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Active volatiles of cabernet sauvignon wine from Changli County

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ABSTRACT

This study investigated the contribution of volatile compounds to the overall aroma of Cabernet Sauvignon wines from Changli County (China). Wine samples were collected from vintages from 2000 to 2005. Volatile compounds were extracted by PDMS solid-phase micro-extraction fibers and identified by Gas Chromatography-Mass Spectrometry (GC-MS). A total of 65 volatile compounds were identified and quantified, including higher alcohols, ethyl and acetate esters, and fatty acids. According to their odor active values (OA-Vs), 21 volatile compounds were considered to be the powerful impact odorants of Cabernet Sauvignon wines from Changli. Odor descriptions of impact volatiles suggested Cabernet Sauvignon red wines from Changli County as having a complex aroma, which included not only pleasant floral and fruity odors, but also cheese, clove flavors, and grassy and smoky aromas.

Keywords: Cabernet Sauvignon; Red wine; Aroma compounds; OAV; GC-MS

1. INTRODUCTION

Cabernet Sauvignon, Cabernet Franc and Cabernet Gernischet are known as "the Three Pearls" of wine grapes in China, often used by Chinese wineries to produce premium quality red wines. In contrast to Cabernet Franc and Cabernet Gernischet, Cabernet Sauvignon can be found in almost all wine production districts and has the largest growing area in China. Changli County, a region of North China, has become a famous wine producing district as one of the four districts of Wine Denomination of Origin in China, and the winemaking sector is the principal economy of the county. In Changli County, the main red grape variety used in wine production is Cabernet Sauvignon. The growing area of Cabernet Sauvignon is 2400 Ha and accounts for 72% of the total grape planting areas. Therefore, it is important to understand the characters of Cabernet Sauvignon red wine made from Changli.

Wine aroma is an important aspect of wine quality. In a recent consumer study, the flavor of wine was found to be one of the attributes most important to consumers when buying wine. Volatile compounds influence the organoleptic characteristics of wines, particularly the aromatic characteristics, and the aroma constituents of different grapes and wines have been extensively studied in the last few years. In the order of 1000 volatile compounds, such as alcohols, esters, organic acids, phenols, thiols, monoterpenes and norisoprenoids have been found in wines, only several tens of which can be impact odorants. Volatile compounds found in wines can reflect the influence of variety, climate and soil, etc. Therefore, these compounds play a decisive role in wine quality and regional characteristics [1-3]. Since the contribution of volatile compounds to the final aroma depends on whether the concentration in the wine is above the perception threshold, OAV (odor activity value) was introduced to determine impact odorants [4,5]. OAV calculation depends both on measuring concentration and on odor threshold in the same matrix. Only those odorants with OAV >1 can be perceived.

Some studies have indicated that the young red wines of Cabernet Sauvignon, Merlot and Grenache have similar aromatic characteristics [6]. The most active odorants of these three varietal young red wines suggested by aroma extract dilution analysis (AEDA) were isopentyl and β-phenylethyl alcohols, the ethyl esters of butyric, isobutyric, 2-methyl butyric and hexanoic acids, γ-nonalactone and eugenol. Data showed that differences between these varieties are quantitative rather than qualitative [7,8]. In past decades, the unique characteristics of Chinese wine began to attract notice with the rapid development of wine production in China. However, sensory data for Chinese wine are scarce, especially for wines with denomination of origin. A study of aromatic compounds of the Cabernet Sauvignon red wine Shacheng (China) showed that ethyl octanoate, ethyl hexanoate and isopentyl acetate jointly contributed to more than 97% of the global aroma according to OAVs [9].

However, this result may be misleading; further studies are necessary to understand the nature of aromatic compounds found in premium Chinese wine.

Quantitative assessment of volatile compounds in wines has met with some difficulty, mainly due to their complexity and large concentration variations from 1 ng/L to several g/L. Therefore, sample preparation essentially consists of extraction and concentration of the compounds of interest. In this study, volatile compounds were extracted by solid-phase micro-extraction and detected by GC-MS, which has been published [10]. This work reported the results of the first study profiling of the major volatile compounds and the impact odorants in Cabernet Sauvignon wines from the Changli County region of China.

2. MATERIALS AND METHODS

2.1. Wines

Changli Cabernet Sauvignon wines from vintages between 2000 and 2005 (Each year has two samples which were supplied by Huaxia Winemaking Company and Yueqiannian Winemaking Company respectively, Changli County.) were used to analyze the composition of volatile compounds. Wine samples were collected six months after winemaking and then stored at 5-10 ℃ before analysis.

Wine making: Sound grapes of Cabernet Sauvignon were obtained from the vineyard. Grapes were destemmed and crushed on a commercial grape destemmer-crusher, the output of which was pumped to stainless steel tanks. The must was treated with sulfur dioxide (45 mg/L) and soaked for approximately 24 h. Alcohol fermentation was going on at 25-30℃. After fermentation, the wines were racked and subjected to malo-lactic fermentation. The wines were then racked and sulfur dioxide (75mg/L) was added. The wines were stored at 15℃ in stainless-steel tanks. Racking and stabilizing processes were carried out prior to analysis.

Reducing sugars, density, ethanol, extract, titratable acidity, pH, volatile acidity, total and free SO_2 were analyzed with the methods provided by the Office International de la Vigne et du Vin (OIV, 1990) [11].

2.2. 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. 32 pure reference compounds were from Sigma–Aldrich (China sector): 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, and 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, five-point calibration curves were prepared for each compound using the method described by Ferreira *et al.* (2000) [8]. 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 1M 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. All these solutions were stored at 4 ℃ in darkness [1,12].

2.4. Solid Phase Micro-Extraction (SPME) Sampling Conditions

SPME was performed following the methods described previously [13]. Both wine samples and model solutions were analyzed in 15-ml glass vials, filled with 10 ml of each sample and 2 g 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 fiber for micro-extraction. The vial was equilibrated at 40℃ for 10 min, and the power magnetic stirrer was then added. SPME was performed at 40℃ for 30 min, and was immediately followed by the desorption of the analytes into the gas chromatograph injector. The solid-phase fiber remained into the injector for about 3 min.

2.5. GC–MS Analysis

GC–MS apparatus: TRACE DSQ (Thermo-Finnigan, USA). Analytical column: DB-Wax capillary column (30m×0.32mm i.d., 0.25 μm film thickness), (J&W, Folsom, USA). Carrier: He at 1ml/min. The temperature program used was 40 ℃ for 3 min, raised to 160 ℃ at 4 ℃/min, then raised to 230℃ at 7 ℃/min for 8 min. The transfer line temperature was 230℃, and the injection temperature was 250 ℃. Mass spectra were recorded in electron impact (EI) ionization mode. Mass spectrometry:

Table 1. General composition of cabernet sauvignon must and wine.

	Ranges
Must composition	
Titratable acidity[a](g/L)	9.3-9.7
pH	3.2-3.4
Reducing sugars (g/L)	191-200
Wine composition	
Density (20℃)	0.991-0.994
Ethanol (%, v/v)	10.4-12.1
Reducing sugars (g/L)	0.78-1.82
Extract (g/L)	21-25
Titratable acidity[a] (g/L)	3.6-4.5
pH	3.3-3.6
Volatile acidity[b] (g/L)	0.46-0.71
Free SO_2 (mg/L)	11-19
Total SO_2 (mg/L)	90-121

(a) As tartaric acid. (b) As acetic acid.

mass range 33-450 amu, scanned at 1 s intervals. The ion source temperature was 230℃.

2.6. Qualitative Analysis and Quantification

Identification of volatile compound 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 or the mass spectra found in the NIST2.0 MS library Database or found 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 the formula and chemical character [3,14].

3. RESULTS AND DISCUSSION

Those general compositions of sample wines were displayed in **Table 1**. There is no significant difference among these samples.

Volatile compounds found in Cabernet Sauvignon red wines from Changli County detected by SPME-GC-MS are shown in **Table 2**. There are 65 aroma compounds and their concentrations vary from 0.5μg/L to 2.23 g/L. The majority of the compounds were higher alcohols, esters, and fatty acids. Other compounds identified were terpenes, norisoprenoids, volatile phenols and furans. The OAV of each compound was obtained using concentration divided by odor threshold. Twenty-one compounds had OAV values greater than one. Impact odorants of the Chardonnay white wine from Changli had previously been identified using the same method. Thirteen of the 41 volatile compounds detected had aroma activity and contributed to the pleasant fruity and floral aroma of the Chardonnay wine [14]. The active aroma compounds identified in that study were approximately half of the total volatiles detected in Cabernet Sauvignon red wines identified in this study, indicating the aroma of the red wine may be more complex.

3.1. Esters

Esters found in wine include acetates, ethyl esters and other esters of fusels and fatty acids. In the sample wines, 21 esters were identified with concentrations ranging from 62 to 390 mg/L. Contents of esters accounted for about 20-30% of the total aroma compounds. Five acetates, 13 ethyl esters and three others were found in this chemical group. In acetates, the OAVs of ethyl acetate and isopentyl acetate were higher than one. Ethyl acetate may contribute a pleasant, fruity fragrance to the general wine aroma at concentrations lower than 150 mg/L. However, at higher concentrations, ethyl acetate can contribute a sour-vinegar odor [21]. Isopentyl acetate contributes a fresh fruity odor, reminiscent of banana flavors.

Among 13 ethyl esters, ethyl butyrate, ethyl isovalerate, ethyl hexanoate, ethyl lactate and ethyl octanoate have OAVs over one. Ethyl butyrate has the favor of sour fruit, strawberry and sweet fruit. Ethyl isovalerate smells of banana and sweet fruit. Ethyl hexanoate has the flavor of green apple, fruit, strawberry and anise. Ethyl octanoate gives pineapple, pear and floral aromas. Ethyl lactate contributes lactic and raspberry odors. These active ethyl esters are responsible for the full-bodied fruity and floral aroma of wine. Results also confirmed most of the wines rich in these compounds showed elevated levels of higher alcohol acetates, thus adding to the sweet and soapy odors, and pleasant floral and fruity aroma.

Esters of fusel and fatty acids had lower concentrations, but their odor thresholds were also lower. In this study, isopentyl lactate had OAVs over one, and influences the overall aroma of the wine. Isopentyl lactate contributes cream and nut flavors. This compound is produced by malo-lactic fermentation [2]; therefore malo-lactic fermentation may be occurring in the wine as well.

3.2. Higher Alcohols

Higher major alcohols were the most abundant volatiles in all the studied wines. They are formed mainly during the first two stages of alcoholic fermentation [3,21]. In our work, 25 higher alcohols were identified and quanti fied, forming the largest group of volatile compounds. Their concentrations varied from 248 to 886 mg/L and

Table 2. Concentrations and OAVs of volatile compounds in cabernet sauvignon wines from Changli County.

NO.	RT	Compounds	Concentration(μg /L)			Odor threshold[a] (μg/L)	OAV[b]	Odor description
			Max.	Min.	Mean			
1	3.26	ethyl acetate	90000	11700	42600	7500 [1]	>1	fruity, sweet
2	5.60	isobutyl acetate	180	70	80	1600[15]	0.1	strawberry, fruity, flowery
3	6.15	ethyl butyrate	1900	500	800	20 [16]	>1	sour fruit, strawberry, fruity
4	6.54	1-propanol	20400	5800	10300	50000 [2]	0.1-0.5	fresh, alcohol
5	6.96	ethyl isovalerate	80	20	30	3[8]	>1	banana, sweet fruity
6	8.14	isobutyl alcohol	105200	31000	52900	40000 [16]	>1	fusel, alcohol
7	8.36	isopentyl acetate	2800	200	600	30 [16]	>1	fresh, banana
8	9.66	1-butanol	4700	1600	2800	150000 [16]	<0.1	medicinal, alcohol
9	11.59	isopentyl alcohol	567500	164400	328100	30000 [16]	>1	alcohol, harsh, bitter
10	12.03	ethyl hexanoate	1300	400	700	14 [16]	>1	green apple, fruity, strawberry, anise
11	12.83	3-methyl-3-buten-1-ol	300	100	200	600[*]	0.1-0.5	light fruity, sweet fruity[8]
12	12.94	1-pentyl alcohol	400	200	300	80000[2]	<0.1	alcohol
13	13.34	hexyl acetate	20	10	10	1500 [16]	<0.1	pleasant fruity, pear
14	13.84	2-O-2-phenylethyl formate	2600	60	600	n.d.		
15	14.99	isohexyl alcohol	600	200	400	5000 [*]	0.5	tropical fruity, light fruity
16	15.20	2-heptanol	40	10	20	200-300[*]	0.1-0.5	lemon, orange, copper[8]
17	15.40	3-methyl-1-pentanol	900	200	500	500[*]	1	soil, mushroom
18	15.80	ethyl lactate	237400	43300	100100	14 000 [2]	>1	lactic, raspberry
19	1392	1-hexanol	28400	11400	17300	8000 [16]	>1	green, grass
20	16.56	*(E)*-3-hexen-1-ol	2100	600	1000	400[17]	>1	Green grass, herb[8]
21	16.95	3-ethoxy-1-propanol	600	100	70	100[20]	0.5-1	
22	17.20	*(Z)*-3-hexen-1-ol	1500	700	900	400[17]	>1	Green grass, herb[8]
23	17.93	*(E)*-2-hexen-1-ol	800	150	300	400[17]	0.5-1	Green grass, herb[8]
24	18.23	*(Z)*-2-hexen-1-ol	370	100	110	400[17]	0.1-0.5	Green grass, herb[8]
25	18.43	ethyl 2-hydroxy -3-methyl butyrate	50	10	30	1000[19]	<0.1	Pineapple, strawberry, tea, honey[8]
26	18.69	ethyl octanoate	740	130	400	5 [16]	>1	pineapple, pear, floral
27	19.51	1-heptanol	260	40	100	200-300[*]	0.1-0.5	lemon, orange, copper[8]
28	19.87	linalool oxide	50	10	10	500[19]	<0.1	rose, wood [8]
29	20.58	2-ethyl hexanol	80	30	40	8000[*]	<0.1	mushroom, sweet fruity[8]
30	21.17	isooctanol	400	60	150	900[2]	0.1-0.5	fatty, orange, rose
31	21.39	β-ionone	9	1	4	0.09[17]	>1	raspberry, violet, sweet fruity
32	21.48	α -ionone	6	2	3	0.09[17]	>1	raspberry, violet, sweet fruity
33	22.14	ethyl 2-hydroxy -4-methyl valerate	80	10	40	n.d.		
34	22.30	linalool	130	10	40	25[15]	>1	muscat, flowery, fruity
35	22.67	1-octanol	230	70	140	900[2]	0.5-0.1	flesh orange, rose, sweet herb

NO.	RT	Compounds	Concentration(μg /L)			Odor threshold[a] (μg/L)	OAV[b]	Odor description
			Max.	Min.	Mean			
36	22.89	isopentyl lactate	740	170	300	200[*]	>1	cream, nut[4]
37	23.08	isobutyric acid	200	40	60	8100[14]	<0.1	phenol, chemical, fatty
38	23.25	2,3-butanediol	8600	800	3200	120000 [2,18]	<0.1	butter, creamy
39	23.83	4-terpineol	110	10	20	110-400[13]	0.1-0.5	light aroma, wood, soil[8]
40	24.29	2(3H)-dihydro-furanone	900	100	300	50000[15]	<0.1	milk, cream[8]
41	24.91	ethyl decanoate	100	4	30	200 [20]	0.1-0.5	fruity, fatty, pleasant
42	25.49	isopentyl octanoate	240	40	90	125[2]	0.5-1	sweet, light fruity, cheese, cream
43	25.67	1-nonanol	110	30	40	600[*]	0.1-0.5	apple, banana, raspberry, strawberry, rose[8]
44	25.98	diethyl succinate	52800	4800	23100	200000 [16]	0.1-0.5	light fruity
45	26.40	ethyl 9-decenoate	5	1	1	100[*]	<0.1	light fruity, fatty[8]
46	26.62	β- terpineol	200	20	80	110-400[13]	0.1-0.5	wood, soil [8]
47	27.10	3-methoil-1-propanol	120	60	70	1000[15]	0.1	raw potato, garlic
48	28.53	1-decanol	150	20	60	400 [2]	0.1-0.5	orange flowery, special fatty
49	29.71	phenethyl acetate	500	80	170	250 [16]	0.5-1	pleasant, floral
50	29.86	β-damascenone	20	3	7	0.05 [16]	>1	bark, canned peach, baked apple, dry plum
51	30.60	ethyl laurate	40	0	5	1500[*]	<0.1	sweet, floral, fruity, cream
52	30.91	hexanoic acid	1700	100	900	420 [16]	>1	cheese, rancid
53	31.34	benzyl alcohol	2000	500	900	200000[15]	<0.1	almond
54	32.15	2-phenyl-ethanol	140100	30800	71700	14000 [16]	>1	flowery, pollen, perfume
55	32.99	5-butyl-dihydro-4-methyl -2(3H)-furanone	1350	80	170	67[2]	>1	peach, coco
56	33.44	dodecan-1-ol	40	0	10	1000 [2]	<0.1	unpleasant in higher concentration, flowery in low concentration
57	34.48	p-ethyl-2-methoxy phenol	10	0	1	33[16]	0.1	medicine, wood, clove, smoky
58	34.76	[*E*]-nerolidol	200	10	30	700[*]	0.1-0.5	wood, orange, light fruity
59	34.90	ethyl myristate	10	0	1	2000[*]	<0.1	sweet fruity, butter, fatty odor[8]
60	35.24	octanoic acid	10000	700	3400	500 [16]	>1	rancid, harsh, cheese, fatty acid
61	36.77	eugenol	6	1	1	6[2,17]	0.1-0.5	smoky, clove
62	36.94	p-ethyl phenol	24	2	8	440[15]	<0.1	phenolic, leather, spicy, almond
63	38.15	ethyl hexadecanoate	24	0	2	1500 [2,18]	<0.1	fatty, rancid, fruity, sweet
64	38.59	n-decanoic acid	730	10	140	1000 [16]	0.1-0.5	fatty, unpleasant
65	38.94	2,4-di-tert-butyl-phenol	370	60	150	200 [2,17]	0.5-1	phenolic

(a) The reference from which the odor threshold and odor description have been taken is given in parentheses. [1] Guth (1997b). The matrix was a 10% water/ethanol solution; [2] and [19] Li (2006) and Sun *et al*. (2004). The matrix was a 12% ethanol/water mixture containing 5 g/L tartaric acid at pH 3.2. [8,15-18] Ferreira *et al*. (2000), Aznar *et al*. (2003), Cullere *et al*. (2004), Gomez *et al*. (2007) and Lopez *et al*. (2004). The matrix was an 11% water/ethanol solution containing 7 g/l glycerol and 5 g/l tartaric acid, with the pH adjusted to 3.4 with 1 M NaOH; [13] José *et al*. (2004). The matrix was a 10% water/ethanol solution containing 5 g/l tartaric acid. [20] Peinado, *et al*. (2004). The matrix was an 11% water/ethanol solution containing 5 g/l tartaric acid, with the pH adjusted to 3.4 with 1 M NaOH; [*] 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.

(b) Odor activity value calculated by dividing concentration by the odor threshold value of the compound.

they made up of about 75% of the total aromatic compounds. Aromatic compounds with OAVs higher than one were isobutyl alcohol, isopentyl alcohol, 3-methyl-1-pentyl alcohol, 1-hexanol, (*E,Z*)-3-hexen-1-ol and 2-phenyl-ethanol. Isobutyl and isopentyl alcohols have fusel characters and may give a bitter or harsh sensory odor when in high concentrations. 3-methyl-1-pentyl alcohol has soil and mushroom nuances. 1-hexanol and hexen-1-ol contribute green grass, herb odor. 2-phenyl-ethanol gives flowery, pollen, and perfume nuances.

3.3. Fatty Acids

Four fatty acids were detected in the sample wines. Their concentrations ranged from 0.816 to 12.63 mg/L and accounted for 0.26-0.98% of the total volatile compounds. The OAVs of hexanoic and octanoic acids were higher than one. They contributed cheese and cream flavors in lower concentrations, while giving a rancid and harsh odor in higher concentration. Although the presence of C_6–C_{10} fatty acids is usually related to the occurrence of negative odors, they are very important for aromatic equilibrium in wines because they oppose the hydrolysis of the corresponding esters [22].

3.4. Terpenols

Numerous studies have reported that the terpenoid compounds could be used analytically for varietal characterization. Terpene compounds belong to the secondary plant constituents, of which biosynthesis begins with acetyl-coenzyme A (CoA). Terpenes are not changed by yeast metabolism during fermentation [20]. Five terpenes were detected in sample wines: linalool, linalool oxide, 4-terpineol, *β*-terpineol and [*E*]-nerolidol. Only linalool had an OAV greater than one and contributed muscat, flowery and fruity odors. Because they have overlapping effects, terpenols may play an important role in contributing to the overall aroma.

3.5. Norisoprenoids

In this chemical group, *α*-ionol, *β*-ionol, and *β*-damascenone, three norisoprenoids often reported, were all detected in sample wines, and all had odor activity. The ionols are responsible for the raspberry, violet and sweet fruity nuances, while *β*-damascenone contributes odors of bark, canned peach, baked apple, and dry plum.

3.6. Volatile Phenols

Some volatile phenols, such as eugenol and guaiacol, may be the major differences between Cabernet Sauvignon and other red variety wines [8]. Four phenols were identified in our study, but all seemed to have no odor contribution. Eugenol and 2,4-di-tert-butyl phenol have OAVs between 0.5 to 1. Eugenol has smoky and clove odors. 2,4-di-tert-butyl phenol gives phenols' chemical character.

3.7. Others

An AEDA study regarding the odorants of Bordeaux Cabernet Sauvignon red wines showed that 3-methiol-1-propanol, furaneol and homofuraneol had high flavor dilution (FD) factors [6]. In our work, two furans and one sulfur compound were detected in the sample wines: 2(3H)-dihydrofuran, 5-butyl-dihydro-4-methyl-2(3H)-furan and 3-methiol-1-propanol. Only 5-butyl-dihydro-4-methyl-2(3H)-furan had odor activity and smelled of peach and cocoa.

4. CONCLUSIONS

Aroma compounds in Cabernet Sauvignon dry red wine from Changli County were evaluated by SPME-GC-MS; 65 volatile compounds were identified and quantified. Their concentrations ranged from 0.5 μg/L to 2.23 g/L. Twenty-one volatile compounds were considered to be the powerful impact odorants of this wine because their OAVs were more than one. These active volatile compounds include eight esters, seven higher alcohols, two fatty acids, one terpenols (linalool), α/β-ionol and β-damascenone, one compound of furan. These compounds have different sensory characters and give the wine very complicated aroma, which included not only pleasant floral and fruity odors, but also cheese, clove flavors, and grassy and smoky aromas. Taste or olfactory experiments could be designed to confirm the sensory characteristics of the wine.

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