



Original Article

Volatile compounds of young Cabernet Sauvignon red wine from Changli County (China)

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ABSTRACT

Some 69 volatile compounds of young red wines from *Vitis vinifera* cv. Cabernet Sauvignon in Changli County (China), were identified by GC–MS. HS-SPME (headspace solid-phase microextraction) was used to extract and concentrate volatile and semi-volatile compounds in the wine. Higher alcohols made up about 46% of the total level of volatiles and this group was mainly composed of isobutyl alcohol, 2-phenyl ethanol, 1-propanol and isopentyl alcohol. Acetates and ethyl esters make up 51% of the total volatiles, of which acetates made up 5% and ethyl esters 46%. Fatty acids made up 1.6% of the total volatiles. Among the small quantity of detected volatiles, there were five terpenes, one norisoprenoid (β -damascenone), seven fatty acid esters of higher alcohols, two carbonyl compounds, one volatile phenol and one sulfur compound. This represent 1.3% of total volatiles. Considering all the volatiles detected, higher alcohols and acetates and ethyl esters are the main contributors to young Cabernet Sauvignon wine in Changli County. Terpenes and β -damascenone also contributed to the overall flavor and aroma of the wine.

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1. Introduction

Changli County is one of the four districts of Wine Denomination of Origin in China. The winemaking sector is one of the principal economic assets of this county. The main red grape variety used in production is *Vitis vinifera* cv. Cabernet Sauvignon. In recent sensory studies based on consumer preferences, flavor of the wine was found to be one of the most important attributes considered when buying wines. The volatile composition influences the organoleptic characteristics of wines, particularly the aromatic characteristics. But the flavor of a wine presents an extremely complex chemical pattern in both qualitative and quantitative terms. Over 800 volatile compounds have been found in wines, with a wide concentration range varying from hundreds of mg/L to the μ g/L or ng/L level (Li, 2006).

The aroma of young wines is the product of a biochemical and technological sequence. Its formation derives from the grapes and juice production (grape de-stemming, crushing, and pressing technology), and is decisively influenced by the fermentation procedure (Bayonove et al., 1998). All of these parameters will determine the complexity of the wine aroma. In red wines, aroma research was often focused on the identification of specific compounds generating characteristic hints in wines, for example,

green pepper notes in Cabernet Sauvignon wines attributable to 2-methoxy-3-isobutylpyrazine (Bayonove et al., 1975). Cabernet Sauvignon is a very famous grape variety in the world. It originates in the Bordeaux region, France, but now it is planted in vineyards all over the world. The aroma of this wine is often described as fruity or floral with roasted, wood-smoke, and cooked meat nuances (Peynaud, 1980) and often as herbaceous (Allen et al., 1990, 1994). Research shows that the aroma profiles of Merlot and Cabernet Sauvignon wines in Bordeaux are very close. Only the caramel descriptor distinguishes the wines of these two varieties. Analysis of two odorant zones with this odor identifies 4-hydroxy-2,5-dimethylfuran-3(2H)-one (HDMF) and 4-hydroxy-2(or 5)-ethyl-5(or 2)-methylfuran-3(2H)-one (HEMF). The impact odorants in Cabernet Sauvignon wine identified by AEDA are 2-/3-methyl-butanol, 2-phenylethanol, 2-methyl-3-sulfanylfuran, acetic acid, 3-(methylsulfanyl) propanal, 2-/3-methylbutanoic acids, β -damascenone, 3-sulfanylhexasan-1-ol, Furanol, and homofuraneol in the wine extracts (Kotseridis and Baumes, 2000; Kotseridis et al., 2000). Two reports also indicate that the young red wines of Cabernet Sauvignon, Merlot and Grenache have similar aromatic characteristics. The most active odorants of these three monovarietal young red wines suggested by AEDA are isopentyl and β -phenylethyl alcohols, the ethyl esters of butyric, isobutyric, 2-methyl butyric and hexanoic acids, γ -nonalactone and eugenol. Data shows that differences between these varieties are quantitative rather than qualitative (Lopez et al., 1999; Ferreira et al., 2000).

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A study of wine components made from different grape varieties, having different geographical origins and prepared by individual manufacturing methods, allows us to gather precise information regarding the influence of such variables on the character and final quality of the resulting wine. The unique characteristics of a product from a delimited geographical area, both chemical and sensory, give the product *typicité*, meaning that the product is representative of its *terroir*. Research into 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. Altitude can exert an important influence on grape maturation and wine composition that is strictly related to the local climate (Falcao et al., 2007). Using GC–MS to study characteristic odors of Brazilian Cabernet Sauvignon wines, nine compounds are identified, namely acetic acid, butyric acid, isovaleric acid, 2-phenylethanol, methional, 2-methoxy-3-isobutylpyrazine (MIBP), β -damascenone, β -ionone and furaol (Falcao et al., 2008). The most intense odorants in Merlot and Cabernet Sauvignon wines produced in California and Australia detected by GC–O and GC–MS are 3-methyl-1-butanol, 3-hydroxy-2-butanone, octanal, ethyl hexanoate, ethyl 2-methylbutanoate, β -damascenone, 2-methoxyphenol, 4-ethenyl-2-methoxy-phenol, ethyl 3-methylbutanoate, acetic acid, and 2-phenylethanol. Both Merlot and Cabernet Sauvignon wines are characterized by high fruity, caramel, green and earthy aromas. Merlot wines from both Australia and California contain 4–5 times more ethyl octanoate than Cabernet Sauvignon wines from the same source (Gurbuz et al., 2006).

With rapid development of the wine industry in China, the quality of Chinese wine improves quickly and appeals to more and more consumers. However, sensory data of Chinese wine is still scarce, especially for wines of a specific denomination. The aim of this paper is to define the profile of major volatile compounds of young Cabernet Sauvignon wines in Changli County, with volatiles being extracted by solid-phase microextraction and being detected by GC–MS.

2. Materials and methods

2.1. Wine samples

Changli Cabernet Sauvignon wines were supplied by Huaxia winemaking company, Changli district. Five wine samples made in 2005 were taken and the Cabernet Sauvignon grapes used in the winemaking came from different villages. Cabernet Sauvignon grapes had been harvested at 22°Brix. Then grapes were de-stemmed and crushed on a commercial grape de-stemmer-crusher and then transferred into a stainless-steel tank for maceration and treated with sulfur dioxide (35 mg/L). The maceration and fermentation temperature was 25–30 °C. When maceration was completed, pomace was moved and fermentation continued at 18–20 °C. After settlement, wine was subjected to malo-lactic fermentation. After fermentation wine racking was carried out, followed by the stabilizing process. Wine samples were collected 6 months after winemaking and then analyzed.

2.2. Reagents

All reagents used were of analytical grade. Absolute ethanol, tartaric acid, sodium chloride was 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 pure reference compounds used were from

Sigma-Aldrich (Beijing, China). They were ethyl acetate, ethyl butyrate, 1-propanol, 2-methyl thiophene, 2-methyl-1-propanol, isopentyl acetate, 1-butanol, 2,5-dimethyl-tetrahydro-furan, isopentyl alcohol, ethyl hexanoate, ethenyl benzene, ethyl lactate, 1-hexanol, 3-octanol, ethyl octanoate, furfural, decanal, *cis*-geraniol, β -ionone, linalool, β -damascenone, ethyl decanoate, phenethyl acetate, 1-decanol, hexanoic acid, benzyl alcohol, 2-phenyl-ethanol, ethyl dodecanoate, ethyl hexadecanoate, octanoic acid, decanoic acid, *p*-ethyl-phenol.

2.3. Standard solutions

Exact volumes of the standard chemical compounds were dissolved in synthetic wines to prepare the calibration data. These standard compounds were dissolved in synthetic wines at concentrations three orders of magnitude higher than typically found in wines. For quantification, 5-point calibration curves were prepared for each compound using the method described by Ferreira et al. (2000). The final alcohol content of the synthetic wine was 11% (v/v). The synthetic wine had 6 g/L of tartaric acid and its pH was 3.3–3.4 adjusted with 1 M NaOH (synthetic wine matrix). Octan-3-ol was employed as an internal standard because it was not the typical volatile compound in wine and it had a perfect ion peak shape and peak place in the TIC. Exact volumes of octan-3-ol were dissolved in absolute ethanol and made up to volume (50 mL). All these solutions were stored at 4 °C in darkness (Guth, 1997; Ferreira et al., 1998).

2.4. SPME sampling conditions

SPME sampling was carried using the following method (Tao et al., 2007). Both wine samples and model solutions were analyzed in 15 mL glass vials, filled with 8 mL of each sample and given 1 g NaCl. For SPME analyses, the vials were dipped in a glass interspaced beaker filled with distilled water and connected to a thermostatic water bath. Water flowed from the thermostatic bath into the hollow space, heating the water inside the beaker and providing the vial with a thermostatication. The beaker was put on the plate of a magnetic stirrer. A magnetic stirring bar was put in the vial and provided the sample with agitation. The fiber for SPME is PDMS (100 μ m polydimethylsiloxane). The vial was equilibrated at 45 °C for 10 min, then magnetic stirring began with the solid-phase microextraction being performed at 45 °C for 15 min. This was immediately followed by desorption of the analytes into the gas chromatograph injector, while fiber remained into the injector for the whole period of the split-less time. Each sample had three replicates.

2.5. GC–MS analysis

GC–MS apparatus: TRACE DSQ (Thermo-Finnigan, USA). Analytical column: DB-Wax capillary column (30 m \times 0.32 mm i.d., 0.25 μ m film thickness), J&W (Folsom, USA). Carrier: He at 1 mL/min. Temperature programme: 40 °C for 4 min, then raised to 50 °C at 3 °C/min, then raised to 120 °C at 5 °C/min, then raised to 175 °C at 7 °C/min, then raised to 230 °C at 10 °C/min and hold for 8 min. Transfer line temperature 230 °C. Injection temperature 250 °C. Injected volume 1 μ L. Mass spectrometry: mass range 33–450 amu. Ion source temperature 220 °C.

2.6. Qualitation and quantification

Identification was achieved by comparing mass spectra obtained from the sample with those from pure standards injected in the same conditions and by comparing the Kov'ats

index and the mass spectra presents in the NIST2.0 MS library Database, or in the literature.

The internal standard quantification method was used. Thus, octan-3-ol was chosen as an internal standard. Quantitative data of the identified compounds were obtained by interpolation of the relative areas versus the internal standard area, in 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 one of the compounds with the most similar chemical structure according to the formula and chemical character (Li et al., 2008; Perestrelo et al., 2006).

3. Results and discussion

Fig. 1 is the TIC of volatiles of sample wines detected by SPME–GC–MS. The analytical methods allowed correct identification and quantification of over 69 compounds in the volatile fraction of sample wines (Table 1), the majority being higher alcohols, ethyl esters, fatty acids, carbonyl compounds and acetates from higher alcohols. Other compounds identified were five terpenes, one norisoprenoid, one volatile phenol, one sulfur compound and some esters of fatty acids and higher alcohols. In the R.S.D. column of Table 1, several values were observed above 60%, which were related to physico-chemical characteristics of these compounds. So in the other hand, this indicated that the method used in the work was very good in detecting most volatile compounds of red wines. Difficulties in finding a method to analyze all the volatile compounds were avoided, despite their belonging to several chemical groups and having a large range of concentrations.

3.1. Terpenes

Numerous studies have shown that the terpenoid compounds form the axis for sensory expression of the wine bouquet, being typical of each variety and could be used analytically for varietal characterization. Apart from the hitherto known compounds in grape must and wine (terpene ethers, monoterpene alcohols), numerous monoterpene compounds were identified, in particular monoterpene diols. It is known that terpene compounds belong to the secondary plant constituents, in which biosynthesis begins

with acetyl-coenzyme A (CoA). Microorganisms were known to synthesize terpene compounds, but formation of terpenes by *Saccharomyces cerevisiae* had not previously been observed. Terpenes were not changed by the yeasts metabolism during fermentation (Mateo and Jimenez, 2000).

Five terpenes were detected in the sample wine. They were linalool oxide (3 µg/L), citronellol (21 µg/L), geraniol (19 µg/L), [*E*]-nerolidol (42 µg/L) and [*E,E*]-farnesol (18 µg/L). Their concentrations were low. They made up of 0.2% of the total volatile compounds. The flavor thresholds of citronellol and geraniol were about 100 µg/L. Linalool oxide had flavor thresholds of 3000–5000 µg/L. Citronellol had “clove” and geraniol “citric” smells. Linalool oxides had “flower, fruity, muscat” nuances (Li, 2006; Mateo and Jimenez, 2000). Terpenes might play some role in the overall favor and aroma perception, so they could play a significant role in the flavor of wine.

3.2. Norisoprenoids

In this group, β - and α -ionones, and β -damascenone were the three often-detected compounds. In our work, only β -damascenone was detected and its concentration was 29 µg/L. β -Damascenone had flavor thresholds of 0.05 µg/L, it provided the wine “bark, canned peach, baked apple” nuances (Li, 2006).

3.3. Higher alcohols

Iso-butanol, *iso*-amyl alcohol, 2-phenylethanol and 1-propanol were among the aromas released as secondary products of yeast metabolism. These compounds could be synthesized by yeast through either the anabolic pathway from glucose, or the catabolic pathway from their corresponding amino acids (valine, leucine, *iso*-leucine and phenylalanine). Another compound related to the catabolic pathway was methionol [3-(methylthio)propan-1-ol], formed from the amino acid methionine (Li, 2006; Perestrelo et al., 2006). Amino acids composition depends on the variety of grape and for that reason all these volatile compounds would be related to the variety of grape used.

In our work, 25 higher alcohols were identified in Changli Cabernet Sauvignon wines. This was the largest group of volatile compounds. The subtotal concentration of higher alcohols was 22 910 µg/L, being 46.0% of the total volatile compounds detected. This volatile fraction was mainly composed of isobutyl alcohol

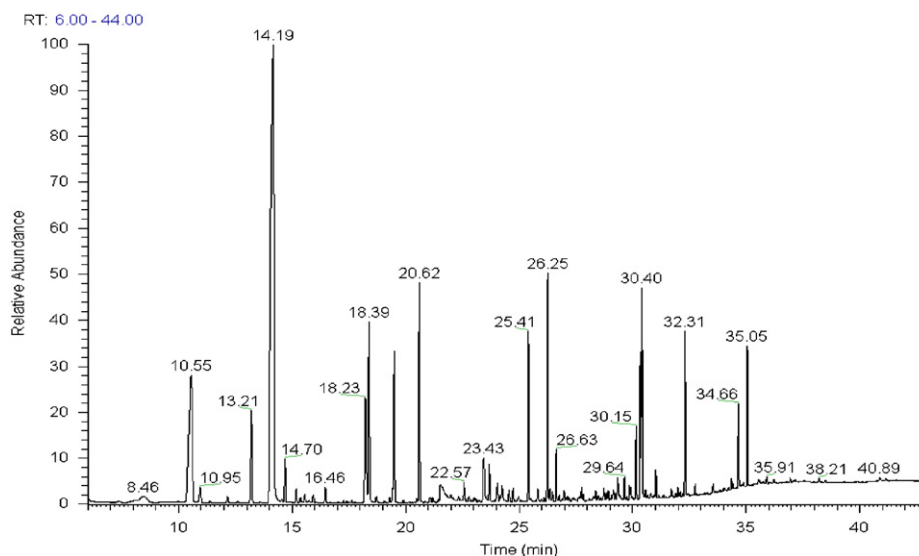


Fig. 1. TIC of volatile compounds in young Cabernet Sauvignon wines from Changli County detected by SPME–GC–MS.

Table 1
Concentrations of free volatile compounds in young Cabernet Sauvignon wines from Changli County

No.	KI ^a	Compounds	Formula	Concentration (µg/L)	R.S.D. ^b (%)
<i>Terpenes</i>					
1	1448	Linalool oxide	C ₁₀ H ₁₈ O ₂	3.0	33.3
2	1786	Citronellol	C ₁₀ H ₂₀ O	21.0	19.5
3	1856	Geraniol	C ₁₀ H ₁₈ O	19.0	15.8
4	2058	[<i>E</i>]-Nerolidol	C ₁₅ H ₂₆ O	42.0	21.4
5	2373	[<i>E,E</i>]-Farnesol	C ₁₅ H ₂₆ O	18.0	18.1
		Subtotal		102.0	
		Subtotal (%)		0.2	
<i>Norisoprenoids</i>					
6	1832	β-Damascenone	C ₁₃ H ₁₈ O	29.0	12.9
		Subtotal		29.0	
		Subtotal (%)		0.6	
<i>Higher alcohols</i>					
7	1036	1-Propanol	C ₃ H ₈ O	3642.0	24.7
8	1108	Isobutyl alcohol	C ₄ H ₁₀ O	9210.0	19.7
9	1165	1-Butanol	C ₄ H ₁₀ O	568.0	11.8
10	1230	Isopentyl alcohol	C ₅ H ₁₂ O	1412.0	24.2
11	1330	Isohexyl alcohol	C ₆ H ₁₄ O	10.0	10.0
12	1335	2-Heptanol	C ₇ H ₁₆ O	5.0	20.0
13	1339	Cyclopentanol	C ₅ H ₁₀ O	1.0	68.8
14	1343	3-Methyl-pentan-1-ol	C ₆ H ₁₄ O	15.0	26.7
15	1392	1-Hexanol	C ₆ H ₁₄ O	617.0	38.1
16	1401	[<i>E</i>]-3-Hexen-1-ol	C ₆ H ₁₂ O	18.0	21.1
17	1409	3-Ethoxy-1-propanol	C ₅ H ₁₂ O ₂	13.0	17.7
18	1415	[<i>Z</i>]-3-Hexen-1-ol	C ₆ H ₁₂ O	14.0	50.0
19	1429	[<i>E</i>]-2-Hexen-1-ol	C ₆ H ₁₂ O	6.0	16.7
20	1449	1-Octen-3-ol	C ₈ H ₁₆ O	8.0	12.5
21	1450	1-Heptanol	C ₇ H ₁₆ O	15.0	13.3
22	1531	3-Ethyl-4-methyl-pentanol	C ₈ H ₁₈ O	34.0	25.9
23	1598	2,3-Butanediol	C ₄ H ₁₀ O ₂	743.0	13.2
24	1605	1-Octanol	C ₈ H ₁₈ O	38.0	17.9
25	1633	<i>p</i> -Menth-1-en-4-ol	C ₁₀ H ₁₈ O	2.0	50.0
26	1639	(<i>Z,E</i>)-2-Octen-1-ol	C ₈ H ₁₆ O ₃	7.0	14.3
27	1718	<i>p</i> -Menth-1-en-8-ol	C ₁₀ H ₁₈ O	2.0	50.0
28	1781	1-Decanol	C ₁₀ H ₂₂ O	31.0	19.7
29	1896	Benzyl alcohol	C ₇ H ₈ O	411.0	14.1
30	1931	2-Phenyl-ethanol	C ₈ H ₁₀ O	6089.0	33.6
31	2194	1-Hexadecanol	C ₁₆ H ₃₄ O	0.2	38.0
		Subtotal		22910.0	
		Subtotal (%)		46.0	
<i>Acetates</i>					
32	885	Ethyl acetate	C ₄ H ₈ O ₂	2399.0	11.2
33	1132	Isopentyl acetate	C ₇ H ₁₄ O ₂	142.0	64.8
34	1829	Phenethyl acetate	C ₁₀ H ₁₂ O ₂	7.0	14.3
		Subtotal		2548.0	
		Subtotal (%)		5.1	
<i>Ethyl esters</i>					
35	1244	Ethyl hexanoate	C ₈ H ₁₆ O ₂	140.0	15.0
36	1317	Ethyl heptanoate	C ₉ H ₁₈ O ₂	1.3	57.0
37	1360	Ethyl 2-hexenoate	C ₈ H ₁₄ O ₂	2.0	50.0
38	1363	Ethyl lactate	C ₅ H ₁₀ O ₃	22476.0	41.6
39	1446	Ethyl octanoate	C ₁₀ H ₂₀ O ₂	145.0	17.2
40	1486	Ethyl 7-octenoate	C ₁₀ H ₁₈ O ₂	0.8	32.2
41	1581	Ethyl nonanoate	C ₁₁ H ₂₂ O ₂	0.8	43.1
42	1651	Ethyl decanoate	C ₁₂ H ₂₄ O ₂	43.0	16.3
43	1701	Diethyl succinate	C ₈ H ₁₄ O ₄	51.0	21.8
44	1711	Ethyl 9-decenoate	C ₁₂ H ₂₂ O ₂	2.0	39.5
45	1489	Lauric acid ethyl ester	C ₁₄ H ₂₈ O ₂	3.0	33.3
46	2065	Ethyl tetradecanoate	C ₁₆ H ₃₂ O ₂	1.4	33.7
47	2274	Palmitic acid ethyl ester	C ₁₈ H ₃₆ O ₂	0.3	45.8
48	2407	Diethyl phthalate	C ₁₂ H ₁₄ O ₄	0.1	67.3
49	2483	Stearic acid ethyl ester	C ₂₀ H ₄₀ O ₂	0.3	54.7
50	2574	Linoleic acid ethyl ester	C ₂₀ H ₃₆ O ₂	0.7	38.4
51	2675	Linolenic acid ethyl ester	C ₂₀ H ₃₄ O ₂	0.5	50.2
		Subtotal		22862.0	
		Subtotal (%)		45.9	
<i>Other esters</i>					
52	1417	Methyl octanoate	C ₉ H ₁₈ O ₂	0.5	29.9
53	1450	Isopentyl hexanoate	C ₁₁ H ₂₂ O ₂	1.0	26.7
54	1615	Isopentyl lactate	C ₈ H ₁₆ O ₃	15.0	13.3
55	1628	Methyl decanoate	C ₁₁ H ₂₂ O ₂	0.2	16.0

Table 1 (continued)

No.	KI ^a	Compounds	Formula	Concentration (µg/L)	R.S.D. ^b (%)
56	1674	Isopentyl octanoate	C ₁₃ H ₂₆ O ₂	2.0	28.9
57	1871	Isopentyl decanoate	C ₁₅ H ₃₀ O ₂	0.2	35.1
58	2610	Diisobutyl phthalate	C ₁₆ H ₂₂ O ₄	0.3	73.3
		Subtotal		19.0	
		Subtotal (%)		0.0	
<i>Fatty acid</i>					
59	1618	Isobutyric acid	C ₄ H ₈ O ₂	35.0	14.3
60	1863	Hexanoic acid	C ₆ H ₁₂ O ₂	120.0	39.2
61	2083	Octanoic acid	C ₈ H ₁₆ O ₂	555.0	14.2
62	2296	<i>n</i> -Decanoic acid	C ₁₀ H ₂₀ O ₂	76.0	7.9
63	2517	Dodecanoic acid	C ₁₂ H ₂₄ O ₂	5.0	20.0
64	2847	Tetradecanoic acid	C ₁₄ H ₂₈ O ₂	0.1	58.3
65	2433	Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	1.1	30.9
		Subtotal		792.0	
		Subtotal (%)		1.6	
<i>Carbonyl compounds</i>					
66	1266	3-Octanone	C ₈ H ₁₆ O	17.0	23.5
67	2123	4 <i>a</i> -Methoxy-1,1,2 <i>a</i> ,5-tetramethyl-decahydro-cyclopenta[<i>cd</i>]indene	C ₁₆ H ₂₈ O	0.1	90.6
		Subtotal		17.1	
		Subtotal (%)		0.0	
<i>Volatile phenols</i>					
68	2330	2,4-Di- <i>tert</i> -butyl-phenol	C ₁₄ H ₂₂ O	257.0	28.4
		Subtotal		257.0	
		Subtotal (%)		0.5	
<i>Sulfur compounds</i>					
69	1738	3-(Methylthio)-propan-1-ol	C ₄ H ₁₀ OS	18.0	11.1
		Subtotal		18.0	
		Subtotal (%)		0.0	

^a Retention indices of KI were on a DB-Wax column.

^b R.S.D. = (standard deviation (S.D.)/mean) × 100%.

(fusel alcohol; 4000 µg/L), 2-phenyl-ethanol (roses, pollen, flowery; 14 000 µg/L), 1-propanol (bright flavor, alcohol; 50 000 µg/L), isopentyl alcohol (bitter, harsh; 30 000 µg/L). These four alcohols had concentrations > 1000 µg/L. Alcohol concentrations > 100 µg/L were 1-butanol (alcohol; 150 000 µg/L), 1-hexanol (green, grass; 8000 µg/L), 2,3-butanediol (chemical; 120 000 µg/L) and benzyl alcohol (bitter almond note; 200 000 µg/L). Aromatic characteristics and flavor thresholds of volatile compounds are given in parentheses (Li, 2006; Li et al., 2008; Sun et al., 2004).

3.4. Acetate esters

Acetate esters were the result of the reaction of acetyl-CoA with higher alcohols formed by degradation of amino acids or carbohydrates (Li, 2006). Sample wines showed the lowest concentration of acetate esters of higher alcohols. Only three acetate esters were detected. The subtotal concentration was 2548 µg/L, being 5.1% of the total volatile compounds detected. They were ethyl acetate (fruity; 7500 µg/L), isopentyl acetate (fresh, banana; 30 µg/L) and phenethyl acetate (pleasant, flowery; 250 µg/L). They all gave a pleasant odor of wine.

3.5. Ethyl esters

One of the most important groups of aroma compounds in wine is the ethyl esters of fatty acids that are produced enzymatically during yeast fermentation and from ethanolysis of acyl-CoA that is formed during fatty acids synthesis or degradation. Their concentration is dependent on several main

factors: yeast strain, fermentation temperature, aeration degree and sugar contents (Perestrello et al., 2006).

Seventeen ethyl esters were identified. The subtotal concentration was 22 862 µg/L, being 45.9% of the total. Ethyl hexanoate (green apple, fruity, strawberry, anise; 14 µg/L), ethyl lactate (lactic, raspberry; 14 000 µg/L) and ethyl octanoate (sweet, soap, fruity, anise; 5 µg/L) had concentrations > 100 µg/L. These esters made a positive contribution to the general quality of wine. Most of them had mature fruit flavor nuances, so they were responsible for the “fruity” and “floral” sensory properties of wine.

3.6. Other esters

Besides the ethyl esters, some other fatty acid esters of higher alcohols were also identified, which were isopentyl lactate, isopentyl octanoate, methyl octanoate, isopentyl hexanoate, methyl decanoate, isopentyl decanoate and diisobutyl phthalate. Among them, only the former two had the concentrations > 1 µg/L. Though these esters had fruity nuances, they played a smaller role in the overall aromatic profile due to their low concentrations. The subtotal concentration of these esters was 19 µg/L, which was < 0.1% of the total.

3.7. Fatty acids

Concentration of fatty acids detected in the wine was 792 µg/L, being 1.6% of the total. Within the family of fatty acids, hexanoic and octanoic acids were notable for their higher concentrations, but they were all below their flavor threshold (about 500 µg/L).

The remaining three acids had low concentrations, they were dodecanoic, tetradecanoic and hexadecanoic acid.

3.8. Other compounds

They were two carbonyl compounds, one volatile phenol and one sulfur compound. The subtotal concentration was <400 µg/L, only 2,4-di-tert-butyl-phenol having a concentration >100 µg/L. The only sulfur compound identified was 3-(methylthio)-propan-1-ol (raw potato, garlic, cooked vegetable). It was found at levels below its olfactive perception threshold (1000 µg/L).

4. Conclusions

Young Cabernet Sauvignon wines in Changli County were characterized by the presence of higher levels of higher alcohols, ethyl esters and acetates, fatty acids. Higher alcohols made up about 46% of the total level of volatiles and this group was mainly composed of isobutyl alcohol, 2-phenyl-ethanol, 1-propanol and isopentyl alcohol. Acetates and ethyl esters made up 51% of the total volatiles, of which acetates made up 5% and ethyl esters 46%. The higher concentration esters were ethyl acetate, ethyl lactate, isopentyl acetate, phenethyl acetate, ethyl hexanoate, ethyl octanoate and ethyl decanoate. Fatty acids made up 1.6% of total volatiles. Hexanoic and octanoic acids were notable in this group, but their concentrations were not high enough to give unpleasant odor.

Five terpenes were detected in the sample wine. They were linalool oxide, citronellol, geraniol, [E]-nerolidol and [E,E]-farnesol. Their concentrations were low. Since terpenes might have some an overlap role in overall favor and aromatic perceptions, they could play a significant role in the flavor of wine. One norisoprenoid, β -damascenone, was detected and its concentration was above its flavor threshold. β -Damascenone gave “bark, canned peach, baked apple” nuances. In contrast, young Cabernet Sauvignon wines showed lower values of carbonyl compounds, volatile phenols and sulfur compounds.

Considering all the volatiles detected, higher alcohols and acetates and ethyl esters are main contributors to young Cabernet Sauvignon wine in Changli County. Terpenes and β -damascenone also contributed to the overall flavor and aroma of the wine.

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