SPME-GC-MSOAV analysis, which showed that thirty of these compounds were active on the basis of their odour active value (OAV). According to the aroma descriptions of eleven impact odorants in all the sample wines, the collective aroma characteristics of Chinese Merlot red wine are complex. Its main flavour is that of some tropical and temperate fruits, such as banana, pineapple, green apple, pear and strawberry, along with a lactic flavour from the malolactic fermentation. It also has some traits of processed fruits, Muscat and floral pollen flavour. Moreover, different districts gave Merlot wine distinct characters. Changli wine had a higher intensity and complexity of global aroma, a strong fruity aroma, and an obvious nuance of lactic and nut traits. The sine from Helanshan had weak fusel flavour and some lemon fruity flavour. Shacheng wine had weak fusel flavour, along with green grass and some fruity flavour of raspberry and violet. Manasi wine had the odour of unpleasant fatty acids and phenol due to its high content of fatty acids and volatile phenol. The sensory analysis confirmed the aroma prediction from the active odorants of the sample wines. Changli wine had the highest sensory scores, while Manasi wine had the worst evaluation of aroma, taste and harmony. The results suggest that the Merlot variety is more suitable for planting in Changli than in the Manasi region.

INTRODUCTION

The main wine-making grape variety in China is *Vitis vinifera* L, which originated from Europe. Merlot is a popular cultivar in the main wine-producing districts in China. The earliest odour studies of Merlot and Cabernet Sauvignon wines in Bordeaux indicated that the wine had a fruity and flowery aroma, with a marked toasty, caramel, smoky, roast and herb flavour (Peynaud, 1980; Allen *et al*., 1994; Lopez *et al*., 1999). Merlot Wine in the State of California and in Australia has a rich fruity flavour, with caramel, grassy and soil nuances. Volatile analysis demonstrated that the content of ethyl octanoate in Merlot wine was four to five times higher than that in Cabernet Sauvignon wine (Gurbuz *et al.*, 2006).

A number of studies have indicated that the volatiles in wine are responsible for the characteristic bouquet of wines. There is a relationship between specific volatile compounds and aroma in the wine, and therefore some sensory descriptors can be predicted by gas chromatographic data. Thus far nearly 1 000 volatile substances have been reported in wine, and their concentrations range from ng/L to mg/L (Li, 2006). It has been demonstrated that the profile of aroma components in wine is influenced by origin, variety, vintage, viticultural technology and the winemaking process (Guth, 1997; Perestrelo *et al*., 2006). The aroma characters of wine have been used to identify different wine products (Diaz *et al*., 2003; Escudero *et al*., 2004). In many complex wines there are no key compounds that can dominative the aroma, which rather is contributed by the mixture of different odorants. A comparison of aroma compounds in different wines concluded that there were concentration differences of some volatiles among the wines. The most significant differences are quantitative rather than qualitative (Lopez *et al*., 1999; Ferreira *et al*., 2000). To estimate the contributions of the volatiles in wine, the odour active value (OAV) was introduced. It is the ratio between the measurement of the concentration of volatiles in wines and their odour threshold. The contribution of volatiles to the final aroma depends on whether their concentration in the wine is above the perception threshold (Tao & Zhang, 2010). Only those odorants with an OAV > 1 can be perceived (Guth, 1997; Li, 2006; Vilanova & Martinez, 2007). Celleré studied the volatile compounds of six premium Spanish red wines with denomination of origin, and proved that forty aroma compounds were impact odorants (Culleré et al., 2004).

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Chinese Merlot wine characteristics have not been described much in the past ten years, although some articles on the aroma compounds of this wine cultivar from other areas have been published (Wang *et al*., 2005). In this work, Merlot wines from different origins were sampled. Using OAV analysis of the volatile compounds, some active odorants of this mono-varietal red wine in China were revealed. The aim was to predict wine flavour features from those impact odorants using their odour description. The aroma evaluation of the wine was also subjected to testing by sensory analysis.

MATERIALS AND METHODS

Wines

Wine samples were collected from the four main wine-producing districts in China. Samples were supplied by Huaxia Winemaking Company (Changli County), Rongcheng Winemaking Company (Shacheng County), Xixiawang Winemaking Company (eastern region of Helanshan maintain), Xintian Winemaking Company (Manasi County). All samples were produced in 2006 and were collected in the tenth month after alcoholic fermentation. General indexes, such as reducing sugars, ethanol, density, extract, titratable acidity, pH, volatile acidity, total and free SO_2 were determined with the methods provided by the Office International de la Vigne et du Vin (O.I.V., 1990). Values of all indexes were measured up to the Wine Product Standards in China (GB/15037-2006), and no significant differences were found among these samples.

Wine making

Healthy Merlot grapes were obtained from the vineyard. The grapes were destemmed and crushed in a commercial grape destemmer-crusher. The juice was then pumped to stainless steel tanks. The must was treated with sulphur dioxide (45 mg/L) in H_2SO_3 (6%) form and soaked for approximately 24 h at 20°C. Alcoholic fermentation was carried out at 25 to 30°C after the yeast (*Saccharomyces cerevisiae* VR5, Netherlands, 0.2 g/L) was added, and followed by spontaneous malolactic fermentation at 18 to 20°C. The wines were then racked and sulphur dioxide (75 mg/L) was added. Wines were stored in stainless steel tanks at 15°C. Racking and stabilising processes were carried out prior to analysis.

Apparatus

GC–MS: TRACE DSQ (Thermo-Finnigan, USA). Analytical column: DB-Wax capillary column (30m × 0.32 mm i.d., 0.25 μm film thickness) (J&W, Folsom, USA); SPME, Supelco Company, USA; solid phase extraction fibre: PDMS (100 μm polydimethylsiloxane), Supelco Company.

Reagents

All reagents used were analytical grade. Absolute ethanol, tartaric acid and sodium chloride were purchased from Xi'an chemical factory (Xi'an, China). Water was obtained from a Milli-Q purification system (Millipore). Solvents did not require additional distillation. The 34 pure reference compounds were from Sigma-Aldrich (China sector): ethyl acetate, ethyl butyrate, isoamyl acetate, phenylethyl acetate, ethyl hexanoate, ethyl lactate, ethyl octanoate, ethyl DL-3-hydroxybutyrate, ethyl decanoate, diethyl succinate, ethyl laurate, ethyl palmitate, isoamyl lactate, isoamyl octanoate, 1-propanol, 1-butanol, isobutanol, isopentanol, 1-hexanol, 1-heptanol, 3-octanol, 1-decanol, benzyl alcohol, β-phenyl ethanol, lauryl alcohol, furfural, *cis*-geraniol, linalool, β-damascenone, hexanoic acid, octanoic acid, decanoic acid, lauric acid, and *p*-ethyl phenol.

Standard solutions

Exact volumes of the standard chemical compounds were dissolved in synthetic wines to prepare the calibration data. The synthetic wine had 12% (v/v) alcohol and 6 g/L of tartaric acid. Its pH was 3.3 to 3.4, adjusted with 1M NaOH. These standard compounds were dissolved in synthetic wines at concentrations at three orders of magnitude higher than typically found in wines. For quantification, five-point calibration curves were prepared for each compound. Octan-3-ol was employed as an internal standard because it was not the typical volatile compound in the wine and has a perfect ion peak shape and peak place in the total ion chromatograph (TIC). Exact volumes of octan-3-ol were dissolved in absolute ethanol. All these solutions were stored in darkness at 4°C.

SPME extraction

SPME was performed following the methods described previously. Both wine samples and model solutions were analysed in 15-mL glass vials, filled with 10 ml of each sample and 2 g of NaCl. For SPME analyses, the vials were dipped in a thermostatic water bath. A magnetic stirring bar was placed in the vial to agitate the sample. PDMS (100 µm polydimethylsiloxane) was used as the solid-phase fibre for micro-extraction. The vial was equilibrated at 40°C for 10 min, after which the power magnetic stirrer was added. SPME was performed at 40°C for 30 min, and then the solid-phase fibre was immediately put into the gas chromatograph injector. The fibre remained in the injector for about 3 min.

GC–MS analysis

Carrier: He at 1 mL/min. The temperature program used was 40°C for 3 min, raised to 160°C at 4°C/min, then raised to 230°C at 7°C/min for 8 min. The transfer line temperature was 230°C and the injection temperature was 250°C. Mass spectra were recorded in electron impact (EI) ionisation mode. Mass spectrometry: mass range 33 to 450 amu, scanned at 1 s intervals. The ion source temperature was 230°C.

Qualitative analysis and quantification

The identification of volatile compounds was achieved by comparing mass spectra obtained from the sample with those from pure standards injected in the same conditions, and by comparing the Kovats index or the mass spectra found in the NIST2.0 MS library database or in the literature. An internal standard quantification method using octan-3-ol was employed. Quantitative data of the identified compounds were obtained by interpolation of the relative areas versus the internal standard area using calibration graphs built for pure reference compounds. The concentration of volatile compounds, for which there was no pure reference, was obtained by using the same calibration graphs as the compounds with the most similar chemical structure according to formula and chemical character (Tao *et al*., 2008).

Sensory evaluation

The sensory analysis was developed by the expert panel in sensory analysis – a panel of 30 judges consisting of teachers and graduate students from the College of Enology, Northwest A & F University. They all had extensive knowledge of wines and had previously participated in wine descriptive sensory analysis training programmes. The descriptive sensory analysis provides the visual aspect, aroma, taste and harmony of the wine samples, which accounted for 15, 30, 44 and 11 scores respectively. Panellists were also trained with Le Nez du Vin (54 aroma terms) over 70 days to assess wine aroma. The wines were coded randomly and were presented to the panel arbitrarily.

Statistical analysis

Significant differences were assessed with one-way analysis of variance (ANOVA) using the SPSS version 17 statistical package for Windows (SPSS, Chicago, IL). Statistical differences between the means were evaluated using Duncan's test at the p = 0.05 level. Discriminant analysis was performed on the wines from different regions using the bound aroma fraction as differentiating variable.

RESULTS

Analysis of volatile composition

Volatile compounds in Merlot wines from the four districts detected by SPME-GC-MS are shown in Table 1. Fifty-seven aroma compounds were identified and their concentrations varied from 1 μg/L to 495 mg/L. The majority of the compounds were higher alcohols, esters and organic acids. The trace compounds were terpenols, norisoprenoids and volatile phenols. According to the ANOVA, there was a significant difference between four wine samples in relation to the number of volatile compounds detected. Table 1 shows that more volatile compounds were found in the wines from Changli and Helanshan. The odour active values of these potential aroma active compounds are shown in Table 2. Active odour compounds in wines from Changli, Helanshan, Shacheng and Manasi amounted to 18, 14, 16 and 21 respectively.

In our work, 13 of the 19 esters detected in sample wines were active and had aroma impact. Wines from Changli and Manasi had a higher accumulation of odour active values. Table 2 shows that ethyl hexanoate, ethyl octanoate, isopentyl acetate and ethyl butyrate had higher OAVs than the others, with fruity flavours of banana, strawberry, pineapple and pear. Ethyl acetate and ethyl lactate were active in almost all the wine samples and contributed to sweet flavour and lactic odour. Some esters, such as phenyl ethyl acetate, isopentyl acetate, ethyl DL 2-hydroxy-3-methyl butyrate, ethyl decanoate, isopentyl lactic and isopentyl octanoate, were active only in wines from one or two districts. Higher alcohols were the most abundant volatiles in the sample wines, amounting to 70% of all volatiles detected. However, only eight of the 20 higher alcohols detected had concentrations over their respective olfactory thresholds. As shown in Table 2, isopentanol, 3-methyl-1-pentanol and β-phenyl ethanol were odour active in all the samples. Five fatty acids, isobutyric acid, 2-methyl butyric acid, hexanoic acid, octanoic acid and decanoic acid, were detected in the sample wines. Four of them had OAVs >1 in one or more wines.

Concerning trace volatile compounds, α-ionol, β-ionol and β-damascenone were detected in the sample wines. They had a potential aroma contribution. β-Damascenon had an OAV > 1 in all the wines. Five terpenols were detected in the sample wines: linalool, linalool oxide, 4-terpineol, citronellol, trans-geraniol and trans-nerolidol. Linalool had an OAV > 1 in the wines from Changli, Shacheng and Manasi. Citronellol also was active in the Manasi wine. One volatile phenol, 2,4-di-tert-butyl-phenol, was quantified in the sample wines, and it had activity.

Sensory analysis

Sensory data were collected from a visual, aroma, taste and global evaluation by panellists with wine-tasting training. The results are shown in Table 3. Shacheng wine had better visual scores. Changli wine had better aroma. Manasi wine had the worst evaluation of aroma, taste and harmony. Therefore, Changli wine received the highest sensory scores, while Manasi wine was in last position in the sensory evaluation.

DISCUSSION

Major compounds

Although OAV does not consider the synergism between and suppression among odorants, it seems to be the basic way to predict wine aroma (Ferreira *et al*., 2000; Moyano *et al*., 2002). Only those compounds of which the concentrations exceed their respective olfactory thresholds could contribute to the odour. Esters are the main odour active compounds in wine, contributing both fruity and floral flavours. Three kinds of esters have been found in wine, namely acetates esters, ethyl esters, and other esters of fusels and fatty acids (Li, 2006). Gil *et al*. (2006) investigated the aroma compositions of white wines and rosé wines from Madrid, Spain and found that ethyl octanoate, ethyl hexanoate, isoamyl acetate and isoamyl alcohol had higher OAV values than the other esters. According to the OAVs and odour description of active esters in Table 2, the aroma prediction of sample wines is possible. Merlot wines from the four districts had obviously fruity traits of banana, pineapple, strawberry and pear. The wines from Changli and Manasi had a higher aroma intensity from esters, which had higher OAV accumulation. In addition, Changli wine had lactic and nut odours, and also some flowery nuances. Helanshan wine had lactic traits. Manasi wine had more nuances of lactic and cream (Sun & Liu , 2004).

Some researchers have concluded that certain alcohols have aroma, such as 1-butanol, isobutanol, isopentanol, 1-hexanol, 1-pentanol, benzyl alcohol, β-phenyl ethanol and 3-hexene-1-alcohol (Gil *et al*., 2006; Vilanova & Martinez, 2007). Active alcohols in the sample wines showed that all wines had odours of fusel alcohol, soil and flower pollen. In addition, Changli wine had much fusel odour and green grass nuances. Wine from Helanshan had weak fusel and smelled of lemon. Shacheng wine had green grass nuances. Manasi wine had an unpleasant fusel odour, obvious green grass nuances and some flowery traits.

Isobutyric acid, butyric acid, isovaleric acid, hexanoic acid, octanoic acid, decanoic acid, 9-decenoic acid and lauric acid have been reported in previous research (Ferreira *et al*., 2000; Kotseridis & Baumes, 2000; Gil *et al*., 2006; Li *et al*., 2008). Although C_6 to C_{10} fatty acids are related to

TABLE 1
Volatile compounds detected by SPME-GC-MS in Merlot wines from four districts in China.

No.	RT (min.)	Compounds	Concentration (mg/L)				Odour threshold (μg/L)
			Changli	Helanshan	Shacheng	Manasi	
1	3.26	ethyl acetate	51.122 c	18.205 b	17.667 a	111.434 d	7500
2	6.15	ethyl butyrate	1.149 c	0.663 b	0.709 b	0 a	20
3	6.54	1-propanol	4.152 b	9.723 d	5.731 c	0 a	50000
4	6.96	ethyl isovalerate	0.078 c	0 a	0.035 b	0 a	3
5	8.14	isobutanol	38.925 b	36.081 a	39.616 c	70.329 d	40000
6	8.36	isopentyl acetate	0.808 c	0.404 b	0.219 a	2.557 d	30
7	9.66	1-butanol	1.1 a	4.86 d	3.784 c	3.339 b	150000
8	11.59	isopentanol	306.059 c	281.69 b	262.037 a	495.457 d	30000
9	12.03	ethyl hexanoate	0.758 b	0.371 a	0.917 c	1.199 d	14
10	13.72	3-hydroxy-2-butanone	0 a	0 a	0 a	10.184 b	150000
11	13.84	2-O-2-phenylethyl formate	0.573 a	0.591 a	0.681 b	2.378 c	n.d.
12	14.99	isohexyl alcohol	0.247 a	0.315 b	0.354 c	0.72 d	5000[*]
13	15.20	2-heptanol	0 a	0.29 b	0 a	0 a	250[*]
14	15.40	3-methyl-1-pentanol	0.495 a	0.65 b	0.683 c	1.578 d	500[*]
15	15.80	ethyl lactate	97.516 c	29.136 a	40.78 b	175.058 d	14 000
16	16.24	1-hexanol	9.319 b	6.508 a	10.39 c	29.466 d	8000
17	16.56	*(E)*-3-hexen-1-ol	0.16 b	0.123 b	0.31 c	0 a	400
18	16.95	3-ethoxy-1-propanol	0.566 b	0 a	0 a	0 a	100
19	17.20	*(Z)*-3-hexen-1-ol	0 a	0.154 b	0 a	0 a	400
20	17.93	*(E)*-2-hexen-1-ol	0 a	0.107 b	0 a	0 a	400
21	18.43	ethyl DL 2-hydroxy -3-methyl butyrate	0.671 c	7.574 d	0.168 b	0 a	1000
22	18.69	ethyl octanoate	0.525 b	0.542 c	0.336 a	1.092 d	5
23	19.51	1-heptanol	0.154 b	0.024 a	0.042 a	0.211 c	250[*]
24	19.87	linalool oxide	0 a	0.013 a	0 a	0 a	500
25	20.58	2-ethyl hexanol	0.098 d	0.041 c	0.03 b	0 a	8000[*]
26	21.39	β-ionone	0.007 a	0 a	0.002 a	0 a	0.09
27	21.48	α-ionone	0.011 a	0 a	0 a	0 a	0.09
28	22.30	linalool	0.038 a	0.024 a	0.027 a	0.202 b	25
29	22.67	1-octanol	0.119 b	0.113 b	0.068 a	0.163 c	900
30	22.89	isopentyl lactate	0.563 c	0.069 a	0.097 a	0.387 b	200[*]
31	23.08	isobutyric acid	0 a	0 a	0.086 a	0 a	8100
32	23.25	2,3-butanediol	1.536 c	1.099 b	0.697 a	10.197 d	120000
33	24.91	ethyl decanoate	0.03 a	0.077 b	0.038 a	0.233 c	200
34	25.49	isopentyl octanoate	0.092 c	0 a	0.058 b	0.48 d	125
35	25.98	diethyl succinate	40.601 c	2.424 a	17.669 b	142.932 d	200000
36	26.10	2-methyl butyric acid	0 a	0.126 a	0 a	0 a	50
37	26.40	ethyl 9-decenoate	0.003 a	0.001 a	0.001 a	0.027 a	100[*]
38	26.62	β- terpineol	0.081 b	0.01 a	0 a	0 a	250
39	27.10	3-methyl-1-propanol	0 a	0.14 b	0.14 b	0 a	1000
40	28.53	1-decanol	0.093 b	0 a	0 a	0.403 c	400
41	28.61	citronellol	0 a	0.037 b	0.008 a	0.234 c	100
42	28.92	ethyl phenyl-acetate	0.223 b	0 a	0 a	0 a	650[*]
43	29.71	phenethyl acetate	0.262 c	0.19 b	0.071 a	1.444 d	250
44	29.86	β-damascenone	0.011 a	0.005 a	0.001 a	0.023 a	0.05
45	30.60	ethyl laurate	0.002 a	0.036 a	0.005 a	0.054 a	1500[*]
46	30.76	*trans*-geraniol	0 a	0.026 a	0 a	0 a	36
47	30.91	hexanoic acid	0.942 c	0.08 a	0.485 b	3.9 d	420

TABLE 1 (CONTINUED).

No.	RT (min.)	Compounds	Concentration (mg/L)				Odour threshold (μg/L)
			Changli	Helanshan	Shacheng	Manasi	
48	31.17	butyl butyrate	0.082 b	0 a	0 a	0 a	100
49	31.34	benzyl alcohol	1.789 c	1.545 b	0.711 a	3.377 d	200000
50	32.15	β-phenyl-ethanol	95.712 c	32.601 b	31.055 a	323.366 d	14000
51	33.44	lauryl alcohol	0.038 a	0.016 a	0 a	0 a	1000 [4]
52	34.76	[*E*]-nerolidol	0.023 a	0.016 a	0.007 a	0.239 b	700[*]
53	34.90	ethyl myristate	0.001 a	0.001 a	0 a	0 a	2000[*]
54	35.24	octanoic acid	3.23 c	0.885 a	1.369 b	13.207 d	500
55	38.15	ethyl palmitate	0.002 a	0.001 a	0 a	0 a	1500
56	38.59	n-decanoic acid	0.191 c	0.037 b	0.097 a	1.765 d	1000
57	38.94	2,4-di-tert-butyl-phenol	0.207 c	0.088 b	0.048 a	0.51 d	200
		Total	660.364	437.712	437.229	1408.145	

(a) The references from which the odour thresholds have been taken are Li (2006); Li *et al*. (2008); Tao *et al*. (2008); Tao & Yang (2010).
[*] Calculated in the Laboratory of Wine Olfactometry, College of Enology, Northwest A & F University, China. Orthonasal thresholds were calculated in a 12% ethanol/water mixture containing 5 g/L tartaric acid at pH 3.2.
n.d., not detected.
Means with the same letter do not differ significantly by Duncan's test (p < 0.05).

negative flavours in wine, they are important in the balance of aroma compounds as they can restrain the hydrolysis of aromatic esters (Edwards *et al*., 1990). Shinohara (1985) showed that C_6 to C_{10} fatty acids gave the smell of cheese and cream at concentrations of 4 to 10 mg/L, while they emitted an unpleasant fatty odour, and even a rancid smell, when present at higher concentrations (> 20 mg/L). In this work, Changli wine had the appropriate content of fatty acids, which could contribute a pleasant, fatty smell, but also retain a sufficient content of aromatic esters. The wines from Helanshan and Shacheng had somewhat lower contents of fatty acids. However, Manasi wine had a much higher content of fatty acids, and hence also an obvious rancid odour.

Trace compounds

Trace compounds in wine may contribute to global aroma due to their very low olfactory threshold. α-Ionol, β-ionol and β-damascenone are three norisoprenoids that are often reported (Boido *et al*., 2003; Lopez *et al*., 2004; Gómez-Míguez *et al*., 2007; Vilanova & Martinez, 2007). They have concentrations < 10 μg/L in wine generally. Because their olfactory threshold is very low, between 0.05 and 0.09 μg/L, they usually have odour activity. In our work, β-damascenone was active in all the samples, providing the flavour of processed fruit, such as canned peach, and baked apple. α-Ionol was active in the Changli wine, and β-iono in the Changli and Shacheng wine. These two compounds smelled of raspberry and added violet flavour.

Numerous studies have reported that the terpenoid compounds could be used analytically for varietal characterisation. Terpene compounds are one class of plant secondary metabolites whose biosynthesis begins with acetyl-coenzyme A (CoA). Terpenes are not changed by yeast metabolism during fermentation and differ between varieties (José *et al*., 2004; Câmara *et al*., 2007; Falque *et al*., 2008). According to the monoterpenes content in grape juices, three grape classes can be classified: 1) muscat varieties, with monoterpenes more than 6 mg/L, 2) non-muscat but aromatic varieties, with monoterpenes at 1 to 4 mg/L, and 3) neutral varieties not dependent upon monoterpenes for their odour (Mateo & Jiménez, 2000). Terpene compounds in wine are almost terpenols. Merlot is a neutral variety. In this work, linalool had an OAV > 1 in the Changli, Shacheng and Manasi wine samples, and added muscat flavour. Citronellol was active in Manasi wine and provided traits of clove and rosebush.

Volatile phenols are another class of potential active odorants in wine, such as guaiacol, cresol, 4-ethyl phenol, vinyl phenol, eugenol, vanilla, etc. They are mostly soluble compounds extracted from oak barrels during ageing. In this work, the sample wines were not stored in oak barrels, hence only 2,4-di-tert-butyl-phenol was detected and expressed any phenolic odour activity in the Changli and Manasi wines.

Sensory analysis

Sensory analysis confirmed the contributions of the active odorants in the samples. Changli wine had much higher levels of impact odorants and OAV accumulation. Its aroma was complex and pleasant. Manasi wine also had higher impact odorants, but its short-chain fatty acids and volatile phenol gave an off-flavour, a bad taste and poor harmony. As highlighted in the work of Aznar *et al*. (2003), overall pleasant descriptions are positively correlated with the chemicals with a pleasant aroma, but unpleasant compounds have a much more destructive effect on global aroma quality.

CONCLUSIONS

The differences in sensory and aroma composition profiles of Merlot wines from different geographic origins were characterised successfully. Fifty-seven volatile compounds were identified in Merlot wines in China, 31 of which are active odorants. Furthermore, some aroma compounds

TABLE 2
OAVs and odour descriptions of impact odorants in Merlot wines from four districts in China.

No.	RT (min.)	Compounds	OAVs [a]				Odour description [b]
			Changli	Helanshan	Shacheng	Manasi	
		Acetate esters					
1	3.26	ethyl acetate	6.8	2.4	2.4	14.9	fruity, sweet
2	8.39	isopentyl acetate	26.9	13.5	7.3	85.2	banana
3	29.71	phenethyl acetate	1.0	0.8	0.3	5.8	pleasant, floral
		Sum	34.8	16.7	9.9	105.9	
		Ethyl esters					
1	6.15	ethyl butyrate	57.5	33.2	35.5		sour fruit, strawberry, fruity
2	6.97	ethyl isovalerate	26.0		11.7		banana, sweet fruity
3	12.03	ethyl hexanoate	54.1	26.5	65.5	85.6	green apple, fruity, strawberry, anise
4	15.80	ethyl lactate	7.0	2.1	2.9	12.5	lactic, raspberry
5	18.43	ethyl DL 2-hydroxy-3-methyl butyrate	0.7	7.6	0.2		pineapple, strawberry, tea, honey
6	18.71	ethyl octanoate	105.0	108.4	67.2	218.4	pineapple, pear, floral
7	24.93	ethyl decanoate	0.2	0.4	0.2	1.2	fruity, pleasant fatty
		Sum	250.4	178.1	183.1	317.7	
		Other esters					
1	22.89	isopentyl lactate	2.8	0.3	0.5	1.9	cream, nut
2	25.67	isopentyl octanoate	0.7		0.5	3.8	sweet, cheese, cream, light fruity
		Sum	3.6	0.3	0.9	5.8	
		Higher alcohols					
1	8.21	isobutanol	1.0	0.9	1.0	1.8	fusel, alcohol
2	11.59	isopentanol	10.2	9.4	8.7	16.5	alcohol, harsh, bitter
3	15.20	2-heptanol		1.2			lemon, orange, copper
4	15.38	3-methyl-1-pentanol	1.0	1.3	1.4	3.2	soil, mushroom
5	16.24	1-hexanol	1.2	0.8	1.3	3.7	green, grass
6	16.95	3-ethoxy-1-propanol	5.7				fusel, alcohol
7	28.53	1-decanol	0.2			1.0	orange flowery, especially fatty
8	32.15	β-phenyl-ethanol	6.8	2.3	2.2	23.1	floral, pollen, perfume
		Sum	26.1	15.9	14.6	65.9	
		Organic acids					
1	26.10	2-methyl butyric acid	0.0	2.5	0.0	0.0	cheese
2	30.89	hexanoic acid	2.2	0.2	1.2	9.3	cheese, rancid
3	35.23	octanoic acid	6.5	1.8	2.7	26.4	cheese, fatty acid , harsh, rancid
4	38.59	decanoic acid	0.2	0.0	0.1	1.8	fatty, unpleasant
		Sum	8.9	4.5	4.0	37.5	
		Terpenols					
1	22.32	linalool	1.5	1.0	1.1	8.1	muscat, flowery, fruity
2	28.61	citronellol	0.0	0.4	0.1	2.3	clove, rosebush
		Sum	1.5	1.4	1.2	10.4	
		Norisoprenoids					
1	21.45	β-ionone	77.8		22.2		raspberry, violet, sweet fruity
2	21.54	α-ionone	122.2				raspberry, violet, sweet fruity
3	29.86	β-damascenone	220.0	100.0	20.0	460.0	bark, canned peach, baked apple, dry plum
		Sum	420.0	100.0	42.2	460.0	
		Others					
1	38.94	2,4-di-tert-butyl-phenol	1.0	0.4	0.2	2.6	phenolic
		Sum	1.0	0.4	0.2	2.6	

a: Odour activity values were calculated by dividing the concentration by the odour threshold value of the compound.
b: The odour descriptions are cited in the references of Sun & Liu (2004); Li (2006); Li *et al*. (2008); Tao *et al*. (2008).

TABLE 3
Results of the sensory analysis of Merlot wines from four districts in China.

	Sensory attributes	Changli	Helanshan	Shacheng	Manasi
Visual	Clarity (5)	4.2	4.3	4.2	4.3
	Appearance (10)	6.7	6.8	7.1	6.5
Aroma	Purity (6)	5.5	5.2	4.8	3.7
	Intensity (8)	7.5	6.2	6.5	6.9
	Quality (16)	14.5	12.2	12.3	10.9
Taste	Purity (6)	5.5	5.4	5.5	5.1
	Intensity (8)	7.2	7.1	7.4	7.5
	Prolongation (8)	7.3	6.8	7.5	6.5
	Quality (22)	20.5	21.4	20.6	17.3
Global evaluation	Harmony (11)	10.1	10.2	10.2	9.5
Total*	100	89.0	85.6	86.1	78.2

* > 86 = Excellent; 81–85 = very good; 71–80 = good; 50–70 = regular; < 50 = inadequate

were only active in the wines from one or two districts. Changli wine was found to have an appropriate content of fatty acids. The content of fatty acids in Manas wine was much higher, while it was lower in the Helanshan and Shacheng wines. Changli wine had a higher fruity aroma, obvious lactic and nut traits, and other complex flavours.

The sensory analysis validated the aroma contributions of the active odorants of the sample wines. More pleasant impact odorants gave Changli wine a better aroma and good sensory quality. Too much fatty acid and volatile phenol destroyed the aroma quality of the Manasi wine and resulted in this wine receiving the worst evaluation of aroma, taste and harmony.

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