

Research Article

Comparison of Aroma Compounds in Cabernet Sauvignon Red Wines from Five Growing Regions in Xinjiang in China

Lijun Nan,^{1,2} Liyuan Liu,³ Yashan Li,^{1,2} Jing Huang,⁴ Yanjun Wang,¹ Chunyan Wang,³ Zhenji Wang ^{1,2} and Chengdong Xu ^{1,2}

¹College of Resources, Environment and Chemistry, Chuxiong Normal University, Chuxiong 675000, China

²Engineering Technology Research Center of Grape and Wine for Advanced School in Yunnan, Chuxiong Normal University, Chuxiong 675000, China

³Turpan Technology Extension Service Center for Forest and Fruit Industries, Turpan 838000, China

⁴School of Mathematics and Statistics, Chuxiong Normal University, Chuxiong 675000, China

Correspondence should be addressed to Zhenji Wang; zhenji_wang16@126.com and Chengdong Xu; chengdong_xu123@126.com

Received 6 January 2021; Revised 15 April 2021; Accepted 11 May 2021; Published 29 June 2021

Academic Editor: Alejandro Hernández

Copyright © 2021 Lijun Nan et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

A total of 55 volatiles including esters (29, 52.73%), alcohols (10, 18.18%), acids (3, 5.45%), alkanes (8, 14.55%), and other components (5, 9.09%) were evaluated in five regions. Total concentrations were 0.05–222.23 mg/L, which covered the highest esters (222.23 mg/L) and alcohols (120.65 mg/L) in Turpan, acid (0.53 mg/L) in Shihezi, and alkanes (1.43 mg/L) and others (3.10 mg/L) in the Ili River valley. It proved that numbers and concentrations of volatile compounds, including common ingredients of variety, were closely linked to ecological characteristics of a region. Esters and alcohols were the major ingredients in Xinjiang Cabernet Sauvignon wine. Additionally, appellation could affect performance of concentration, ODE, and OTH, especially for the same flavor substance by fermentation, aging, and even formation and transformation in wines. Therefore, three conditions for formation of flavors were successively appellations, metabolism and fermentation, and appropriate altering according to technology and their decisive role in wine quality. Each volatile compound had its own flavor, the combination of which complicated the flavor. The unique materials in the region were grounded for the development of products with corresponding flavors by producing substrate for fermentation. When choosing a wine you enjoy, the right appellation should be considered first.

1. Introduction

Grapes have been cultivated in Xinjiang for over 7,000 years, mainly in the Turpan basin in the east, Shihezi and Manas basins in the north, Hoxud County in the south, and the Ili River valley in the west. Xinjiang has a geographical feature of “two basins sandwiched with three mountains.” Tianshan Mountain becomes the boundary against cold air from invading southward. The northern region is a middle temperate zone, while the southern region is a warm temperate zone. Resources of Xinjiang include unique snow water, soil, and optothermal condition, such as long sunshine time, high accumulated temperature, large temperature difference between day and night, long frost-free period,

and the extent of annual solar radiation second only to Tibet, which are very beneficial for the growth of grapes. Most of the areas at the northern foothill of Tianshan Mountain are alluvial plain or diluvial plain, flat and open, with little relief and large slopes, gradually tapering from south to north, and an altitude below 1200 meters.

Aroma is an important flavor characteristic of wine. The ecological characteristics of different regions lead to the difference in the aroma components of wines. Even the same variety of wines showed diverse aroma styles in disparate regions [1–4]. Jiang and Sun [3] elucidated the influence of terroir on aroma components of Cabernet Sauvignon red wines in different extents in China. Research of Tang et al. [4] on the aroma profiles of Cabernet Sauvignon wines

established the correlation of sensory characteristics and aroma compounds, and demonstrated significant differences between blackcurrant, pear and dried plum, mushroom, and smoked and green pepper on the five vineyards from a new Loess Plateau. Detection of the aroma characteristics of Cabernet Sauvignon wines by Yue et al. [1] from five different altitudes in Yunnan plateau showed that the numbers of volatile compounds increased with uplifted altitude, while their concentration decreased except for Xidang-2110. Twenty-two percent components in five wines had higher than corresponding threshold values (OAVs > 1). Three most powerful odorants were ethyl hexanoate, ethyl butyrate, and 1-octen-3-ol in the Xidang-2110 sample, and β -damascenone, ethyl hexanoate, and 1-octen-3-ol in Jiunongding-2330 and Jiangpo-2788 wines, respectively. However, odor activity values and relative odor contribution of 1-octen-3-ol were the highest compared with ethyl hexanoate and ethyl butyrate in Dari-2249 and Adong-2610 ones, respectively. Research, on effect of regulated deficit irrigation (RDI) on fatty acids and derived volatiles of Cabernet Sauvignon grapes and wines in the semi-arid area, showed that received water with 60% (RDI-1) increased the content of unsaturated fatty acids in berries and decreased the level of alcohols and esters in wines. 70% (RDI-2) and 80% (RDI-3) enhanced 1-hexanol and esters in wines in comparison with CK [2].

Xinjiang, as an important wine-producing area of high quality in China, has a vast territory and distinct ecological characteristics. Cabernet Sauvignon is the most widely cultivated wine grape in Xinjiang. Long-term production practice and various researches showed that Cabernet Sauvignon in different wine-producing areas displayed visible differences, among which the most prominent is concerning the flavor composition. Based on the above, Cabernet Sauvignon wines from Shihezi, Manas, Turpan, Hoxud County, and Ili River valley were taken as the research objects in this study owing to their own distinct territory to reveal preliminarily differences in the flavor through GC-MS and lay a foundation for further research.

2. Materials and Methods

2.1. Sample Collection and Vinification. The original and healthy Cabernet Sauvignon grapes (200 kg per sample, totally 2000 kg grape samples) were collected manually from five wine-grape-growing regions with distinct terroir characters, including Shihezi (September 26), Manas (September 19), Turpan (September 7), Hoxud County (September 13), and Ili River valley (October 5), in 2016 and 2017, respectively, in Xinjiang, China.

Technological processes of every sample could be duplicated entirely as described by Jiang et al. [5], with slight modifications. Briefly, grapes were crushed on an experimental destemmer-crusher (150825, Xinxiang, China) and then transferred to stainless steel containers. Meanwhile, 30 mL of 6% sulfur dioxide was immediately added. Following 4 h of blending, 0.02 g/L of pectinase (Lalzyme Ex, Bordeaux, France) was also added according to commercial

specifications. During the whole alcoholic fermentation (AF) after another 4 h, 0.2 g/L of dried active yeast (*Saccharomyces cerevisiae* RC 212, Lallemand, Danstar Ferment AG, Switzerland) was replenished onto the supernatant and liquid temperature was monitored between 25°C and 29°C. After adding residual sugar <4 g/L, wines were transferred, respectively, to 10 L–50 L of vitric vessels by siphonage to get rid of air. Afterward, malolactic fermentation was finished favorably by adding *Lactobacillus acidophilus*. Subsequently, wine was stored in aphotic surroundings at 4°C–6°C for 12 months before some conventional parameters were assessed (Table 1).

2.2. Volatile Components Analysis. Aroma components were analyzed by using Gas Chromatography-Mass Spectrometer (GC-MS, TRACE DSQ, Thermo-Finnigan, USA) with special configuration: one injector was connected to a capillary column with a flow splitter. Aroma compounds were extracted by solid-phase micro-extraction (CAR/DVB/PDMS, Supelco, USA) technology. A 16-mL sample was extracted for 30 min by the oscillator (150 r/min) with 16 μ L of 2 octanol (99% optical purity, Aldrich Milwaukee, WI, USA) as the internal standard. Then, the filtrate by 0.4 μ m of membrane was injected in the GC. All samples were analyzed in triplicate. The injector temperature was set at 260°C. The oven temperature was kept at 40°C for 3 minutes, then heated up to 120°C at a rate of 5°C/min, followed by 230°C at a rate of 8°C/min for 10 minutes. The temperatures for transfer line and ionic source were set at 230°C, respectively. Mass range (m/z) was 33–450 Da. Helium was used as the carrier gas (continuous flow 1.0 mL/min).

Solid-phase micro-extraction: 16 mL of wine sample, little amount of NaCl, 16 μ L of 2-octanol and magnetic rotor were put into a 20 mL headspace bottle to balance for 10 min in a magnetic stirrer with constant temperature heating. After extraction at 30 min, the sample was desorbed at GC inlet for 5 min at 260°C.

The semi-quantification of volatile compounds was calculated using internal standards according to Pino and Barzola-Miranda [6]. Identification of compounds was achieved by matching lineal retention indexes and mass spectra with those of chemical standards and commercial libraries (NIST 05, Wiley 6, NBS 75 k and Adams 2001).

2.3. Odor Activity Values (OAV). To evaluate the contribution of aroma compound to wine, the odor activity value (OAV) was introduced. $OAV = x/OTH$, where x is the concentration mean value of each volatile compound and odor threshold (OTH) is its odor threshold [7].

2.4. Statistical Analysis. Statistical analyses were performed using Microsoft Excel 2000 software (Microsoft Corporation). The results obtained from each treatment were compared by Duncan analysis of variance test, and least significant difference (LSD) at the 5% level was used to identify variant mean values.

TABLE 1: General parameters of Cabernet Sauvignon dry red wine in the different regions.

Regions	Alcohol level (%)	PH	TSS (%)	TA (g/L)	Residual sugar (g/L)
Shihezi	15.28 ± 0.45a	4.05 ± 0.05a	20.3 ± 0.48a	6.70 ± 0.04a	5.50 ± 0.03a
Manas	12.73 ± 0.35a	3.71 ± 0.08ab	26.57 ± 0.81a	5.50 ± 0.24a	3.56 ± 0.28ab
Turpan	12.40 ± 0.02b	3.92 ± 0.02b	8.50 ± 0.05ab	4.96 ± 0.02a	3.98 ± 0.04ab
Hoxud County	15.30 ± 0.06b	3.60 ± 0.13b	27.24 ± 0.53b	6.90 ± 0.03b	3.50 ± 0.03c
Ili River valley	12.33 ± 0.07a	3.45 ± 0.48c	27.92 ± 1.33b	6.48 ± 0.34ab	3.10 ± 0.43bc

Note: the format of data in Table 1 is $X \pm SE$, where X means the average and SE is the standard error; different letters after the same column of data indicate a significant difference of the same index on different regions ($P < 0.05$), hereinafter inclusive.

3. Results and Discussion

3.1. General Analysis. General properties of wines, including alcohol (12.33–15.30 %, v/v), pH (3.45–4.05), total soluble solid (TSS, 4.96–6.90 %), total acid (TA, 4.96–6.90 g/L expressed as tartaric acid), and residual sugar (3.10–5.50 g/L expressed as glucose) after a year of aging, including malolactic fermentation (MLF), were determined according to GB 15037 2006. All parameters were analyzed in triplicate (Table 1).

3.2. Volatile Compounds. The quantification of volatile compounds was calculated using internal standards. The quantitative data for compounds in free aroma fraction of Cabernet Sauvignon wines in 5 regions of Xinjiang during a year of aging are shown in Tables 2–6. GC-MS analysis of the wines allowed the identification and quantification of 55 volatile compounds, which included esters (29, 52.73%), alcohols (10, 18.18%), acids (3, 5.45%), alkanes (8, 14.55%), and other components (5, 9.09%). Like most studies, the majority of volatiles were esters, and alcohols accounted for more than 62.9%.

Esters have long been considered important contributors to wine aroma [8]. It proved that the numbers and concentrations of volatile compounds were closely linked to okanagan wine region. With rising altitudes (-155 m in Turpan, 450.8 m in Shihezi, 578 m in Manas, 663 m in the Ili River valley, 932 m in Hoxud County), temperature decreased generally and light intensity increased in corresponding appellations [9]. Therefore, local temperature could affect wine aroma by adjusting berry composition in vineyard altitude [1].

3.2.1. Esters. From Table 2, 29 types of volatile esters, 0.05–222.23 mg/L, was quantified in 5 wines. Twenty four, 22, 20, 23, and 22 kinds of esters were identified from Shihezi, Manas, Ili River valley, Turpan, and Hoxud County samples, with concentrations ranging from 0.10–133.50 mg/L (254.79 mg/L), 0.08–99.29 mg/L (239.54 mg/L), 0.09–47.16 mg/L (126.67 mg/L), 0.23–222.23 mg/L (337.51 mg/L), and 0.05–100.28 mg/L (174.64 mg/L), respectively. Esters in Turpan wine had the highest total value in five regions.

Esters, responsible in large part for the fresh flowery and fruity aroma of wine, could be produced from an activated fatty-acyl CoA molecule and alcohol, catalyzed by alcohol acetyltransferase and other enzymes [10] during the alcoholic fermentation and slow aging. Ethyl esters and butyl

esters were the most complex volatiles. Ethyl acetate was an important compound for aroma deterioration [11]; isoamyl acetate and acetate phenethyl, with fruity and floral notes, correlated with the fermentation for yeast [12].

These esters, such as propanoic acid 2-hydroxy-ethyl ester, (L)-, butanoic acid ethyl ester, butanedioic acid diethyl ester, hexanoic acid, ethyl ester, octanoic acid, ethyl ester, nonanoic acid, ethyl ester, decanoic acid, ethyl ester, acetic acid, 2-phenylethyl ester, tetradecanoic acid, ethyl ester, hexadecanoic acid, ethyl ester, 1-butanol, 2-methyl-, acetate, 1-butanol, 3-methyl-, acetate, octanoic acid, 3-methylbutyl ester, were characteristic components of the more flavorful substances found in every Cabernet Sauvignon dry red wine. Like previous studies by Tao et al. [13] and Jiang et al. [5], octanoic acid, ethyl ester, decanoic acid, ethyl ester, 1-butanol, 3-methyl-, acetate, hexanoic acid, and ethyl ester were the four esters of higher concentrations in Shihezi, Manas, Ili River valley, Turpan and Hoxud counties, respectively, especially the highest concentrations of ethyl ester. Butanoic acid, 3-methyl-, and ethyl ester were detected only in wines of Turpan and Hoxud counties, which was related to the hot climate, higher temperatures, and almost no snow in winter compared with the other three wine-producing areas, unique soil structure on the two fields. Pentanoic acid, 2-hydroxy-4-methyl-, and ethyl ester was formed in the Ili River valley and Hoxud County; pentanoic acid, ethyl ester in Turpan; 2-hexenoic acid, ethyl ester in Shihezi and Manas; heptanoic acid, ethyl ester without Shihezi and Manas; ethyl 9-decenoate, n-caprylic acid isobutyl ester in Shihezi and Turpan; isobutyl acetate, isopentyl hexanoate and acetic acid, hexyl ester in the Ili River valley; butanedioic acid, ethyl 3-methylbutyl ester without Hoxud County; methoxyacetic acid, pentyl ester, arsenous acid, tris (trimethylsilyl) ester, decanoic acid, decyl ester without Turpan; propanoic acid, pentyl ester in Manas; isopentyl hexanoate and acetic acid, hexyl ester without the Ili River valley; ethyl oleate only in Shihezi, the Ili River valley, and Turpan. Selection of specific ester needs to meet the appropriate producing conditions. Although the contents of some esters, such as heptanoic acid, ethyl ester (Hoxud County), propanoic acid, pentyl ester (Manas), decanoic acid, decyl ester (Shihezi) and heptanoic acid, ethyl ester (Ili River valley), were trace quantities in wines, they promoted wine aroma more abundant and complex [14]. Avellone et al. [15] detected out butanedioic acid, ethyl-3-methylbutyl ester in Sicilian Nero d'Avola wines influenced by spray-drying technology, Welke et al. [16] did decanoic acid, decyl ester (decyl decanoate) in Merlot wines, which existed also in the Carbernet Sauvignon

TABLE 2: Comparison of esters in Cabernet Sauvignon dry red wine from 5 regions in Xinjiang (mg/L).

Compound name	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Propanoic acid, 2-hydroxy-, ethyl ester, (L)-/ethyl lactate	14 ^a	Lactic, raspberry acid ^{b,c}	2.46 ± 0.02a	2.32 ± 0.03a	7.82 ± 0.12a	2.27 ± 0.03a	2.42 ± 0.01a
Butanoic acid, ethyl ester/ethyl butanoate	0.02 ^d	Banana, pineapple, sweet, strawberry ^e	2.07 ± 0.02a	1.43 ± 0.01a	1.35 ± 0.01a	2.67 ± 0.02a	1.68 ± 0.01a
Butanoic acid, 3-methyl-, ethyl ester	0.0001 ^f	Fruity apple ^g , mulberry ^h , banana ^f Light wine ^{b,c}	N	N	N	0.25 ± 0.02a	0.28 ± 0.02a
Butanedioic acid, diethyl ester/diethyl succinate	200 ⁱ	Lavender ^e vinous, fruity, wine, cheese, earthy, spicy ^{e,i}	6.40 ± 0.12ab	4.54 ± 0.06ab	17.13 ± 0.22b	19.85 ± 0.33a	1.45 ± 0.02b
Pentanoic acid, 2-hydroxyl-4-methyl-, ethyl ester/ethyl 2-hydroxy-4-methylpentanoate/ethyl 2-hydroxy-isohexanoate	0.126 ^e	Blackberry ^e	N	N	0.30 ± 0.01a	N	0.11 ± 0.01a
Pentanoic acid, ethyl ester/ethyl valerate	0.0015 ^f	Grass ^f	N	N	N	0.23 ± 0.01a	N
Hexanoic acid, ethyl ester/hexyl acetate	0.67 ^b	Fruity, green apple, banana, wine-like, brandy ^{c,d,f,i} , brandy pineapple, banana ^{b,c}	22.30 ± 0.32a	24.75 ± 0.36a	14.29 ± 0.14a	25.45 ± 0.34a	15.78 ± 0.23a
2-Hexenoic acid, ethyl ester			0.45 ± 0.11a	0.75 ± 0.01a	N	N	N
Heptanoic acid, ethyl ester	0.021 ^f	Winelike, brandy, fruity ^{b,e,f,i}	N	N	0.09 ± 0.01a	0.25 ± 0.01a	0.05 ± 0.01a
Octanoic acid, ethyl ester	0.580 ^e	Sweet, flowery, fruity, banana, pear ^{b,c,d,e} brandy ^f lentil flavor, musty ^{b,c}	133.50 ± 0.82a	99.29 ± 0.56b	47.16 ± 0.34a	222.23 ± 0.98a	100.28 ± 0.92a
Nonanoic acid, ethyl ester	0.2 ^e	Fruity, fatty, joyful ^e	0.60 ± 0.01a	1.49 ± 0.05ab	0.42 ± 0.03b	3.94 ± 0.12a	2.10 ± 0.02a
Ethyl 9-decenoate	0.1 ^e	Rose ^e	0.56 ± 0.01a	N	N	0.48 ± 0.01a	N
Decanoic acid, ethyl ester	0.2 ^d	Sweet fruity, fatty, pleasant ^{b,c,i}	38.49 ± 0.83a	73.79 ± 0.41ab	24.86 ± 0.35b	44.94 ± 0.33a	24.08 ± 0.61a
Acetic acid, 2-phenylethyl ester/phenethyl acetate	1.8 ^e	Fruity, rose ^e	0.97 ± 0.03a	1.29 ± 0.02b	0.24 ± 0.01b	1.18 ± 0.01a	0.32 ± 0.01a
Tetradecanoic acid, ethyl ester/ethyl tetradecanoate	1.0 ^e	Soap, mild, polish ^e Sour ^{b,c}	1.50 ± 0.03a	2.70 ± 0.04b	2.98 ± 0.01b	2.26 ± 0.02a	2.94 ± 0.03a
Hexadecanoic acid, ethyl ester/ethyl palmitate	1.5 ^a	N/A	1.93 ± 0.04a	1.93 ± 0.03b	3.42 ± 0.13bc	3.32 ± 0.12a	3.03 ± 0.14a
1-Butanol, 2-methyl-, acetate/2-methylbutyl acetate	0.005 ^a	N/A	1.58 ± 0.04a	1.10 ± 0.02b	0.38 ± 0.03bc	1.29 ± 0.05a	0.59 ± 0.03a
1-Butanol, 3-methyl-, acetate/isoamyl acetate	0.002 ⁱ	Sweet, fruity ^e Banana, pineapple, strawberry ⁱ	35.62 ± 0.14a	19.36 ± 0.24b	4.25 ± 0.04c	38.10 ± 0.23a	16.69 ± 0.25a
Isobutyl acetate	1.605 ^d	Sweet, solvent ^d	0.56 ± 0.02a	0.19 ± 0.01b	N	0.59 ± 0.02a	0.40 ± 0.01a
n-Caprylic acid isobutyl ester			0.19 ± 0.02a	N	N	0.35 ± 0.02a	N
Butanedioic acid, ethyl 3-methylbutyl ester/ethyl 3-methylbutyl succinate/ethyl isopentyl succinate/3-methylbutyl-ethyl-succinat/	N/A ^a	Pungent ^c	0.96 ± 0.03a	0.82 ± 0.02b	0.62 ± 0.04c	1.23 ± 0.07a	N
butanedioic acid, ethyl-(3-methyl-1-butyl) ester							
Octanoic acid, 3-methylbutyl ester	0.125 ⁱ	Fruity ⁱ	2.68 ± 0.13a	2.17 ± 0.05b	0.59 ± 0.01c	4.22 ± 0.13a	1.52 ± 0.12a
Methoxyacetic acid, pentyl ester			0.11 ± 0.01a	0.12 ± 0.02b	0.09 ± 0.01c	N	0.17 ± 0.01a

TABLE 2: Continued.

Compound name	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Propanoic acid, pentyl ester/pentyl propanoate			N	0.08 ± 0.02b	N	N	N
Isopentyl hexanoate	N/A ^a	Apple, fruity ^{b,c}	0.43 ± 0.01a	0.31 ± 0.02bc	N/900.00 µg/L ^j	1.90 ± 0.04a	0.47 ± 0.02a
Acetic acid, hexyl ester	6.701 ^f	Rage grape, apple, pear, floral, green, cherry, anise ^{b,c,f,i}	0.95 ± 0.05a	0.87 ± 0.04c	N	0.23 ± 0.01a	0.13 ± 0.01a
Decanoic acid, decyl ester/decyl decanoate	N/A	N/A	0.10 ± 0.01a	0.16 ± 0.02c	0.16 ± 0.02c	N	0.11 ± 0.01a
Arsenous acid, tris (trimethylsilyl) ester	N/A	N/A	0.10 ± 0.01a	0.11 ± 0.01c	0.13 ± 0.02c	N	0.06 ± 0.01a
Ethyl oleate		N/A	0.30 ± 0.01a	N ^c	0.40 ± 0.03c	0.30 ± 0.01a	N
Subtotal			254.79	239.54	126.67	377.51	174.64

Note: N = not detected and N/A = not available, hereinafter inclusive. ^aAvellone et al. (2018), ^bJiang and Zhang (2010), ^cYu et al. (2019), ^dFeng et al. (2017), ^eZhu et al. (2016), ^fWu et al. (2019), ^gZhu et al. (2007), ^hXia et al. (2017), ⁱWei et al. (2019), and ^jWang et al. (2015).

red wine in the trial. Martins et al. [17] did decanoic acid, decyl ester (decyl decanoate) in white (0.087%, relative peak area), red (0.125%), and palhete (0.108%) wine, while 0.10 mg/L (Shihezi), 0.16 mg/L (Manas), 0.16 mg/L (Ili River valley), 0 mg/L (Turpan), 0.11 mg/L (Hoxud County) in Carbetnet Sauvignon red wine trial. Methoxyacetic acid, pentyl ester in Sufu was detected out [18], Arsenous acid, tris (trimethylsilyl) ester was also in the methanolic extract of salvinia vermicompost [19]. Therefore, these compositions belong to common ingredients of the variety.

The more ethyl esters were synthesized by esterification of acids with an ample ethanol from both microbial metabolism and chemical reaction during the fermentation [18]. Among esters, hexadecanoic acid ethyl ester in the Ili River valley owned the highest content, with a strong oil fragrance and a greater contribution to wine [20]. Methoxy acetic acid pentyl ester with the fresh fruit flavor was found in relatively high levels in Hoxud County. In addition, wines in Shihezi and Turpan showed also floral, fatty, and spice-like aroma owing to ethyl 9-hexadecenoate (Table 2) by the microbiological lipases [21]. Importantly, other esters could also improve the wine flavor. For example, hexanoic acid ethyl ester had intense fruity pineapple and banana [22]. At the same time, octanoic acid ethyl ester and nonanoic acid ethyl ester had strong brandy aromas. Beyond that, fruity flavors afforded by ethyl esters might also modify the rancidity odor by too high concentrations of carboxylic acids [23]. Therefore, the highest numbers of esters had various unique odor characteristics, which were the paramount compounds contributing to the wine flavor. Each ester could release its own flavor characteristics, any combination of which complicated the flavor of the product. As mentioned above, esters were closely related to the appellation, the flavored complexity of which on product was rooted in the unique appellation characteristics. The unique raw materials created the foundation for the development of unique flavors in products. When choosing a wine you enjoy, the first requirement is to consider the right region.

Clearly, dominant group of esters depended on several factors, such as yeast strain, aeration degree, sugar contents,

and fermentation temperature [23, 24]. The esters originated not only from the primary compounds of material [25, 26] but also from the organic matter in the soil, and the conditions forming the precursors of these flavors such as air temperature and light in various territories. The results are also the same in this experiment. Cheng et al. [27] verified that the most abundant esters were ethyl hexanoate and ethyl octanoate; however, ethyl octanoate, decanoic acid, ethyl ester, 1-butanol, 3-methyl-, acetate and ethyl hexanoate appeared in the trial, and the content of each ester displayed out corresponding difference from the producing area, especially 1-butanol, 3-methyl-, acetate of 35.62 mg/L in Shihezi, 19.36 mg/L in Manas, 4.25 mg/L in the Ili River valley, 38.10 mg/L in Turpan, and 16.69 mg/L in Hoxud County (Table 2), which further proved that appellation was the basic condition for the formation of esters.

Table 2 lists OTH and odor descriptors (ODE) for several volatile compounds in wine. The significant contribution of each to the characteristic flavor could be determined by the OAV. Despite the limitations, OAV was still very useful to aroma [28]. Due to the unavailability of the pure standard or OTH in the literature, some OAV was not determined [29]. Among a total of 29 esters, hexanoic acid, ethyl ester, 1-butanol, 3-methyl-, acetate, ethyl butanoate, decanoic acid, ethyl ester, and ethyl octanoate had the relatively highest OAV. Ethyl octanoate was associated with sweet, fruity, and fresh notes [30]. 2-Hydroxy esters detected in wine (Table 2), such as propanoic acid, 2-hydroxy-, ethyl ester, (L)- and ethyl 2-hydroxy-isohexanoate, were also reported in mango fruit [29]. Hydroxy esters originated from the esterification of the corresponding hydroxy fatty acids with fruity-floral notes [30, 31], or from the reduction of keto acids [32]. Therefore, metabolism and fermentation were secondary conditions for the formation of flavor substances.

Esters were responsible for fruity aromas and the quality of young wines [33]. Turpan sample was characterized by higher ester content than the other four wines, which could be one of the main reasons for total acid's disappearance (Table 4). In 5 samples, ten esters with an OAV >1 (butanoic acid, ethyl ester, hexanoic acid, ethyl ester, octanoic acid,

ethyl ester, nonanoic acid, ethyl ester, ethyl 9-decenoate only in Shihezi and Hoxud counties; decanoic acid, ethyl ester, tetradecanoic acid, ethyl ester, hexadecanoic acid, ethyl ester, 1-butanol, 3-methyl-, acetate, and octanoic acid, 3-methylbutyl ester) contributed positively to the flowery and fruity characteristics of the wine. Especially, octanoic acid, ethyl ester contributed to sweet and fruity [34], flowery, banana, and pear [35], or lentil flavor and musty [36]. In addition, decanoic acid, ethyl ester aroused sweet and fruity [34], fatty [37], 1-butanol, 3-methyl-, acetate induced sweet and fruity [35], banana, pineapple, and strawberry [37]. Ethyl 2-hydroxy-4-methylpentanoate, directly contributed by a fresh blackberry aroma, was identified in red and white table wines for the first time; 900 $\mu\text{g/L}$ of threshold and 400 $\mu\text{g/L}$ average concentration in red wine. Sensory omission tests identified a perceptive interaction with ethyl butanoate [38]. In the trial, there were only 0.30 mg/L in the Ili River valley and 0.11 mg/L in Hoxud County wine. Therefore, changes in appellation affect the performance of ODE in wines.

Concentrations of 2-methylbutyl acetate met 129–200 mg/L in white wines and 181–359 mg/L in red wines [39], while 0.38 mg/L (Ili River valley)—1.58 mg/L (Shihezi) in the experimental samples, which was usually associated with banana and fruity descriptors, and the olfactory threshold was 5 mg/L in water and 160 mg/L in wine [39–41]. Previous reports on a correlation between 2-methylbutyl acetate and 2-methylbutan-1-ol demonstrated that the formation of the ester depended on the corresponding higher alcohol [40, 42]. The results in every region catered to the above researches further. OTH of 2-methylbutyl acetate was 3.5-fold higher in fruity aromatic reconstitution (1083 mg/L) than in dilute alcohol solution (313 mg/L) [43]. In our trials, 2-methylbutyl acetates in five samples surpassed 313 mg/L, namely 384 mg/L, in the Ili River valley, 586 mg/L in Hoxud County, 1103 mg/L in Manas, 1288 mg/L in Turpan, and 1584 mg/L in Shihezi. Increased concentrations of the branched ester could contribute to the typical character of fruity aroma and the complexification and intensification of wine aroma during the aging. Therefore, concentration and OTH of esters were related closely to fermentation conditions and aging time. Appropriate alteration was the third condition for the formation of flavor substances.

Ethyl acetate is one of the main esters produced during the fermentation. The lower concentrations, ≤ 80 mg/L, could impart a fruity aroma, and 160–170 mg/L of concentrations was associated with undesirable nail Polish remover and solvent sensory descriptors [44]. Only *M. pulcherrima* with 0.05 volume of air/volume of culture/minute (VVM) produced excessive ethyl acetate (280 mg/L) and impacted negatively the flavor profile of wines, while without observation for 0.025 VVM treatments [45] also increased scores of wines for the solvent sensory descriptor. Therefore, an oxygen threshold was suggested for overproduction of ethyl acetate in wine.

3.2.2. Alcohols. Alcohols, accounting for 18.18% of the aromatic content in five wines, were the second largest group of volatiles (Table 3). The subtotal level of alcohols ranged

from 165.01 (Ili River valley) to 195.50 mg/L (Manas). The results showed that 10 volatile alcohols identified totally covered 10 varieties (168.70 mg/L) in Shihezi, 10 (195.49 mg/L) in Manas, 7 (165.04 mg/L) in the Ili River valley, 8 (184.79 mg/L) in Turpan, and 7 (168.09 mg/L) in Hoxud County.

The alcohols significantly affected by the features of region (Table 3), as expected, usually proceed from grapes and yeast metabolism [46], which played a vital role in the wine flavor [46, 47]. These alcohols, such as ethanol, phenylethyl alcohol, 1-butanol, 3-methyl-, 2, 3-butanediol, 1-hexanol, could be detected in each region as characteristic component. However, there were benzyl alcohol and 1-nonanol without the Ili River valley and Hoxud County; 1-butanol, 2-methyl- without the Ili River valley; (S)-3-ethyl-4-methylpentanol without Turpan; and 1-octanol without Turpan and Hoxud counties. In addition, only Shihezi and Manas detected out all alcohols, which was related to the ecological conditions forming the precursors of these components. Isoamyl alcohol and phenylethyl alcohol, with strong and pungent taste related to herbaceous notes [8], were the higher concentrations in the five wines, in accordance with previous studies [5, 12]. The appropriate content and proportion of higher alcohol played an important role in improving the wine taste [48]. Concentrations of the higher alcohols below 300 mg/L contributed to the desirable complexity of the wine, while a negative quality was above 400 mg/L [7, 46]. In this study, all the alcohols displayed concentrations below 300 mg/L, which were beneficial to the contribution of flavor in five different samples. In addition, 2-phenylethanol, produced mainly by the metabolism of phenylalanine during the yeast fermentation, provided the fragrance of rose flowers at low concentrations [48, 49], the concentration of which, however, decreased with the rising altitude [1] and was closely associated with some other integrated factors, such as the soil, sunlight, and weather conditions. Therefore, there was 37.71 mg/L of 2-phenylethanol with a diverse degree of rose flavor in Turpan (–155 m), 15.54 mg/L in Shihezi (450.8 m), 34.86 mg/L in Manas (578 m), 22.93 mg/L in the Ili River valley (663 m), and 13.92 mg/L in Hoxud County (932 m). The above studies show that yeast fermentation can significantly affect the type and concentration of alcohols in wine. Under normal circumstances, yeast fermentation needs to meet the three main basic factors, such as substrate, active yeast, and suitable environmental conditions for fermentation, while the production area can produce the substrate for yeast fermentation, which indirectly affects significantly the type and concentration of alcohols.

As the second largest group of volatile compounds, alcohols were similarly released as secondary products of yeast metabolism through either the anabolic pathway from glucose or the catabolic pathway from corresponding amino acids [21, 50]. Isoamyl alcohol, phenethyl alcohol, 2-methyl-1-butanol, and alcohol were the main alcohols in 5 samples, which were in agreement with Liberatore et al. [51]. However, these alcohols were present in significantly different proportions. For example, some alcohols were seldom present in certain samples, including 2-methyl-1-butanol in

TABLE 3: Comparison of alcohols in Cabernet Sauvignon dry red wine from 5 regions in Xinjiang (mg/L).

	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Ethanol	100 ^a		12.76 ± 0.52a	18.28 ± 0.43a	17.59 ± 0.32a	7.78 ± 0.14a	23.52 ± 0.43a
Benzyl alcohol	200 ^b	Roasted, toasted, sweet, fruity ^f	0.12 ± 0.01a	0.12 ± 0.02a	N	0.37 ± 0.01a	N
Phenylethyl alcohol/2-phenylethyl alcohol	14 ^a	Floral, rose, honey, flowery, pollen, perfume ^{d,e,i} , rose-like, bitter, sweet, peach ^c	15.54 ± 0.56a	34.86 ± 0.46a	22.93 ± 0.33a	37.71 ± 0.47a	13.92 ± 0.23a
1-Butanol, 3-methyl-/Isopentanol/Isoamyl alcohol	30 ^b	Cheese ^b , solvent, sweet, alcohol, nail polish ^k	120.30 ± 1.28a	119.50 ± 1.46a	119.30 ± 1.33a	120.70 ± 1.42a	119.40 ± 1.21a
1-Butanol, 2-methyl-/2-methyl-1-but/2-methylbutanol/2-methylbutanol-1		Harsh, nail Polish remover ^l	14.33 ± 0.47a	15.45 ± 0.53a	N	13.15 ± 0.25a	7.66 ± 0.34a
2, 3-Butanediol	120 ^b	Fruity ^m , butter, creamy ^b	1.10 ± 0.23a	1.06 ± 0.37a	0.56 ± 0.03a	0.20 ± 0.02a	0.86 ± 0.25a
(S)-3-ethyl-4-methylpentanol		N/A	0.08 ± 0.02a	0.10 ± 0.02a	0.30 ± 0.01a	N	0.16 ± 0.01a
1-Hexanol	8 ^b	Flower, green, cut grass, resin ^{f,n} , grass, herbaceous, wood ^f	3.57 ± 0.27a	5.26 ± 0.25a	3.71 ± 0.12a	3.70 ± 0.14a	2.58 ± 0.13a
1-Octanol	0.8 ^o	Jasmine, lemon, rose ^o	0.44 ± 0.13a	0.41 ± 0.12a	0.66 ± 0.11a	N	N
1-Nonanol	0.6 ^o	Fresh, clean, fatty, floral, rose, orange, dusty, wet ^p	0.47 ± 0.11a	0.45 ± 0.12a	N	1.18 ± 0.15a	N
Subtotal			168.70	195.50	165.01	184.74	168.10

Note: ^kWang et al. (2017), ^lMolina et al. (2009), ^mPeinado et al. (2006), ⁿSánchez-Palomo et al. (2017), ^oMoyano et al. (2002), and ^pCharlier et al. (2012).

the Ili River valley samples, (S)-3-ethyl-4-methylpentanol in Turpan, benzyl alcohol and 1-nonanol in the Ili River valley and Hoxud counties, and 1-octanol in Turpan and Hoxud counties, which were up to respective ecological conditions in five regions. Cabernet Sauvignon wine detected 40 µg/L of (S)-3-ethyl-4-methylpentanol without threshold [52], which were less than the results of trials, 0.08 mg/L in Shihezi, 0.10 mg/L in Manas, 0.30 mg/L in Ili River valley, and 0.16 mg/L in Hoxud County, except for no detection in Turpan, respectively. However, the results of He et al. [53] found that (S)-3-ethyl-4-methylpentanol in Cabernet Gernischt wine was 193.4 µg/L and 86.7 µg/L in Jingyang County in China in Vintage 2010 and 2011, respectively, and showed further that the number and concentration of volatile compounds quantified in wine were lower under rain-shelter cultivation compared with open-field cultivation. However, effects of rain-shelter cultivation improving the wine quality were obvious in some rainy regions, which demonstrated the obvious contribution of ecological conditions in producing areas. The above studies further indicate that, regardless of the fermentation conditions, the ecological conditions in the producing areas are the most basic control factors. Without a good producing area, no fermentation substrates satisfying the yeasts can be produced, so no pleasant volatile alcohols can be obtained. Each region has its own ecological characteristics that make it possible to produce own, unique style of wine.

Alcohols were characterized by the vegetal and herbaceous aromas, varieties of which depended widely on the

β-glucosidase [54]. As listed in Table 3, the lowest alcohols were found in the Ili River valley wine (165.01 mg/L), while the richest were in the Manas sample (195.50 mg/L), which indicated that the ecological conditions played the same role as the enzyme. Therefore, Shihezi and Manas had a stronger ability to release more 2-methylbutanol, analogously, Ili River valley and Hoxud County had the same capacity to (S)-3-ethyl-4-methylpentanol, and Turpan and Manas to phenylethyl alcohol (Table 3), which promoted discrepant flavor substances in every wines. Interestingly, formation of some higher alcohols contributing to fruity and floral notes correlated also with the fermentation of yeast [12]. The content of higher alcohols increased significantly after the yeast fermentation. However, the concentrations of 1-octanol, typically contributed floral aroma, showed a significant decrease owing to previous esterification with fatty acids to esters with *S. cerevisiae* [55]. Therefore, 1-octanol was esterified into octanoic acid, ethyl ester, n-caprylic acid, isobutyl ester, and octanoic acid, 3-methylbutyl ester in the trial (Tables 2 and 3).

Isopentyl alcohol and phenethyl alcohol were found in higher concentrations in amphora wines [17], including the trial. The only difference was that isopentyl alcohol and phenethyl alcohol represented about 50% of alcohols in the total concentration in amphora wines analyzed compared with 80% of those in our trial. The high amount could probably be explained by the clay material of the amphorae allowing some oxygen transfer during the fermentation, which was consistent with the previous conclusion that the

proportion of fruit stalk could regulate the influence of the proportion of oxygen infiltration on the aroma of wine during the fermentation [56] except for the ecological and fermentation conditions of the region. Isopentyl alcohol, with a cheese odor owing to a low odor threshold [34], was the major higher alcohol found in wines [57], thus supporting the results obtained. For benzene-derived higher alcohols, phenethyl alcohol was the most important and only fusel alcohol with positively perfumed, sweet and dry rose [58]. Both phenyl ethyl alcohols including related acetate ester contributed to floral notes. The fining process might have a limited impact on the aroma traits related to these specific components [59]. In addition, other higher alcohols, namely, hexyl alcohol, octyl alcohol, and benzyl alcohol, had been detected with very important contributors to the wine aroma [13]. Benzyl alcohol was also an important raw material for the synthesis of resveratrol, which played an important role in the improvement of flavor substances and antioxidant properties of wine. Therefore, these alcohols were very important components of wine flavor.

Jung [60] found that volatile compounds in the root peels were mainly composed of monoterpene hydrocarbons, while the stem peels and fruit peels were characterized by alcohols. Therefore, volatile components in wine were not produced entirely by the fermentation and aging but partly by exotic substances, such as stalks, stems, and leaves. Furthermore, the optimal choice was retaining 20% stalk compared with zero stalk, 40% stalk, and all stalk [56]. Oxygen supplementation could increase the concentration of ethyl esters [60, 61], decrease the level of acetate esters [62], and alter the proportion of acetate to ethyl esters and of branch-chain acids to medium-chain fatty acids [61], by the different strains, media, and fermentation conditions. In the current study, esters and higher alcohols in 5 samples showed significant differences, which was perhaps related to the oxygen intake including its amount induced by the space of grape juice with fruit stalks formed during the fermentation except for ecological characteristics of the appellation, such as atmospheric pressure.

Amino acids, precursors of higher alcohols, esters, aldehydes and ketones, made up the important aroma features of wine [63]. However, almost all the amino acids, particularly serine, histidine, threonine, arginine, valine, isoleucine, tryptophan, and leucine, had significantly changed in concentration after fermentation [50]. The conversional pathway of the specific amino acids into the flavor-related key alcohols and esters had been clarified during the yeast fermentation. For example, L-phenylalanine promoted the yield of 2-phenylethyl hexanoate, 2-phenylethyl isobutyrate, 2-phenylethyl alcohol, and 2-phenylethyl acetate [64]. Leucine and valine were converted into isopentanol, butanedioic acid diethyl ester, and isobutanol [65]. Threonine, the precursor of ethanol, endowed wine with a strong fruity flavor [65]. Amino acids came from raw materials [66]. The types and yields of amino acids in different wine regions were different, which was one of the main reasons for the differences in wine flavor substances. In the present study, 5 samples had a high content of alcohols, including 1-butanol, 3-methyl-, with 2-phenylethanol in Turpan and Manas wine;

ethanol in Hoxud County; and esters such as octanoic acid, ethyl ester, and isoamyl acetate in Turpan and Shihezi; hexanoic acid, ethyl ester in Turpan, Manas, and Shihezi; decanoic acid, ethyl ester in Manas, Turpan, and Shihezi, which originated from higher concentrations of amino acids improving the resulting wine flavor [50]. Note that pyruvate carboxylase could convert pyruvate into oxaloacetic acid and final alcohols [67], which, therefore, might also influence the formation of volatile compounds. During the fermentation, carbon dioxide was inevitably produced as the precursor of HCO_3^- , which was characteristic of stalked fermentation for red wine [56]. Alkaline electrolyzed waters (AIW) dissolved easily in proteins with a strong permeation capacity [68]. However, the amount of volatile compounds in wine with alkaline electrolyzed water (WAIW) was much lower than that of wine with acidic electrolyzed water (WAcW), due to the suppressive ability of yeast to convert amino acids in alcohols and esters in AIW [50]. Thus, alcohols and esters in wines need a certain pH condition. In the final analysis, the environmental conditions for fermentation and aging were created by grape materials, and the composition of raw materials was closely related to ecological conditions [69].

3.2.3. Acids. From Table 4, a total of 3 acids (0.14–0.53 mg/L) were identified in the 5 wines, which covered 2 varieties (0.84 mg/L) in Shihezi, 2 kinds (0.42 mg/L) in Manas, 3 (0.66 mg/L) in the Ili River valley, and 1 (0.35 mg/L) in Hoxud County. Volatile acids in Shihezi wine were from 0.31 mg/L to 0.53 mg/L with the highest total value in five regions. Similarly, the Ili River valley sample obtained 0.14 mg/L–0.36 mg/L of volatile acids with the second highest total number in five regions, followed by Manas (0.16–0.26 mg/L), Hoxud County (0.35 mg/L), and Turpan (0 mg/L). These characteristic constituents could not be ignored although less. A cool climate in Shihezi and the Ili River valley increased the concentration of fatty acids. On the contrary, hot Turpan eliminated them in the trial.

Within the volatile acids, particular attention had to be paid to medium chain fatty acids owing to the aroma descriptors of cheese or rancid. Furthermore, other acids, including octanoic, hexanoic, and decanoic acids, were not observed from lees [51]. In the trial, octanoic acid was only detected in wine in Shihezi, Manas, and the Ili River valley (Table 4). Therefore, these three regions had no release of these acids from lees. However, octanoic acid, ethyl ester and octanoic acid, and 3-methylbutyl ester were obtained by the esterification in every wine (Table 2), which demonstrated that octanoic acids in Shihezi, Manas, and the Ili River valley were accumulated more compared with that in Turpan and Hoxud County. A mass of 1-butanol, 3-methyl- (more than 100 mg/L) (Table 3) revealed the higher ripeness of grapes; however, less than 5 mg/L of octanoic acid, 3-methylbutyl ester (Table 2) indicated an indisputable fact, namely, higher sugar content and lower acid content in grape berries. Rancid octanoic acid, 7.382 mg/L, and 0.034 mg/L butanoic acid, 4-hydroxy without aroma descriptors were detected in Chardonnay white wine in

TABLE 4: Comparison of acid components in Cabernet Sauvignon dry red wine from 5 regions in Xinjiang (mg/L).

	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Butanoic acid, 4-hydroxy-			N	N	0.14 ± 0.01a	N	N
Octanoic acid	0.5 ^b	Rancid, harsh, cheese, fatty, sweat ^{b,i}	0.53 ± 0.01a	0.16 ± 0.01a	0.15 ± 0.01a	N	N
Phosphonoacetic acid, 3TMS derivative			0.31 ± 0.01a	0.26 ± 0.01a	0.36 ± 0.02a	N	0.35 ± 0.01a
Subtotal			0.84	0.42	0.66	0	0.35

stainless steel containers at 10 months of aging [51]. Two acids were also detected in our wine, which demonstrated that, on the one hand, octanoic acid and butanoic acid, 4-hydroxy were common volatile components in Chardonnay white wine and Cabernet Sauvignon dry red wine and, on the other hand, our wines were also fermented and aged without lees in stainless steel containers except for production disparities. In the trial, only the Ili River valley wine had more than the butanoic acid, 4-hydroxy (0.14 mg/L) in Chardonnay white wine. Meanwhile, octanoic acid in Shihezi (0.53 mg/L), Manas (0.16 mg/L), Ili River valley (0.15 mg/L) wine were much less than Chardonnay white wine (7.382 mg/L) in the output, which manifested that octanoic acid was more propitious to cool climate conditions and white wine, and even the concentrations were varied with the cool ecological conditions in the growing areas. The colder it is, the greater the decrease. In addition, 4-hydroxy-butanoic acid was also obtained in carbonic maceration wine [70] and clones of Pinot Noir grapes in Zhang Jiagang vineyard [71]. Therefore, the formation of 4-hydroxy-butanoic acid in wine relied on the combined action of various factors, such as the grape variety, fermentation conditions, and features of the region. When choosing a wine, appellation factors should be considered first. Appellation factors would affect the fermentation, aging, and even formation and transformation of flavor substances in wines.

Odorant acids, with cheesy, fatty, fruity, and rancid notes [72], were determined by the initial composition of must and fermentation conditions with yeast metabolism [5]. In this study, except for the fact that octanoic acid (0.53 mg/L) in Shihezi wine was of the highest content, phosphonoacetic acid, 3TMS derivative were more in the Ili River valley wine than those of other wines. Butanoic acid, 4-hydroxy- was only detected out in the Ili River valley, and phosphonoacetic acid, 3TMS derivative in Hoxud County. Relative contents of phosphonoacetic acid of pomegranate wine drop with fermentation time [73], while the difference of ecological characteristics has more obvious influence on it in the trial. It is noteworthy that Turpan did not produce any acid, because of the extremely hot weather and sandy soil structure leading to a small temperature difference between day and night, which resulted finally in the rapid ripening of grapes, a further sharp decrease in acidity, and the conversion of acids to esters during the fermentation and aging of wine [17].

Acids, originated mainly from lipolysis and proteolysis [74], were the most important precursor substances

synthesizing some unique flavors, such as esters, aldehydes, and alcohols [75]. Enzymes with lipolytic activity could release linear-chain acids. Proteases and lipase derived mainly from the metabolism of some microorganisms [76]. Proteolytic enzymes were responsible for the formation of amino acids by deamination [77]. Therefore, acids in wine depended mainly on metabolic activity. In the trial, there was very little acid in samples. There were two reasons for this phenomenon. On the one hand, there was less acid in the raw material originated from the ecological conditions of the producing areas; on the other hand, the transformation between other flavor substances during the fermentation and aging led to little acid. In conclusion, the region could affect activity of enzymes during the fermentation and aging. The total content of acids was higher during the prefermentation than that during the postfermentation, because vigorous microorganism metabolism tended to increase lipolysis and proteolysis during the prefermentation, which stimulated acids to transform into esters during the postfermentation [78], one of the main reasons for the few types and quantity of acids in our experiment, especially the absence of acids.

C6–C10 fatty acids, <4 mg/L, gave a positive effect on the global aroma quality; 4 mg/L–10 mg/L of acid imparted a mild and pleasant aroma; and >20 mg/L did affect wine negatively. Therefore, there was no significant impact of acid on the aroma of the five wines because all had far below than 4 mg/L of C6–C10 fatty acids in the current study, which was consistent with the result of Yue et al. [1].

3.2.4. Alkanes. From Table 5, 8 types of volatile alkanes, 0.07–80.21 mg/L, were quantified in 5 wines, which covered 7 varieties (16.63 mg/L) in Shihezi, 7 kinds (48.32 mg/L) in Manas, 8 (189.83 mg/L) in the Ili River valley, 8 (86.55 mg/L) in Turpan, and 8 (84.89 mg/L) in Hoxud County. Volatile alkanes in the Ili River valley wine were from 0.13 mg/L to 80.21 mg/L, the highest total value in all the five regions. Similarly, volatile alkanes in Turpan wine were from 0.20 mg/L to 38.88 mg/L, the second highest total value, followed by Hoxud County (0.07–33.09 mg/L), Manas (0.19–18.86 mg/L), and Shihezi (0.17–8.52 mg/L). These alkanes were found in almost every region except for pentasiloxane, dodecamethyl- found only in the Ili River valley, Turpan, and Hoxud County, which demonstrated that these alkanes were characteristic of the volatile constituents of Cabernet Sauvignon red wine, and formation of dodecamethyl pentasiloxane needs a hot climate.

TABLE 5: Comparison of alkanes in Cabernet Sauvignon dry red wine from 5 regions in Xinjiang (mg/L).

	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Cyclononasiloxane, octadecamethyl-			0.79 ± 0.04a	0.82 ± 0.03a	0.65 ± 0.02a	1.03 ± 0.03a	0.58 ± 0.01a
Cyclotrisiloxane, hexamethyl-			0.50 ± 0.01a	0.58 ± 0.02a	0.66 ± 0.02a	0.41 ± 0.03a	0.07 ± 0.02a
Cyclotetrasiloxane, octamethyl-			0.17 ± 0.04a	0.19 ± 0.01a	0.13 ± 0.01a	0.20 ± 0.02a	0.16 ± 0.01a
Cyclopentasiloxane, decamethyl-			2.17 ± 0.25a	18.86 ± 0.13a	59.52 ± 0.48a	38.88 ± 0.34a	29.39 ± 0.62a
Cyclohexasiloxane, dodecamethyl-			1.79 ± 0.03a	14.90 ± 0.23a	80.21 ± 0.45a	27.24 ± 0.36a	33.09 ± 0.22a
Cycloheptasiloxane, tetradecamethyl-			8.52 ± 0.11a	10.00 ± 0.33a	42.45 ± 0.46a	14.54 ± 0.12a	17.83 ± 0.15a
Cyclooctasiloxane, hexadecamethyl-			2.69 ± 0.31a	2.97 ± 0.13a	5.83 ± 0.22a	3.80 ± 0.15a	3.58 ± 0.23a
Pentasiloxane, dodecamethyl-			N	N	0.38 ± 0.01a	0.43 ± 0.02a	0.19 ± 0.01a
Subtotal			16.63	48.32	189.83	86.55	84.89

TABLE 6: Comparison of other components in Cabernet Sauvignon dry red wine from 5 regions in Xinjiang (mg/L).

	OTH	ODE	Shihezi	Manas	Ili River valley	Turpan	Hoxud County
Thymol, TBDMS derivative			0.26 ± 0.01a	N	N	N	N
Nonanal	0.001 ⁱ	Green, slightly pungent ^{b,e} Fat, citrus, green, fruity ^{f,i}	0.38 ± 0.02a	0.21 ± 0.01a	N	N	N
2,4-Di-tert-butylphenol	0.2 ^a		2.39 ± 0.15a	1.59 ± 0.11a	1.54 ± 0.08a	1.55 ± 0.05a	1.52 ± 0.04a
2-Buten-1-one, 1-(2,6,6-trimethyl-1,3-cyclohexadien-1-yl)-, (E)-(β-damascenone)	0.00005 ^a	Sweet, perfume, floral, fruity, (Stabilwax Column) ^q sweet, cooked pineapple (DB-5 Column) ^q	N	0.79 ± 0.01a	0.28 ± 0.01a	N	N
Benzaldehyde	0.35 ^f	Sweet, fruity, roasted, cherry or almond, fragrant, burnt sugar ^f	N	N	3.10 ± 0.24a	N	N
Subtotal			3.03	2.59	4.92	1.55	1.52

^qKlesk et al. (2004).

The total content of alkanes in wine increased to a maximum in the Ili River valley but decreased to the minimum in Shihezi during the aging (Table 5), which depended mostly on indole playing an important role in content variation based on the local ecological characteristics. However, the indole content decreased because of unstable and easily oxidized chemical properties in the postfermentation period [79]. Alkanes had little contribution to the characteristic flavor of our results because of high threshold values [80], which was corresponding with Kedong sufu [81]. Nevertheless, some compounds identified, OAVs <1, could also contribute to the fruity character of wine due to synergistic effects [29].

3.2.5. Other Aroma Compounds. The other ingredients, though very few, are likewise very important in regulating the wine flavor. From Table 6, 5 types of volatile other components, 0.21–3.10 mg/L, was quantified in 5 wines, which covered 3 varieties (3.03 mg/L) in Shihezi, 3 varieties (2.59 mg/L) in Manas, 3 varieties (4.92 mg/L) in the Ili River valley, 1 variety (1.55 mg/L) in Turpan, and 1 variety (1.52 mg/L) in Hoxud County. Thymol, TBDMS derivative, and benzaldehyde were only in Shihezi and the Ili River valley wine, nonanal only in Shihezi and Manas, 2-buten-1-one, 1-(2, 6, 6-trimethyl-1, 3-cyclohexadien-1-yl)-, (E)- only in Manas and the Ili River

valley, which indicated that the existence of these ingredients needed also to meet certain ecological conditions.

In Table 6, aldehydes and ketones detected from five wines were nonanal (0.38 mg/L in Shihezi and 0.21 mg/L in Manas), benzaldehyde (3.10 mg/L in the Ili River valley), and 2-buten-1-one, 1-(2, 6, 6-trimethyl-1, 3-cyclohexadien-1-yl)-, (E)- (0.79 mg/L and 0.28 mg/L in Manas and Ili River valley, respectively). Yue et al. [1] found that the concentration of benzaldehyde was inversely proportional to the altitude. In the trial, only wine in the Ili River valley yielded benzaldehyde, which could rely on the unique ecological conditions in the Ili River valley except for the altitude. However, nonanal was suitable for environmental conditions for medium altitude based on discovery only in Shihezi (450.8 m) and Manas (578 m). Octanal, nonanal, and 2-decenal could be derived from oleic acid [82]. There was only nonanal in Shihezi and Manas (Table 6), and ethyl oleate in Shihezi, the Ili River valley, and Turpan (Table 2) without oleic acid (Table 4) in the trial, which meant that environmental conditions in Shihezi could promote maximum nonanal, including precursor such as oleic acid, and Hoxud County did not have the ecological conditions to form oleic acid and nonanal.

Aldehydes, the main products of lipid oxidation and degradation or the autooxidation of unsaturated fatty acids via hydroperoxides [83], might be converted to alcohols or

acids in the fermentation [84], and also help enhancing the flavor under the low content and cause off-flavors with high concentration [84, 85]. These aldehydes had been categorized as sweet, fruity, nutty, and caramel-like odors [86]. Among nonaldehyde and benzaldehyde (cherry or almond-like odor) from microorganism transformation and amino acid degradation [87], benzaldehyde was detected only in the Ili River valley wine, accounting for more than 84.01% of the total aldehydes (Table 6), which was comparable to Guyue Longshan rice wine [88]. Benzaldehyde depended mainly on chemical characteristics of grape [51], which was related to bitter almond notes with a nondesirable trait [59] or a mix of fruity and nutty aromas [18]. The nonaldehyde was higher in Shihezi wines than that in Manas samples. Furthermore, the content of aldehydes varied from region to region, which reflected the oxidizing reaction of alcohols among different regions during the aging. The relatively small amounts of aldehydes in wines (Table 6) were due to the reduction of aldehyde to the corresponding alcohol during lipid metabolism [17]. The aliphatic aldehyde series presented a range of fragrances from the green aroma associated with lower aldehydes to the citrus fruit fragrance of aldehydes with C₈–C₁₁ [89]. C₈–C₁₁ family of aldehydes is quite common in nature. Nonanal was the most powerful aldehyde with thresholds in 1.0 $\mu\text{g/L}$ of water, well below the thresholds of other linear aliphatic aldehydes. It must be remarked that a very low level of nonanal, with a powerful fatty-floral odor [90], had been often identified as potentially active odorants of wine [90, 91], which was in accordance with our results. Altogether, the levels and sensory roles of these elements in red wines were not well understood today, and more quantitative data would be necessary. Another relevant question on aldehydes could be established on different chemical or physicochemical interactions with other species in wine, such as sulfur dioxide [92, 93], which could be important contributors to the citrus aroma of some specific wines [89]. Therefore, there were many factors that affected the yield of aldehydes.

Volatile phenols are one of the key aromatic molecules responsible for olfactory defects in wine. It's worth noting that 2, 4-di-tert-butylphenol (2, 4 DTBP) with a known antioxidant was a characteristic component of Cabernet Sauvignon dry red wine [13] and amphora wines [17]. Because of the difference in content in the trial, antimicrobial activity of wine in Shihezi (2.39 mg/L) was higher than other samples, such as Manas (1.59 mg/L), Ili River valley (1.54 mg/L), Turpan (1.55 mg/L), and Hoxud County (1.55 mg/L). Result of Choi et al. [94] confirmed the antifungal activity of 2, 4 DTBP in fruits and seeds against the plasmodial growth in vitro [95]. 2, 4 DTBP could inhibit the assembly of spindle microtubules, disturb the chromosomal alignment at the metaphase plate and microtubule–kinetochore interactions, and cause further chromatid loss, which reduced the mycelia growth and the germination of spores [96]. Therefore, the presence of 2, 4 DTBP could enhance the antibacterial properties of wine.

Terpenes with floral and citric aromas had low olfactory thresholds [97], which were thought of as a good indicator for the variety and quality of grape during the fermentation [98]. β -damascenone was isolated from Bulgarian rose (*Rosa*

damascena) oil [99] and first identified in grapes and wines by Schreier and Drawert [100]. Although having a very low odor threshold (0.05 $\mu\text{g/L}$) and concentration in Chinese wild/hybrid species wines [37], β -damascenone, as an important terpene compound with a rose-like fruity, perfume, sweet, and berry odor, exceeded the odor threshold in wines from Jiunongding-2330 (OAV 85.60) and Jiangpo-2788 (OAV 78.00) [1]. There were similar results in the trial; for example, β -damascenones far exceeded the entire odor threshold (15791 in Manas and 5615 in the Ili River valley). Additionally, β -damascenone also showed a significantly higher aroma impact in Arkansas than that in Oregon [101], which displayed that producing areas could affect the difference of concentrations of β -damascenone. Just in the experiment, there were 0.79 mg/L (Manas) > 0.28 mg/L (Ili River valley) > 4000 ng/L [102]. This value was also estimated at 4.5 $\mu\text{g/L}$ in sweet white wine [103] and 50 ng/L in a model wine [97]. Therefore, concentrations and thresholds rely also on types of product; the compound was considered as a positive contributor to wine aroma [91], and the region affected the threshold, especially for the same flavor substance.

β -damascenone could enhance some fruity aromas and mask the herbaceous aroma of methoxypyrazine, owing to more of an indirect than a direct sensorial impact on red wines [104]. The enhancement of β -damascenone proposed as carotenoid breakdown products chemically degraded in Uruguayan wines [91] and aged Spanish red wines [105], which played an important role in the evolution of aroma during the aging. This complexity of the aroma ingredient complicated the aroma properties of a wine, because of the effect of other volatile compounds on the perception. Moreover, the long period of aging (more than 4 years both for bottle-aged vintage category after barrel-aged tawny category) also led potentially to chemical reactions with the norisoprenoid and other constituents of oak woods [106], which was one of main reasons promoting β -damascenone reduce or even disappeared in five regions in the research (Table 6).

Moreover, the long period of aging (more than 4 years for bottle-aged period after barrel-aged period) also led potentially to chemical reactions with the norisoprenoid and other constituents of oak woods [107, 108] which was one of the main reasons promoting β -damascenone to reduce or even disappear in five regions in the research (Table 6). The threshold of thymol in honey was 1.1 mg/kg–1.3 mg/kg [109], which was conducive to revealing further its contribution to the flavor of wine.

Research found that alcohols, alkanes, aldehydes, and esters originated from fruit peels and stem peels, and carboxylic acids from fruit peels [55, 59], which gave us a useful hint on supplementing a proportion of fruit peels and stem peels for the fermentation in red wine [56] to make up for the defects in the production area with regard to aroma.

4. Conclusions

Wines from Shihezi, Manas, Hoxud County, Turpan, and the Ili River valley allowed the identification and quantification

of 55 volatile compounds, which included esters (29, 52.73%), alcohols (10, 18.18%), acids (3, 5.45%), alkanes (8, 14.55%), and other components (5, 9.09%). The majority of volatiles were esters and alcohols. The concentrations of total volatiles in the five samples ranged from 0.05 mg/L (Hoxud County) to 222.23 mg/L (Turpan). Turpan had the highest concentrations of esters (222.23 mg/L) and alcohols (120.65 mg/L), Shihezi had the highest acid concentration (0.53 mg/L), and the Ili River valley had the highest concentration in alkanes (1.43 mg/L) and other components (3.10 mg/L). It proved that the numbers and concentrations of volatile compounds were closely linked to the wine region, no matter whether it is common or a large number of or trace components, which was the indispensable part of wine flavor. Each region has its own ecological characteristics that make it possible to produce unique styles in wine, in term of esters, alcohols, acids, alkanes, and others. Some compositions were common for the variety. Esters and alcohols were the major components of Cabernet Sauvignon wine in Xinjiang.

In addition, changes in appellation were related closely to the performance of concentration, ODE, and OTH in wines, especially for the same flavor substance. Appellation factors would affect the fermentation, aging, and even formation and transformation of flavor substances in wines. The environmental conditions for fermentation and aging were created by grape materials related closely to ecological conditions. Therefore, three conditions for the formation of flavor substances were in turn appellation factors, metabolism and fermentation, and appropriate alteration according to production processes and their decisive role in wine quality. Moreover, an oxygen threshold and the amount of oxygen intake induced by the space of grape juice with fruit stalks formed were necessary during the fermentation.

Each volatile matter had its own flavor characteristics, any combination of which complicated the flavor of the product. The unique raw materials created in the region laid the foundation for the development of products with unique flavors. However, the production area can produce disparate type and concentration of the substrate for fermentation. When choosing a wine you enjoy, the first requirement is to choose the right region.

Data Availability

The data used to support the findings of this study are included within the article.

Additional Points

Practical Applications. It is a technique to select the right region to extract the potential quality of wine grapes, improve the quality of wine, and make wines with different styles. The quality of grapes is fully reflected in this region, which can increase its added value and reduce the production cost of wine, which is also very beneficial for the development of the grape and wine industry in the arid and semi-arid high-quality wine-grape-producing areas.

Conflicts of Interest

The authors declare no conflict of interests with respect to the authorship and/or publication of this article.

Acknowledgments

This work was supported by Back-Up Personnel Project of Young and Middle-Aged Academic Professionals of Yunnan Province (2019HB055); Youth Outstanding Talents Project of Yunnan Province; Leading Talents in Science and Technology Project of Chuxiong, Surface Project of Joint Special Fund Project on Basic Research for Local Undergraduate Colleges and Universities (part) in Yunnan Province (Grant No. 2018FH001-043); Engineering Technology Research Center of Grape and Wine for Advanced School in Yunnan, the Develop Special Funds Supporting Local Universities from Central Finance for Grape and Wine Engineering Teaching Experimental Platform Construction Project, the 12th Five-Year Degree Authorized Construction Discipline in Biology of Yunnan Province; and the Support Plan of Scientific and Technological Innovation Team for Research and Development of Characteristic Plant Resources in Colleges and Universities in Yunnan Province (IRTSTYN).

References

- [1] T.-X. Yue, M. Chi, C.-Z. Song et al., "Aroma characterization of Cabernet Sauvignon wine from the Plateau of Yunnan (China) with different altitudes using SPME-GC/MS," *International Journal of Food Properties*, vol. 18, no. 7, pp. 1584–1596, 2015.
- [2] Y.-L. Ju, M. Liu, T.-Y. Tu et al., "Effect of regulated deficit irrigation on fatty acids and their derived volatiles in "Cabernet Sauvignon" grapes and wines of Ningxia, China," *Food Chemistry*, vol. 245, pp. 667–675, 2018.
- [3] B. Jiang and Z. Y. Sun, "Phenolic compounds, total antioxidant capacity and volatile components of Cabernet Sauvignon red wines from five different wine-producing regions in China," *Food Science and Technology*, vol. 3, 2019.
- [4] K. Tang, Y. R. Xi, Y. Ma, H. N. Zhang, and Y. Xu, "Chemical and sensory characterization of cabernet sauvignon wines from the Chinese loess plateau region," *Molecules*, vol. 24, no. 6, pp. 1–18, 2019.
- [5] B. Jiang, Z. Xi, M. Luo, and Z. Zhang, "Comparison on aroma compounds in Cabernet Sauvignon and Merlot wines from four wine grape-growing regions in China," *Food Research International*, vol. 51, no. 2, pp. 482–489, 2013.
- [6] J. A. Pino and S. E. Barzola-Miranda, "Characterization of odor-active compounds in pechiche (*Vitex cymosa* Berteo ex Speng) fruit," *Journal of Raw Materials to Processed Foods*, vol. 1, no. 2, pp. 33–39, 2020.
- [7] L. Nan, L. Liu, X. Zhao, S. Qiu, H. Wang, and H. Li, "Effect of alternative new pruning system and harvesting times on aroma compounds of young wines from Ecolly (*Vitis vinifera*) in a new grape growing region of the Weibei Plateau in China," *Scientia Horticulturae*, vol. 162, pp. 181–187, 2013.
- [8] E. G. García-Carpintero, E. Sánchez-Palomo, and M. A. González-Viñas, "Aroma characterization of red wines from cv. Bobal grape variety grown in La Mancha region," *Food Research International*, vol. 44, no. 1, pp. 61–70, 2011.

- [9] B. Wildi and C. Lütz, "Antioxidant composition of selected high alpine plant species from different altitudes," *Plant, Cell and Environment*, vol. 19, no. 2, pp. 138–146, 1996.
- [10] H. Erten, H. Tanguler, and H. Cakiroz, "The effect of pitching rate on fermentation and flavour compounds in high gravity brewing," *Journal of the Institute of Brewing*, vol. 113, no. 1, pp. 75–79, 2007.
- [11] V. Englezos, K. Rantsiou, F. Cravero et al., "Volatile profile of white wines fermented with sequential inoculation of *Stammerella bacillaris* and *Saccharomyces cerevisiae*," *Food Chemistry*, vol. 257, pp. 350–360, 2018.
- [12] S. Liu, O. Laaksonen, and B. Yang, "Volatile composition of bilberry wines fermented with non-*Saccharomyces* and *Saccharomyces* yeasts in pure, sequential and simultaneous inoculations," *Food Microbiology*, vol. 80, pp. 25–39, 2019.
- [13] Y. Tao, H. Li, H. Wang, and L. Zhang, "Volatile compounds of young cabernet sauvignon red wine from changli county (China)," *Journal of Food Composition and Analysis*, vol. 21, no. 8, pp. 689–694, 2008.
- [14] H. Li, *Wine Tasting*, China Science Press, Beijing, China, 2006.
- [15] G. Avellone, A. Salvo, R. Costa et al., "Investigation on the influence of spray-drying technology on the quality of Sicilian Nero d'Avola wines," *Food Chemistry*, vol. 240, pp. 222–230, 2018.
- [16] J. E. Welke, V. Manfroi, M. Zanusi, M. Lazarotto, and C. Alcaraz Zini, "Characterization of the volatile profile of Brazilian Merlot wines through comprehensive two dimensional gas chromatography time-of-flight mass spectrometric detection," *Journal of Chromatography A*, vol. 1226, pp. 124–139, 2012.
- [17] N. Martins, R. Garcia, D. Mendes, A. M. Costa Freitas, M. G. da Silva, and M. J. Cabrita, "An ancient winemaking technology: exploring the volatile composition of amphora wines," *LWT*, vol. 96, pp. 288–295, 2018.
- [18] X. Fan, G. Liu, Y. Qiao et al., "Characterization of volatile compounds by SPME-GC-MS during the ripening of Kedong sufu, a typical Chinese traditional bacteria-fermented soybean product," *Journal of Food Science*, vol. 84, no. 9, pp. 2441–2448, 2019.
- [19] N. Hussain, T. Abbasi, and S. A. Abbasi, "Vermiremediation of an invasive and pernicious weed salvinia (*Salvinia molesta*)," *Ecological Engineering*, vol. 91, pp. 432–440, 2016.
- [20] J. M. Broncano, M. J. Petró, V. Parra, and M. L. Timón, "Effect of different cooking methods on lipid oxidation and formation of free cholesterol oxidation products (COPs) in *Latissimus dorsi* muscle of Iberian pigs," *Meat Science*, vol. 83, no. 3, pp. 431–437, 2009.
- [21] C. H. Hwan and C. C. Chou, "Effect of ethanol on the hydrolysis of protein and lipid during the ageing of a Chinese fermented soya bean curd-sufu," *Journal of the Science of Food and Agriculture*, vol. 66, no. 3, pp. 393–398, 2010.
- [22] R. A. Peinado, J. C. Mauricio, and J. Moreno, "Aromatic series in sherry wines with gluconic acid subjected to different biological aging conditions by *Saccharomyces cerevisiae* var. *capensis*," *Food Chemistry*, vol. 94, no. 2, pp. 232–239, 2006.
- [23] F. Mde, J. Sanz, and I. Martinezcastro, "Characterization of artisanal cheeses by GC and GC/MS analysis of their medium volatility (SDE) fraction," *Journal of Agricultural and Food Chemistry*, vol. 39, no. 3, pp. 524–530, 1991.
- [24] R. Perestrelo, A. Fernandes, F. F. Albuquerque, J. C. Marques, and J. S. Câmara, "Analytical characterization of the aroma of Tinta Negra Mole red wine: identification of the main odorants compounds," *Analytica Chimica Acta*, vol. 563, no. 1–2, pp. 154–164, 2006.
- [25] K. M. Sumbly, P. R. Grbin, and V. Jiranek, "Microbial modulation of aromatic esters in wine: current knowledge and future prospects," *Food Chemistry*, vol. 121, no. 1, pp. 1–16, 2010.
- [26] J. A. Pino, J. Mesa, Y. Muñoz, M. P. Martí, and R. Marbot, "Volatile components from mango (*Mangifera indica* L.) cultivars," *Journal of Agricultural and Food Chemistry*, vol. 53, no. 6, pp. 2213–2223, 2005.
- [27] G. Cheng, Y. Liu, T.-X. Yue, and Z.-W. Zhang, "Comparison between aroma compounds in wines from four *Vitis vinifera* grape varieties grown in different shoot positions," *Food Science and Technology (Campinas)*, vol. 35, no. 2, pp. 237–246, 2015.
- [28] R. Teranishi, E. L. Wick, and I. Hornstein, "Flavor chemistry—30 years of progress, an overview," *Flavor Chemistry: Thirty Years of Progress*, pp. 1–8, Springer, Berlin, Germany, 1999.
- [29] J. A. Pino and O. Queris, "Analysis of volatile compounds of mango wine," *Food Chemistry*, vol. 125, no. 4, pp. 1141–1146, 2011.
- [30] A. Burdock, "Fenaroli's handbook of flavor ingredients, 5th ed., CRC Press, Boca Raton, FL, USA, 2005," *Carbohydrate Polymers*, vol. 65, no. 3, p. 386, 2006.
- [31] S. Selli, A. Canbas, V. Varlet, H. Kelebek, C. Prost, and T. Serot, "Characterization of the most odor-active volatiles of orange wine made from a Turkish cv. Kozan (citrus sinensis L. Osbeck)," *Journal of Agricultural and Food Chemistry*, vol. 56, no. 1, pp. 227–234, 2008.
- [32] W. Fan and M. C. Qian, "Characterization of aroma compounds of Chinese "wuliangye" and "jiannanchun" liquors by aroma extract dilution analysis," *Journal of Agricultural and Food Chemistry*, vol. 54, no. 7, pp. 2695–2704, 2006.
- [33] V. Ferreira, R. López, and J. F. Cacho, "Quantitative determination of the odorants of young red wines from different grape varieties," *Journal of the Science of Food and Agriculture*, vol. 80, no. 11, pp. 1659–1667, 2000.
- [34] B. Jiang and Z. Zhang, "Volatile compounds of young wines from cabernet sauvignon, cabernet Gernischt and Chardonnay varieties grown in the loess plateau region of China," *Molecules*, vol. 15, no. 12, pp. 9184–9196, 2010.
- [35] J. Zhu, J. Shi, Y. Lu, L. Liu, and Y. Liu, "Application of strains of *Geotrichum* spp. to decrease higher alcohols and to increase esters," *Journal of the Institute of Brewing*, vol. 122, no. 1, pp. 147–155, 2016.
- [36] H. Yu, T. Xie, J. Xie, L. Ai, and H. Tian, "Characterization of key aroma compounds in Chinese rice wine using gas chromatography-mass spectrometry and gas chromatography-olfactometry," *Food Chemistry*, vol. 293, pp. 8–14, 2019.
- [37] Z. Wei, X. Liu, Y. Huang, J. Lu, and Y. Zhang, "Volatile aroma compounds in wines from Chinese wild/hybrid species," *Journal of Food Biochemistry*, vol. 43, no. 10, Article ID e12684, 2019.
- [38] L. D. Falcao, G. Lytra, P. Darriet, and J.-C. Barbe, "Identification of ethyl 2-hydroxy-4-methylpentanoate in red wines, a compound involved in blackberry aroma," *Food Chemistry*, vol. 132, no. 1, pp. 230–236, 2012.
- [39] R. Baumes, R. Cordonnier, S. Nitz, and F. Drawert, "Identification and determination of volatile constituents in wines from different vine cultivars," *Journal of the Science of Food and Agriculture*, vol. 37, no. 9, pp. 927–943, 1986.

- [40] T. E. Siebert, H. E. Smyth, D. L. Capone et al., "Stable isotope dilution analysis of wine fermentation products by HS-SPME-GC-MS," *Analytical and Bioanalytical Chemistry*, vol. 381, no. 4, pp. 937–947, 2005.
- [41] A. M. Molina, J. H. Swiegers, C. Varela, I. S. Pretorius, and E. Agosin, "Influence of wine fermentation temperature on the synthesis of yeast-derived volatile aroma compounds," *Applied Microbiology and Biotechnology*, vol. 77, no. 3, pp. 675–687, 2007.
- [42] J. H. Swiegers, R. L. Kievit, T. Siebert et al., "The influence of yeast on the aroma of Sauvignon Blanc wine," *Food Microbiology*, vol. 26, no. 2, pp. 204–211, 2009.
- [43] M. Cameleyre, G. Lytra, S. Tempere, and J. C. Barbe, "2-Methylbutyl acetate in wines: enantiomeric distribution and sensory impact on red wine fruity aroma," *Food Chemistry*, vol. 237, pp. 364–371, 2017.
- [44] P. Ribéreau-Gayon, Y. Glories, A. Maujean, and D. Dubourdieu, "Alcohols and other volatile compounds," *Handbook of Enology*, vol. 2, pp. 41–54, 2006.
- [45] J. Röcker, S. Strub, K. Ebert, and M. Grossmann, "Usage of different aerobic non-Saccharomyces yeasts and experimental conditions as a tool for reducing the potential ethanol content in wines," *European Food Research and Technology*, vol. 242, no. 12, pp. 2051–2070, 2016.
- [46] L. Nykänen and H. Suomalainen, *Aroma of Beer, Wine and Distilled Alcoholic Beverages*, Vol. 3, Springer Science & Business Media, Berlin, Germany, 1983.
- [47] S. Selli, T. Cabaroglu, A. Canbas et al., "Volatile composition of red wine from cv. Kalecik Karası grown in central Anatolia," *Food Chemistry*, vol. 85, no. 2, pp. 207–213, 2004.
- [48] J. M. Wang and J. X. Zhang, "Research progress on the origin and formation of wine aroma," *China Brewing*, vol. 5, pp. 5–9, 2014.
- [49] I. Andújar-Ortiz, C. Chaya, P. J. Martín-Álvarez, M. V. Moreno-Arribas, and M. A. Pozo-Bayón, "Impact of using new commercial glutathione enriched inactive dry yeast oenological preparations on the aroma and sensory properties of wines," *International Journal of Food Properties*, vol. 17, no. 5, pp. 987–1001, 2014.
- [50] W. Zhu, B. Zhu, Y. Li, Y. Zhang, B. Zhang, and J. Fan, "Acidic electrolyzed water efficiently improves the flavour of persimmon (*Diospyros kaki* L. cv. Mopan) wine," *Food Chemistry*, vol. 197, pp. 141–149, 2016.
- [51] M. T. Liberatore, S. Pati, M. A. Del Nobile, and E. La Notte, "Aroma quality improvement of Chardonnay white wine by fermentation and ageing in barrique on lees," *Food Research International*, vol. 43, no. 4, pp. 996–1002, 2010.
- [52] M. Zhang, Q. Xu, C. Duan, W. Qu, and Y. Wu, "Comparative study of aromatic compounds in young red wines from Cabernet Sauvignon, Cabernet Franc, and Cabernet Gernischt varieties in China," *Journal of Food Science*, vol. 72, no. 5, pp. C248–C252, 2007.
- [53] Y. N. He, P. F. Ning, T. X. Yue, and Z. W. Zhang, "Volatile profiles of Cabernet Gernischt wine under rain-shelter cultivation and open-field cultivation using solid-phase micro-extraction-gas chromatography/mass spectrometry," *International Journal of Food Properties*, vol. 20, no. 10, pp. 2181–2196, 2017.
- [54] Y. Wang, C. Zhang, J. Li, and Y. Xu, "Different influences of β -glucosidases on volatile compounds and anthocyanins of Cabernet Gernischt and possible reason," *Food Chemistry*, vol. 140, no. 1–2, pp. 245–254, 2013.
- [55] D. Chen and S. Q. Liu, "Chemical and volatile composition of lychee wines fermented with four commercial *Saccharomyces cerevisiae* yeast strains," *International Journal of Food Science and Technology*, vol. 49, no. 2, pp. 521–530, 2014.
- [56] L. J. Nan, M. R. Guo, S. B. Chen et al., "Effect of peduncle on aroma of cabernet sauvignon dry red wine," *AIP Publishing*, vol. 2079, no. 1, Article ID 020008, 2019.
- [57] R. B. Boulton, V. L. Singleton, L. F. Bisson, and R. E. Kunkee, *Principles and Practices of Winemaking*, Springer Science & Business Media, Berlin, Germany, 2013.
- [58] E. Falqué, E. Fernández, and D. Dubourdieu, "Differentiation of white wines by their aromatic index," *Talanta*, vol. 54, no. 2, pp. 271–281, 2001.
- [59] T. M. Granato, P. Ferranti, S. Iametti, and F. Bonomi, "Affinity and selectivity of plant proteins for red wine components relevant to color and aroma traits," *Food Chemistry*, vol. 256, pp. 235–243, 2018.
- [60] J. S. Jung, "Analysis of volatile compounds in the root peel, stem peel, and fruit peel of pomegranate (*Punica granatum*) by TD GC/MS," *International Journal of Bio-Science and Bio-Technology*, vol. 6, pp. 169–181, 2014.
- [61] C. Varela, D. Torrea, S. A. Schmidt, C. Ancin-Azpilicueta, and P. A. Henschke, "Effect of oxygen and lipid supplementation on the volatile composition of chemically defined medium and Chardonnay wine fermented with *Saccharomyces cerevisiae*," *Food Chemistry*, vol. 135, no. 4, pp. 2863–2871, 2012.
- [62] A. Bertrand and V. Torres-Alegre, "Incidence de L'action de L'oxygène sur la formation des produits secondaires de la fermentation alcoolique du moût de raisin," *Sciences des aliments*, vol. 4, no. 1, pp. 45–64, 1984.
- [63] A. Gutiérrez, R. Chiva, and J. M. Guillamón, "Arginine addition in the stationary phase influences the fermentation rate and synthesis of aroma compounds in a synthetic must fermented by three commercial wine strains," *LWT-food Science and Technology*, vol. 60, no. 2, pp. 1009–1016, 2015.
- [64] D. Chen, J. Y. Chia, and S. Q. Liu, "Impact of addition of aromatic amino acids on non-volatile and volatile compounds in lychee wine fermented with *Saccharomyces cerevisiae* MERIT. ferm." *International Journal of Food Microbiology*, vol. 170, pp. 12–20, 2014.
- [65] F. M. Carrau, K. Medina, L. Farina, E. Boido, P. A. Henschke, and E. Dellacassa, "Production of fermentation aroma compounds by *Saccharomyces cerevisiae* wine yeasts: effects of yeast assimilable nitrogen on two model strains," *FEMS Yeast Research*, vol. 8, no. 7, pp. 1196–1207, 2008.
- [66] M. Shiraiishi, H. Fujishima, and H. Chijiwa, "Evaluation of table grape genetic resources for sugar, organic acid, and amino acid composition of berries," *Euphytica*, vol. 174, no. 1, pp. 1–13, 2010.
- [67] L. Niu, K. Nomura, H. Iwahashi et al., "Urea cycle is enhanced by petit-high pressure carbon dioxide stress in yeast *Saccharomyces cerevisiae*," *High Pressure Research*, vol. 37, no. 1, pp. 70–77, 2017.
- [68] P. R. Lee, B. Yu, P. Curran, and S. Q. Liu, "Impact of amino acid addition on aroma compounds in papaya wine fermented with *Williopsis mrakii*," *South African Journal of Enology and Viticulture*, vol. 32, no. 2, pp. 220–228, 2011.
- [69] E. Point, P. Tyedmers, and C. Naugler, "Life cycle environmental impacts of wine production and consumption in Nova Scotia, Canada," *Journal of Cleaner Production*, vol. 27, pp. 11–20, 2012.
- [70] S. Pati, A. Mentana, E. La Notte, and M. A. Del Nobile, "Biodegradable poly-lactic acid package for the storage of

- carbonic maceration wine," *LWT-Food Science and Technology*, vol. 43, no. 10, pp. 1573–1579, 2010.
- [71] Z. Xiao, Z. Zhenwen, and M. Ning, "Investigation on the aroma of wines from four clones of Pinot Noir grapes," in *Proceedings of the Fifth International Symposium on Viticulture and Enology*, Yangling, China, April 2007.
- [72] S. L. Wang, L. P. Liu, L. X. Jiao, and M. T. Fan, "Volatile profile of sea buckthorn wines, raw juices and must in Qinghai (China)," *International Journal of Food Properties*, vol. 14, no. 4, pp. 776–785, 2011.
- [73] Y. Lan, J. Wu, X. Wang et al., "Evaluation of antioxidant capacity and flavor profile change of pomegranate wine during fermentation and aging process," *Food Chemistry*, vol. 232, pp. 777–787, 2017.
- [74] I. M. da Veiga Moreira, L. de Figueiredo Vilela, C. Santos, N. Lima, and R. F. Schwan, "Volatile compounds and protein profiles analyses of fermented cocoa beans and chocolates from different hybrids cultivated in Brazil," *Food Research International*, vol. 109, pp. 196–203, 2018.
- [75] Y. F. Collins, P. L. McSweeney, and M. G. Wilkinson, "Lipolysis and free fatty acid catabolism in cheese: a review of current knowledge," *International Dairy Journal*, vol. 13, no. 11, pp. 841–866, 2003.
- [76] A. Ahhmed, C. Özcan, S. Karaman et al., "Utilization of fermented soybeans paste as flavoring lamination for Turkish dry-cured meat," *Meat Science*, vol. 127, pp. 35–44, 2017.
- [77] D. T. Mannion, A. Furey, and K. N. Kilcawley, "Free fatty acids quantification in dairy products," *International Journal of Dairy Technology*, vol. 69, no. 1, pp. 1–12, 2016.
- [78] G. H. Peralta, I. V. Wolf, M. C. Perotti, C. V. Bergamini, and E. R. Hynes, "Formation of volatile compounds, peptidolysis and carbohydrate fermentation by mesophilic lactobacilli and streptococci cultures in a cheese extract," *Dairy Science & Technology*, vol. 96, no. 5, pp. 603–621, 2016.
- [79] Y. Deng, Y. Zhong, W. Yu et al., "Effect of hydrostatic high pressure pretreatment on flavor volatile profile of cooked rice," *Journal of Cereal Science*, vol. 58, no. 3, pp. 479–487, 2013.
- [80] J. A. Pino and C. E. Quijano, "Study of the volatile compounds from plum (*Prunus domestica* L. cv. Horvin) and estimation of their contribution to the fruit aroma," *Food Science and Technology*, vol. 32, no. 1, pp. 76–83, 2012.
- [81] F. J. Delgado, J. González-Crespo, R. Cava, J. García-Parra, and R. Ramírez, "Characterisation by SPME-GC-MS of the volatile profile of a Spanish soft cheese PDO Torta del Casar during ripening," *Food Chemistry*, vol. 118, no. 1, pp. 182–189, 2010.
- [82] T. H. Smouse and S. S. Chang, "A systematic characterization of the reversion flavor of soybean oil," *Journal of the American Oil Chemists' Society*, vol. 44, no. 8, pp. 509–514, 1967.
- [83] A. Giri, K. Osako, and T. Ohshima, "Identification and characterisation of headspace volatiles of fish miso, a Japanese fish meat based fermented paste, with special emphasis on effect of fish species and meat washing," *Food Chemistry*, vol. 120, no. 2, pp. 621–631, 2010.
- [84] L. Zhang, R. Zhou, R. Cui, J. Huang, and C. Wu, "Characterizing soy sauce moromi manufactured by high-salt dilute-state and low-salt solid-state fermentation using multiphase analyzing methods," *Journal of Food Science*, vol. 81, no. 11, pp. C2639–C2646, 2016.
- [85] L. Moio, P. Piombino, and F. Addeo, "Odour-impact compounds of Gorgonzola cheese," *Journal of Dairy Research*, vol. 67, no. 2, pp. 273–285, 2000.
- [86] S. Fors, "Sensory properties of volatile Maillard reaction products and related compounds: a literature review," *The Maillard Reaction in Foods and Nutrition*, vol. 215, pp. 185–286, 1983.
- [87] Y. R. Song, D. Y. Jeong, and S. H. Baik, "Monitoring of yeast communities and volatile flavor changes during traditional Korean soy sauce fermentation," *Journal of Food Science*, vol. 80, no. 9, pp. M2005–M2014, 2015.
- [88] Y. Cao, G. Xie, C. Wu, and J. Lu, "A study on characteristic flavor compounds in traditional Chinese rice wine-Guyue Longshan rice wine," *Journal of the Institute of Brewing*, vol. 116, no. 2, pp. 182–189, 2010.
- [89] L. Culleré, V. Ferreira, and J. Cacho, "Analysis, occurrence and potential sensory significance of aliphatic aldehydes in white wines," *Food Chemistry*, vol. 127, no. 3, pp. 1397–1403, 2011.
- [90] J. P. Peter, "Observations on the use of 'empty' copper tubular capillary columns," *Journal of Chromatographic Science*, vol. 1, no. 6, pp. 17–19, 1963.
- [91] A. Escudero, E. Campo, L. Fariña, J. Cacho, and V. Ferreira, "Analytical characterization of the aroma of five premium red wines. Insights into the role of odor families and the concept of fruitiness of wines," *Journal of Agricultural and Food Chemistry*, vol. 55, no. 11, pp. 4501–4510, 2007.
- [92] L. Culleré, A. Escudero, J. P. Pérez-Trujillo, J. Cacho, and V. Ferreira, "2-Methyl-3-(methylthio) furan: a new odorant identified in different monovarietal red wines from the Canary Islands and aromatic profile of these wines," *Journal of Food Composition and Analysis*, vol. 21, no. 8, pp. 708–715, 2008.
- [93] J. P. Osborne, A. Dubé Morneau, and R. Mira de Orduna, "Degradation of free and sulfur-dioxide-bound acetaldehyde by malolactic lactic acid bacteria in white wine," *Journal of Applied Microbiology*, vol. 101, no. 2, pp. 474–479, 2006.
- [94] S. J. Choi, J. K. Kim, H. K. Kim et al., "2, 4-Di-tert-butylphenol from sweet potato protects against oxidative stress in PC12 cells and in mice," *Journal of Medicinal Food*, vol. 16, no. 11, pp. 977–983, 2013.
- [95] P. Kusch, S. Deininger, S. Specht et al., "In vitro and in vivo antimalarial activity assays of seeds from *Balanites aegyptiaca*: compounds of the extract show growth inhibition and activity against plasmodial aminopeptidase," *Journal of Parasitology Research*, vol. 2011, Article ID 368692, , 2011.
- [96] P. Sangmanee and T. Hongpattarakere, "Inhibitory of multiple antifungal components produced by *Lactobacillus plantarum* K35 on growth, aflatoxin production and ultra-structure alterations of *Aspergillus flavus* and *Aspergillus parasiticus*," *Food Control*, vol. 40, pp. 224–233, 2014.
- [97] H. Guth, "Identification of character impact odorants of different white wine varieties," *Journal of Agricultural and Food Chemistry*, vol. 45, no. 8, pp. 3022–3026, 1997.
- [98] M. Begala, L. Corda, G. Podda, M. A. Fedrigo, and P. Traldi, "Headspace solid-phase microextraction gas chromatography/mass spectrometry in the analysis of the aroma constituents of 'Cannonau of Jerzu' wine," *Rapid Communications in Mass Spectrometry*, vol. 16, no. 11, pp. 1086–1091, 2002.
- [99] E. Demole, P. Enggist, U. Säuberli, M. Stoll, and E. S. Kováts, "Structure et synthèse de la damascénone (triméthyl-2, 6, 6-trans-crotonoyl-1-cyclohexadiène-1, 3), constituant odorant de l'essence de rose bulgare (rosa damascena mill)," *Helvetica Chimica Acta*, vol. 53, no. 3, pp. 541–551, 1970.

- [100] P. Schreier and F. Drawert, "Gaschromatographisch-massenspektrometrische Untersuchung flüchtiger Inhaltsstoffe des Weines," *Zeitschrift für Lebensmittel-Untersuchung und Forschung*, vol. 154, no. 5, pp. 273–278, 1974.
- [101] Y. Wang, C. Finn, and M. C. Qian, "Impact of growing environment on Chickasaw blackberry (*Rubus L.*) aroma evaluated by gas chromatography olfactometry dilution analysis," *Journal of Agricultural and Food Chemistry*, vol. 53, no. 9, pp. 3563–3571, 2005.
- [102] I. Sabon, G. de Revel, Y. Kotseridis, and A. Bertrand, "Determination of volatile compounds in Grenache wines in relation with different terroirs in the Rhone Valley," *Journal of Agricultural and Food Chemistry*, vol. 50, no. 22, pp. 6341–6345, 2002.
- [103] M. M. Mendes-Pinto, "Carotenoid breakdown products the norisoprenoids-in wine aroma," *Archives of Biochemistry and Biophysics*, vol. 483, no. 2, pp. 236–245, 2009.
- [104] B. Pineau, J. C. Barbe, C. Van Leeuwen, and D. Dubourdieu, "Which impact for β -damascenone on red wines aroma?" *Journal of Agricultural and Food Chemistry*, vol. 55, no. 10, pp. 4103–4108, 2007.
- [105] M. Aznar, R. López, J. Cacho, and V. Ferreira, "Prediction of aged red wine aroma properties from aroma chemical composition. Partial least squares regression models," *Journal of Agricultural and Food Chemistry*, vol. 51, no. 9, pp. 2700–2707, 2003.
- [106] M. A. Sefton, I. L. Francis, and P. J. Williams, "Volatile norisoprenoid compounds as constituents of oak woods used in wine and spirit maturation," *Journal of Agricultural and Food Chemistry*, vol. 38, no. 11, pp. 2045–2049, 1990.
- [107] M. Hudaib, E. Speroni, A. M. Di Pietra, and V. Cavrini, "GC/MS evaluation of thyme (*Thymus vulgaris L.*) oil composition and variations during the vegetative cycle," *Journal of Pharmaceutical and Biomedical Analysis*, vol. 29, no. 4, pp. 691–700, 2002.
- [108] D. Mnayer, A. S. Fabiano-Tixier, E. Petitcolas, K. Ruiz, T. Hamieh, and F. Chemat, "Extraction of green absolute from thyme using ultrasound and sunflower oil," *Resource-Efficient Technologies*, vol. 3, no. 1, pp. 12–21, 2017.
- [109] S. Bogdanov, V. Kilchenmann, P. Fluri, U. Bühler, and P. Lavanchy, "Influence of organic acids and components of essential oils on honey taste," *American Bee Journal*, vol. 139, no. 1, pp. 61–63, 1999.