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Full Length Research Paper

Effect of terrains on the volatiles of Cabernet Sauvignon wines grown in Loess Plateau region of China

Bao Jiang[1], Zhen-Wen Zhang[1,2]* and Jun-Xian Zhang[1]

[1]College of Enology, Northwest A&F University, Yangling, 712100 Shaanxi Province, People's Republic of China.
[2]Shaanxi Engineering Research Center for Viti-Viniculture, Northwest A&F University, Yangling, 712100 Shaanxi Province, People's Republic of China.
[3]Weinan Vocational & Technical College, Weinan, 714000 Shaanxi Province, People's Republic of China

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Volatile compounds of young Cabernet Sauvignon wines from the flat and slope lands grown in Loess Plateau region (China) were investigated in this research. Among the volatile compounds analyzed by headspace solid phase microextraction (HS-SPME) with gas chromatography-mass spectrometry (GC-MS), a total of 43 and 45 volatile compounds were identified and quantified in the flat and slope lands wines, respectively. In the volatiles detected, higher alcohols formed the most abundant group in the aroma components of two wines, followed by esters and fatty acids. According to their odor active values (OAVs) and relative odor contribution (ROC), the aromatic profiles for two wines were similar, showing only quantitative but not qualitative differences. Ethyl octanoate, ethyl hexanoate and isoamyl acetate were found to jointly contribute to 98.8 and 99.2% of the global aroma of the flat and slope wines, respectively. These odorants are associated with "fruity'' and ''ripe fruit'' odor descriptors. Wine from flat land with higher OAVs of ethyl octanoate and isoamyl acetate seems to have more intense fruity aromas (pineapple, pear and banana), with floral notes.

Key words: Cabernet Sauvignon wines, volatiles, terrains, Loess Plateau region, headspace solid phase microextraction (HS-SPME), gas chromatography-mass spectrometry (GC-MS).

INTRODUCTION

Volatile composition is one of the most important factors in the determination of wine character and quality; it influences the organoleptic characteristics of wines, particularly the aromatic characteristics. Moreover, aroma is one of the most important quality attributes to consumers when buying wine (Komes et al., 2006). Aroma constituents of different wines have been extensively studied in the last few years. The flavor of a wine presents an extremely complex chemical pattern in both qualitative and quantitative terms, because over 1000 volatile compounds have been found in wines, with a wide concentration range varying from hundreds of mg/l to the µg/l or ng/l level (Gómez-Míguez et al., 2007), such as alcohols, esters, organic acids, phenols, thiols, monoterpenes and norisoprenoids, have been found in wines and is responsible for the complexity of wine bouquet and ensures the specificity and character, but their contribution to wine aroma does not depend only on the concentration; the perception threshold also plays an

*Corresponding author. E-mail: zhangzhw60@nwsuaf.edu.cn. Tel: +86 29 87091847. Fax: 86 29 87091099.

Abbreviations: HS-SPME, Headspace solid phase microextraction; **GC-MS,** chromatography-mass spectrometry; **MS/EI,** mass spectrometry in the electron impact mode; **OAVs,** odor activity values; **ROC,** relative odor contribution.

important role (Falqué et al., 2004). Wine flavor are mainly derived from varietal, fermentation and aging aroma. Furthermore, the varietal aroma of wines is due to the presence of monoterpenes, norisoprenoids, methoxy-pyrazines and thiols compounds; fermentation aroma from yeast metabolism is the esters, alcohols and acetates; ageing aroma from oak includes phenols, furans and oak-derived-vanillic compounds (Selli et al., 2004; Weldegergis et al., 2007).

Since the aroma of young wines partly, is the result of grape metabolism, many factors (including soil, terrain, climate, etc.) can influence the volatile components of grape and wine and the role exerted by each individual factor is still not clearly established. Altitude can exert an important influence on grape maturation and wine composition that is strictly related to the local climate. Research on the aroma of cabernet sauvignon wine from Brazil indicates that, wines from higher altitudes have a ''bell pepper'' aroma, while wines from lower altitudes are correlated with ''red fruits'' and ''jam'' aromas (Falcao et al., 2007); in Italy, it has been reported that vineyard location has an influence on flavor compounds and wine quality by demonstrating that high monoterpene concentrations are associated with warm sites (Corino and Stefano, 1988); in Canada, Reynolds et al. (1996) have reported that, fruit and wine flavor components and sensory attributes overall in Gewürztraminer, were responsive to vineyard site.

Solid-phase microextracton (SPME), first proposed by Arthur and Pawliszyn (1990), is a simple, solvent-free method for concentration of volatiles present in the headspace. This technique had been used to analyze the volatile compounds of wines (Tao et al., 2008; Pino and Queris, 2010). With the development of Chinese wine industry, areas of grapevines have been increasing, the new grape-growing regions were constantly discovered in recent years, including Loess Plateau region of China. Rongzi Chateau of Xiangning County located in Loess Plateau region, is situated approximately between 35° to 37°N, average altitude of 1100 m. Climatic characteristics of this region which are dryer climate, stronger sunshine and a wide swing in diurnal temperature differences are distinguished by lower night-time temperature creates an especially healthy environment for vines. But these characteristics of the Loess Plateau region such as crisscross gulleys, different slopes, slope direction and altitude contribute together to form the local mountainous microclimate which can significantly influence quality of grape berry and wine. Up till now, relevant research in this region has been a blank. For this study, we selected the Cabernet Sauvignon wines from the flat and slope lands and investigated the volatile compounds of the monovarietial wines, with volatiles being extracted by SPME and being detected by gas chromatography-mass spectrometry (GC-MS). The objectives of this study include to identify and quantify the principal volatile compounds present in the Cabernet Sauvignon wines produced from Loess Plateau region of China as well as to check whether there are differences between the Cabernet Sauvignon wines from two different terrains or not, namely, flat and slope lands.

MATERIALS AND METHODS

Vineyard conditions and vinification

Two vineyards are located in the Rongzi Chateau of Xiangning County in Loess Plateau region, where the loess depth exceeds 200 m. In the collection, two vineyards have similar characteristics (age and cultivation management). All the vines were cultivated in 2007 spring and seedling root system with multiple main vine fan-training, and 2.5×1.0 m (row × vine) spacing.

All grape berries were harvested manually at optimum technological maturity, as judged by indices of sugar and acid content in 2009. Pre-fermentation treatments and winemaking were done as described by Li (2002). Briefly, grapes were crushed on an experimental destemmer-crusher and then transferred to stainless-steel containers. 90 L of each treatment wine were produced. 50 mg/l of SO_2 and 30 mg/l of pectinase (Lallzyme Ex) were added to the musts and the contents were mixed by hand. After maceration of the musts for 24 h, 200 mg/l of dried active yeast (*Saccharomyces cerevisiae* strain, Lallemand, Danstar Ferment AG, Switzerland) was added to the musts, according to commercial specifications. Alcoholic fermentation was carried out at 20 to 25°C to dryness (reducing sugar < 4 g/l) which took place over a 6 to 8 days period and density controls were maintained during this period. At the end of fermentation, the wines were separated from pomace and then 50 mg/l of SO_2 added. After fermentation, the wine samples were bottled and stored at 5°C prior to analysis. All the samples were 5 months old at the time of analysis.

Total sugar, total acidity, pH, total phenolics, total tannins, reducing sugar and ethanol were analyzed according to OIV (1990) official methods (Table 1).

Reagents

All standards were purchased from Aldrich (Milwaukee, Wis., U.S.A.) and Fluka (Buchs, Switzerland). They were 4-methyl-2-pentanol, isoamyl alcohol, 2-heptanol, 1-hexanol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, (*E*)-2-hexen-1-ol, (*Z*)-2-hexen-1-ol, 2-octanol, 1-octen-3-ol, 1-heptanol, 2-ethyl-1-hexanol, 2-nonanol, 2,3-butanediol, linalool, 1-octanol, 3-(methylthio)-1-propanol, 1-decanol, benzyl alcohol, 2-phenylethanol, 1-dodecanol, ethyl acetate, isoamyl acetate, ethyl hexanoate, hexyl acetate, ethyl lactate, ethyl octanoate, ethyl decanoate, diethyl succinate, ethyl dodecanoate, phenethyl acetate, acetic acid, hexanoic acid, octanoic acid, decanoic acid, hexanal, nonanal, benzaldehyde, geranylactone, acetoin, furfural, citronellol, limonene. Purity of all standards was above 99%. Model solutions were prepared using the methods reported by Howard et al. (2005). 4-Methyl-2-pentanol was used as the internal standard. For quantification, 8-point calibration curves for each compound were prepared using the method described by Ferreira et al. (2000), which was also used as a reference to determine the concentration range of standard solutions. The regression coefficients of calibration curves were above 98%. The standard deviation for the SPME method was below 10%.

Headspace solid phase microextraction (HS-SPME) procedure

Aroma compounds of the wine samples were extracted by HS-SPME and analyzed using gas chromatography/mass spectrometry

Table 1. General composition of the musts and wines of Cabernet Sauvignon from the different terrains.

Parameter	Slope land		Flat land	
	Must	Wine	Must	Wine
Altitude (m)	1280.5	-	909.3	-
North latitude	36°01′05″	-	35°57′09″	-
East longitude	110°49′11″	-	110°47′47″	-
Total sugar (g/l)	194.0	-	195.3	-
Total acidity[a] (g/l)	10.4	8.9	9.6	8.4
pH	3.1	3.0	3.3	3.1
Total phenolics[b] (mg/l)	3430.1	1152.2	3460.2	1881.4
Total tannins[c] (mg/l)	4060.4	933.3	4300.1	1630.4
Reducing sugar (g/l)	-	1.7	-	1.8
Ethanol (%,v/v)	-	11.8	-	12.8

Each data in the table was mean values of triplicate samples (maximum SD: ±10%); [a] acidity expressed as grams of tartaric acid equivalents per liter; [b] total phenolics expressed as milligrams of gallic acid equivalents per liter; [c] tannins expressed as milligrams of tannin acid equivalents per liter.

as described by Zhang et al. (2007). Five milliliters of wine sample and 1 g NaCl were placed in a 15-ml sample vial. The vial was tightly capped with a PTFE-silicon septum and heated at 40°C for 30 min on a heating platform agitation at 400 rpm. The SPME (50/30 μm DVB/Carboxen/PDMS, Supelco, Bellefonte, Pa., U.S.A.), preconditioned according to manufacturer's instruction, was then inserted into the headspace, where extraction was allowed to occur for 30 min with continued heating and agitation by a magnetic stirrer. The fiber was subsequently desorbed in the GC injector for 25 min.

GC–MS analysis

The GC-MS system used was an Agilent 6890 GC equipped with an Agilent 5975 mass spectrometry. The column used was a 60 m × 0.25 mm HP-INNOWAX capillary with 0.25 μm film thickness (J & W Scientific, Folsom, Calif., U.S.A.). The carrier gas was helium at a flow rate of 1 ml/min. Samples were injected by placing the SPME fiber at the GC inlet for 25 min with the splitless mode. The oven's starting temperature was 50°C, which was held for 1 min, then raised to 220°C at a rate of 3°C /min and held at 220°C for 5 min. The mass spectrometry in the electron impact mode (MS/EI) at 70 eV was recorded in the range *m/z* 20 to 450 U. The mass spectrophotometer was operated in the selective ion mode under autotune conditions and the area of each peak was determined by ChemStation software (Agilent Technologies). Analyses were carried out in triplicate.

RESULTS AND DISCUSSION

Physico-chemical indexes of musts and wines

Table 1 shows some of the physico-chemical indexes of the Cabernet Sauvignon musts and wines from flat and slope lands. Results showed that, the sugar, titratable acidity, pH, total phenolics and total tannins of musts were not marked differently. Furthermore, after being stored in stainless steel tanks at 5°C for 5 months, young red wines made from the flat and slope grapes showed quite similar titratable acidity, pH, reducing sugar and ethanol concentration. But total phenolics and tannins contents of the Cabernet Sauvignon wines of the different terrains exist in obvious differences; the results were that total phenolics and tannins contents of the flat land wine were 1.6 and 1.7 times higher than those of the slope wine, respectively.

The results were partially in agreement with the results in a previous study (Zhang et al., 2007) showing that the tannin contents of Cabernet Sauvignon wines in the slope land vineyard (1152 and 1096 m) were higher than that of the flat land vineyard (818 m); moreover, for two slope land vineyards, the tannin contents in lower altitude wine (1096 m) was higher than another slope land wine (1152 m). Bajda (2007) studies indicated that, total tannin contents of Malbec wine went steadily up with higher elevations, while bitter monomeric tannins decreased. To our knowledge, little data is available in literature concerning the effect of terrains on phenolic and tannin contents. It was speculated that, the characteristics of local climate and soil could lead to the discrepancy between our results and others or effect of terrains on their contents was different with these varietal wines.

Aroma composition of wines

Two groups of typical total ion chromatograms were generated for Cabernet Sauvignon wines using HS-SPME coupled with GC-MS. The mean concentrations of the key volatile compounds of the 2 monovarietal wines are given in Table 2 by chemical classes. In all, 43 and 45 volatile compounds were identified in the flat and slope lands wines, respectively, including alcohols, esters, fatty acids, terpenes, aldehydes and ketones compounds. Many of these volatile compounds are commonly found in wines and are derived from grapes and yeast strain fermentation and verification process

Table 2. GC-MS analytical results of aroma components in cabernet sauvignon wines from the different terrains.

Compound name	Threshold (mg/l)	Concentration (μg/l)		Sensory properties
		Slope land	Flat land	
Alcohols				
1-Propanol	306[c]	ND	5538.7 ± 74.6	Fresh, alcohol
Isobutyl alcohol	40[a]	22.0 ± 0.2 (mg/l)	31.0 ± 0.5 (mg/l)	Fusel, alcohol
1-Butanol	150[b]	1587.6 ± 15.5	3333.5 ± 56.1	Medicinal, alcohol
Isoamyl alcohol	30[a]	185.6 ± 3.6 (mg/l)	211.2 ± 1.9 (mg/l)	Cheese
1-Pentanol	-	176.1 ± 1.9	223.6 ± 2.4	Fruity, balsamic
4-Methyl-1-pentanol	50[g]	106.8 ± 2.9	213.9 ± 10.5	-
2-Heptanol	0.07[d]	14.7 ± 0.5	18.1 ± 2.0	Fruity, mouldy, musty
1-Hexanol	8[a]	4041.7 ± 76.8	3429.0 ± 233.0	Green, grass
(*E*)-3-hexen-1-ol	0.4[a]	133.8 ± 5.7	180.6 ± 13.1	Green grass, herb
(*Z*)-3-hexen-1-ol	0.4[a]	135.8 ± 17.7	146.3 ± 3.6	Green grass, herb
(*E*)-2-hexen-1-ol	0.1[d]	47.3 ± 1.3	ND	Green grass, herb
2-Octanol	-	24.3 ± 0.5 (mg/l)	ND	Unpleasant, perfumed
1-Heptanol	-	212.2 ± 5.5	121.2 ± 27.9	Grape, sweet
2-Ethyl-1-hexanol	-	Trace	Trace	Mushroom, sweet fruity
2-Nonanol	0.058[d]	6.3 ± 0.1	ND	Intense fruity
2,3-Butanediol	120[h]	405.4 ± 8.3	390.8 ± 11.8	Butter, creamy
1-Octanol	0.12[a]	44.2 ± 0.5	39.0 ± 2.4	Intense citrus , roses
3-(Methylthio)-1-propanol	0.5[a]	1990.2 ± 103.3	2459.8 ± 78.1	Boiled potato, rubber
1-Decanol	0.4[a]	10.7 ± 0.4	ND	Orange flowery, special fatty
Benzyl alcohol	200[e]	150.4 ± 9.0	150.0 ± 14.2	Citrusy, sweet
2-Phenylethanol	14[a]	14.5 ± 0.1 (mg/l)	24.3 ± 0.1 (mg/l)	Flowery, pollen, perfumed
1-Dodecanol	1[h]	897.0 ± 77.2	ND	Unpleasant in high concentration and flowery in low concentration
Subtotal		256.3 (mg/l)	282.8 (mg/l)	
Subtotal (%)		64.7	55.6	
Esters				
Ethyl acetate	7.5[a]	52.2 ± 0.5 (mg/l)	121.9 ± 2.9 (mg/l)	Fruity, sweet
Isoamyl acetate	0.03[a]	14.7 ± 0.8 (mg/l)	14.7 ± 0.2 (mg/l)	Banana
Ethyl hexanoate	0.005[a]	4107.2 ± 225.9	3851.4 ± 371.3	Fruity, anise
Hexyl acetate	0.67[c]	142.4 ± 5.4	127.2 ± 6.9	Pleasant fruity, pear
Ethyl lactate	154.6[b]	11.7 ± 0.1 (mg/l)	19.7 ± 0.3 (mg/l)	Lactic, raspberry
Heptyl acetate	-	14.1 ± 0.7 (mg/l)	10.6 ± 0.3 (mg/l)	Pleasant fruity, pear, roses
Methyl octanoate	-	8.5 ± 0.7	8.9 ± 0.4	Intense citrus
Ethyl octanoate	0.002[a]	5107.9 ± 84.4	5154.0 ± 237.1	Pineapple, pear, floral
Ethyl nonanoate	1.3[h]	ND	1137.8 ± 12.4	Pleasant fruity, roses
Ethyl decanoate	0.2[a]	1451.2 ± 48.4	1373.7 ± 33.8	Fruity, fatty, pleasant
Diethyl succinate	500[b]	182.9 ± 1.0	226.7 ± 9.9	Light fruity

(Cliff et al., 2002).

Alcohols

Alcohols are formed from the degradation of amino acid, carbohydrates and lipids (Antonelli et al., 1999). Alcohols represented the largest group in terms of the numbers and concentration of aroma compounds identified in two wines, followed by esters and fatty acids. The subtotal concentration of alcohols in the flat and slope lands wines were 282.8 and 256.3 mg/l, being 55.6 and 64.7% of the total volatile compounds detected, respectively. This volatile fraction was mainly composed of isoamyl alcohol, isobutyl alcohol, 2-phenylethanol and 2-octanol, these four alcohols had concentrations of >14 mg/l (they existed in at least one of the wines studied). Isoamyl alcohol was the most abundant alcohol accounting for 75

Table 2. Contd.

Compound name	Threshold (mg/l)	Concentration (μg/l)		Sensory property
		Slope land	Flat land	
		ND	41.2 ± 1.7	Pleasant, floral
Ethyl dodecanoate	-	222.7 ± 0.8	156.4 ± 7.3	Flowery, fruity
Subtotal		104.0 (mg/l)	184.0 (mg/l)	
Subtotal (%)		26.3	36.2	
Fatty acids				
Acetic acid	200[a]	18.9 ± 0.5 (mg/l)	16.1 ± 0.6 (mg/l)	Acid, fatty
Propanoic acid	8.1[e]	213.3 ± 18.2	ND	Vinegarish
Isobutyric acid	200[a]	2916.4 ± 26.6	4975.8 ± 24.9	Fatty
Hexanoic acid	3[a]	1709.8 ± 83.9	1033.5 ± 10.6	Cheese, rancid, fatty
Heptanoic acid	3[f]	trace	ND	Fatty, dry
Octanoic acid	0.5[a]	5205.9 ± 335.6	2692.4 ± 72.2	Rancid, harsh, cheese, fatty acid
Decanoic acid	15[a]	2877.7 ± 150.1	1430.1 ± 43.3	Fatty, unpleasant
Subtotal		31.8 (mg/l)	26.2 (mg/l)	
Subtotal (%)		8.0	5.2	
Aldehydes and ketones				
Nonanal	-	49.0 ± 1.1	56.5 ± 0.6	Green, slightly pungent
Benzaldehyde	2[c]	348.6 ± 2.4	121.0 ± 8.8	Almond
Geranylactone	-	29.8 ± 0.7	28.9 ± 1.8	Floral
Furfural	14.1[a]	125.9 ± 5.9	142.1 ± 10.7	Pungent
Decanal	1[g]	ND	3684.7 ± 302.4	Grassy, orange skin-like
Acetoin	150[a]	3378.5 ± 75.5	11.0 ± 0.1 (mg/l)	Flowery, wet
Subtotal		3931.8	15.0 (mg/l)	
Subtotal (%)		1.0	3.0	
Terpenes				
Citronellol	0.1[a]	14.4 ± 0.6	13.6 ± 0.2	Green lemon
Limonene	0.2[d]	ND	156.9 ± 1.1	Flowery, green, citrus
Subtotal		14.4	170.5	
Subtotal (%)		<0.1	< 0.1	
Total		396.1 (mg/l)	508.2 (mg/l)	

Each data in the table was expressed as mean value ± S.D., n=3; ND, not determined; [a] Guth (1997); [b] Tominaga et al. (1998); [c] Peinado et al. (2004); [d] Du et al. (2010); [e] Gómez-Míguez et al. (2007); [f] Souid et al. (2007); [g] Lourdes et al. (2009); [h] Li et al. (2008).

and 72% of the total alcohols in the flat and slope lands wines, respectively. Compared with the flat land wine, the alcohol profile of the slope land wine was more diverse, containing 21 types of alcohols compared with only 17 in the flat land wine. (*E*)-2-Hexen-1-ol, 2-octanol, 2-nonanol, 1-decanol and 1-dodecanol were absent in the wine made from the flat Cabernet Sauvignon. Meanwhile, 1-propanol was missed with alcohol in the slope land wine.

Esters

Acetate esters are the result of the reaction of acetyl-CoA with higher alcohols that are formed from degradation of amino acids or carbohydrates (Perestrelo et al., 2006). On the other hand, ethyl esters of fatty acids are produced enzymatically during yeast fermentation and from ethanolysis of acyl-CoA that are formed during fatty acids synthesis or degradation. Their concentration is dependent on several main factors: Yeast strain, fermentation temperature, aeration degree and sugar content (Perestrelo et al., 2006).

There were also differences in the type and amount of esters present in two wines. In general, the concentration and proportion of esters in the flat land wine (36.2%) were higher than those of the slope land wine (26.3%) and the total number of esters in two wines exhibited the same order. Although, their amount varied between two wines, ethyl acetate, isoamyl acetate, ethyl lactate and heptyl acetate were the major esters found in the aroma

Table 3. Comparison of odor activity values (OAVs) and relative odor contribution[a] (ROC) for the aroma compounds in cabernet sauvignon wines from the different terrains.

Compound name	Sensory properties	Cabernet sauvignon wines	
		Slope land	Flat land
Ethyl octanoate	Pineapple, pear, floral	2554.0 (65.5%)	2577.0 (63.6%)
Ethyl hexanoate	Fruity, anise	821.4 (21.1%)	770.3 (19.0%)
Isoamyl acetate	Banana	491.1 (12.6%)	657.7 (16.2%)
Ethyl acetate	Fruity, sweet	7.0 (0.2%)	16.3 (0.4%)
Octanoic acid	Rancid, harsh, cheese, fatty acid	10.4 (0.3%)	5.4 (0.1%)
Ethyl decanoate	Fruity, fatty, pleasant	7.3 (0.2%)	6.9 (0.2%)
Isoamyl alcohol	Cheese	6.2 (0.2%)	7.0 (0.2%)
3-(Methylthio)-1-propanol	Boiled potato, rubber	4.0 (0.1%)	4.9 (0.1%)
Decanal	—	ND	3.7 (<0.1%)
2-Phenylethanol	Flowery, pollen, perfumed	1.0 (<0.1%)	1.7 (<0.1%)

[a] Relative odor contribution (ROC) of each aroma compound is shown in parentheses and was calculated as the ratio of the OAV of the respective compound to the total OAV of each wine; ND, Not determined.

components of the 2 wines in terms of their concentrations. Ethyl nonanoate and phenethyl acetate were absent in the slope land wine.

Fatty acids

The production of fatty acids has been reported to be dependent on the composition of the must and fermentation conditions (Schreirer, 1979). Acetic acid was the major fatty acid found, constituting 61 and 59% of the total fatty acid content of the flat and slope lands wines, respectively. Acetic acid is produced during alcoholic and malolactic fermentation. At low levels, this compound lifts wine flavors; however, at high levels, it is detrimental to the taste of wine by leaving the wine tasting sour and thin (Joyeux et al., 1984). Propanoic acid and heptanoic acid were only found in the slope land wine, although, amount of heptanoic acid and propanoic acid were only trace and 213.3 μg/l, respectively. Isobutyric, hexanoic, octanoic and decanoic acids were found in two wines, the concentration of them varied from 1033.5 to 5205.9 μg/l. These C6 to C10 fatty acids at concentrations of 4 to 10 mg/l impart mild and pleasant aroma to wine; however, at levels beyond 20 mg/l, their impact on wine becomes negative (Shinohara, 1985). The C6 to C10 fatty acids might have a positive impact on the aroma of the 2 wines examined in the current study since their levels were all far below 10 mg/l.

Terpenes

Numerous studies have shown that, the terpenoid compounds are important component of varietal aroma and are not affected by yeast metabolism during fermentation (Rapp, 1988), they are hence, a good indicator for the variety and quality of grape (Begala et al., 2002). In the present study, two terpenes were detected in the slope land wines, namely, citronellol and limonene. They are made up of less than 0.1% of the total volatile compounds in the 2 wines. Meanwhile, the limonene was absent in the slope wine. Hence, these terpenyl compounds could serve as potential indicators to distinguish quality of wine derived from the flat and slope lands wines of cabernet sauvignon variety.

Aldehydes and ketones

The composition of aldehydes and ketones varied greatly between two wines. Nonanal, benzaldehyde, geranylactone, furfural and acetoin were found in two wines. Furthermore, acetoin was the most abundant component of the group in the flat and slope lands wines, accounting for 73 and 86%, respectively. Decanal was unique in the aroma components of the flat land wine.

Odor activity values (OAVs)

Though dozens of volatiles were detected in each wine sample, not all of the components have great impact on the overall aroma character of this wine. Of all the compounds analyzed, only those displaying OAVs greater than 1 were deemed to contribute to wine aroma (Guth, 1997). OAVs were calculated by dividing the mean concentration of an aroma compound by its odor threshold value.

Table 3 shows total 10 OAVs for compounds that exceeded their thresholds in two wines, namely, ethyl octanoate, ethyl hexanoate, isoamyl acetate, ethyl acetate, octanoic acid, ethyl decanoate, isoamyl alcohol, 3-(methylthio)-1-propanol, decanal and 2-phenylethanol. For the 10 volatile compounds with OAVs above 1, the majority of OAVs were not obviously different in the 2 wines. The computation of relative odor contribution (ROC) proposed by Ohloff (1994) is a useful index for determining the important aroma components in a complex system. Based on the ROC values of single compounds, we found that, the global aroma of the 2 wines was dominated by fermentative aromas, namely, the ethyl esters of fatty acids (ethyl octanoate and ethyl hexanoate) that conferred fruity notes to the wines. Specifically, ethyl octanoate, ethyl hexanoate and isoamyl acetated jointly accounted for 98.8 and 99.2% of the global aroma of the flat and slope lands wines of cabernet sauvignon, respectively. These compounds are responsible for a major part of the aroma characteristics of young wines. The results in the present study were partially consistent with the results in a previous study (Zhang et al., 2007) indicating that, the three aroma compounds mentioned earlier jointly accounted for 97% of the global aroma of cabernet sauvignon wine from Huailai County of China. In this study, alcohols were the predominant groups which constituted the aroma compounds rather than acids as in the previous study (Zhang et al., 2007). The differences in our results from others come into being in various terroirs.

Taking into account the OAVs and ROC of each compound, the aromatic profiles for the 2 wines were similar, showing only quantitative but not qualitative differences. Ethyl octanoate, ethyl hexanoate and isoamyl acetate were the compounds that showed higher differences between the 2 wines. Wine from flat land with higher OAVs of ethyl octanoate and isoamyl acetate seems to have more intense fruity aromas (pineapple, pear and banana) with floral notes.

Conclusions

This was the first study on effect of terrains on the volatiles of cabernet sauvignon wines grown in Loess Plateau region of China. It could provide a better knowledge of the volatile composition of the flat and slope lands wines produced in this region, which could help winemakers to optimize operational conditions in order to emphasize one or more aromas in the respective wines. The study indicated the aromatic profiles for the 2 wines, which were only quantitative but not qualitative differences. Ethyl octanoate, ethyl hexanoate and isoamyl acetate were the most characteristic aroma-active compounds and they contributes to the global aroma of the 2 wines. Wine from the flat land seems to have more intense fruity aromas (pineapple, pear and banana) with floral notes.

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