ISSN(Print) : 1738-7248, ISSN(Online) : 2287-7428
Korean J. Food Preserv.
25(2), 165-172 (2018)
https://doi.org/10.11002/kjfp.2018.25.2.165

사단법인 한국식품저장유통학회
The Korean Society of Food Preservation

Comparison of volatile compounds in juices and wines of white grape cultivars Cheongsoo, Chardonnay, and Riesling

Hyun Il Kim, Youn Young Hur, Sung Min Jung, Dong Jun Im, Su Jin Kim*
Fruit Research Division, National Institute of Horticultural and Herbal Science, Wanju 55365, Korea

화이트 와인 품종 청수, 샤르도네, 리슬링의 주스 및 와인의 향기성분 비교

김현일 · 허윤영 · 정성민 · 임동준 · 김수진*
국립원예특작과학원 과수과

Abstract

The study compared the juice and wine odorants of the Cheongsoo grape cultivar with those of Chardonnay and Reisling wines. The volatile compounds of the three grape varieties were analyzed using headspace solid-phase microextraction coupled with gas chromatography-mass spectrometry. The most common volatile compounds in the juices from the three cultivars were terpenes, C_{13}-norisoprenoids, etones, alcohols, and aldehydes. Terpenes were established as the most abundant group of volatiles in Cheongsoo grape juice, where as aldehydes predominated in Chardonnay and Riesling juices. Forty-two volatile compounds (acids, alcohols, esters, and others) were detected in the three white wines. The concentration of esters was about four times higher in Cheongsoo wine than in Chardonnay and Riesling wines. Five esters found in the Cheongsoo wine, namely, isoamyl acetate, ethyl butanoate, ethyl hexanoate, ethyl octanoate, and ethyl decanoate, exhibited high odor activity values (OAV) of >1. Furthermore, only Cheongsoo wine had a high OAV for isoamyl acetate odorant, which is associated with banana and sweet aromas. Therefore, the abundant and varied esters are believed to be key volatile fruity/sweet odorants in Cheongsoo wine.

Key words : Cheongsoo, volatile compounds, headspace-solid phase microextraction, gas chromatography-mass spectrometry

Introduction

Production of high quality wines requires the cultivation of wine-exclusive grape varieties with excellent wine-specific properties such as high sugar content, appropriate acid content and good flavor. In particular, wine aroma is one of the most important factors to determine the character and quality of wine. Wine flavors dependent on the presence of aromatic compounds originating from grapes, the fermentation process, ageing, and storage. Wine volatiles include as many as 800 different compounds detected thus far, represented mainly by alcohols, esters, aldehydes and ketones (1). Grape volatiles include a great number of compounds, among which monoterpenes, C_{13}-norisoprenoids, alcohols, esters and carbonyls represent some of the main groups (2). The profile of volatile compounds in wine depends on many factors such as geographical origin, grape variety, vintage, as well as growing conditions (3-8). The great variety of volatile compounds, all with different polarities, volatilities and a wide range of concentrations, are responsible for the complexity of wine bouquet and ensure the specific character of different varietals (9). The role of these volatile compounds is related to their odor perception threshold, i.e. the concentration / threshold ratio, known as the odor activity value (OAV) that enables

*Corresponding author. E-mail : himssem@korea.kr
Phone : 82-63-238-6750, Fax : 82-63-238-6705
Received 2 February 2018; Revised 21 February 2018; Accepted 16 March 2018.

us to estimate the contribution of volatile compounds found in grapes and wines (10).

Cultivars of *Vitis vinifera* form the basis of most wines produced around the world. The *V. vinifera* cultivar Chardonnay is renowned for the production of high-quality French white wines and champagne (11). Riesling is the second most widely planted aromatic variety of white wine grapes, and is used to produce varietal wines with aroma attributes that include stone fruits, flowers and wet stones (12). The majority of wine-only varieties introduced in Korea are *V. vinifera* species that usually winter kill at around -2 to -3℃ (13). Additionally, *V. vinifera* is not suitable for hot and humid summer environment, which results in poor quality grapes. However, rainfall in the Republic of Korea exceeds 1,000 mm a year, with almost half of this quantity falling during June and July. Further, the lowest temperature in Korea during the period 2000-2016 was -21.6℃ (14). As a consequence, the *V. vinifera* cultivars have to be cultivated in greenhouses in order to avoid winterkill in Korea. Therefore, new wine cultivars are in high demand in Korea.

Cheongsoo grape variety was produced as a plant cross between Seibel 9110 and Himrod Seedless grape varieties at the National Institute of Horticultural and Herbal Science (NIHHS) in Korea in 1993. Cheongsoo is a highly appreciated grape variety with a golden color and a pleasant fruit flavor. In addition, Cheongsoo is resistant to winter cold and mildew (15). In a previous study, the changes in volatile compounds in Cheongsoo wine were analysed at different stages of ripening (16). Cheongsoo wine was found to possess a high content of ester compounds that give rise to strong sweet flavors such as pineapple, banana and pear. However, the differences between Cheongsoo and other white wine varietals produced from grapes grown in Korea have not been analysed to date. Therefore, in order to understand the volatile characteristics of Cheongsoo grapes, it is necessary to compare it with renowned white grape varieties such as Chardonnay and Riesling. Therefore, the objectives of the present study were to identify the volatile compounds present in grapes and wine produced from three white wine grape varietals Cheongsoo, Chardonnay and Riesling using headspace-solid phase microextraction (HS-SPME) coupled with gas chromatography-mass spectrometry (GC-MS).

Materials and Methods

Reagents

Sodium chloride (NaCl) and 4-nonanol were purchased from Sigma-Aldrich Korea Ltd. (St. Louis, MO, USA). Calcium chloride ($CaCl_2$) was purchased from Kanto Chemical Co., INC. (Tokyo, Japan). All reagents used were of analytical grade.

Plant material

Three grape cultivars, Cheongsoo, Chardonnay, and Riesling were cultivated in the orchards at the National Institute of Horticultural and Herbal Science in Korea. Cheongsoo Chardonnay and Riesling Grapes were harvested on 23 August, 25 August and 31 August, 2016, respectively. All samples were frozen at -20℃ prior to analysis. Before isolating the volatile compounds, the grape samples were defrosted at 5℃ under nitrogen atmosphere.

Winemaking procedure

The wine making process followed a modified Chang's method (16) and micro-vinification method. Grapes were removed from grape bunches and potassium metabisulfite ($K_2S_2O_5$) was added at a concentration of 200 mg/kg. Before fermentation, grape (500 g) must was adjusted to 22 °Brix using table sugar. Five hours after the addition of potassium metabisulfite, active yeasts were inoculated into grape must at a ratio of 0.02% (w/w). The yeast strain, *Saccharomyces bayanus* (EC-1118;Canada) was used for fermentation in all winemaking processes. The grapes were first fermented for two weeks at a constant temperature of 15℃ in a 750 mL DURAN® laboratory bottle equipped with an airlock. After the initial fermentation, the fermented residual sugar and sediment were isolated from wine. The isolated wine was subjected to a second round of fermentation at a constant temperature of 15℃ for 1 week, after which the prepared wine samples were analysed.

HS-SPME conditions

A SPME fiber coated with divinylbenzene/carboxen/polydimethylsiloxane (50/30 μm, DVB/CAR/PDMS) (Supelco, Bellefonte, PA, USA) was used for the analysis owing to its high sensitivity for odorants and good reproducibility in grapes (17). Samples of grape berries (50 g) with $CaCl_2$ (1 g) were defrosted and homogenised using a commercial blender. $CaCl_2$ was added to inhibit enzyme activity prior to crushing (18). The homogenized samples were clarified by centrifugation at 2,700 ×*g* for 10 min at 4℃. A sample of the supernatant (25 mL) or fermentation-finished wine (25 mL) was transferred into a capped 50 mL solid-phase microextraction vial, and 3 g of NaCl and 20 μL of internal standard (4-nonanol in EtOH, 1 mg/mL) were added. Samples were heated at 70℃ in an automated heating block (Wise Therm®, HB-48P). After 20 min of equilibration, the SPME fiber was manually inserted into the sample vial headspace. After 20 min, the fiber was withdrawn and introduced into the GC injection port for desorption at 250℃ and maintained for 10 min in splitless mode. Samples of three different batches of grapes were examined in triplicate. All samples were examined in triplicate.

GC-MS analysis

An Agilent gas chromatograph model 6890N coupled to an Agilent 5975 series mass selective detector (Agilent technologies, Santa Clara, CA, USA) was used to perform the analysis. Volatile compounds were separated on an HP-INNOWAX capillary column (30 m×0.32 mm×0.25 μm; Agilent technologies), with purified helium as the carrier gas, at a constant flow rate of 2 mL/min. Desorption of the DVB/CAR/PDMS fiber was carried out for 10 min in the GC injection port at 250℃. The oven temperature was held at 40℃ for 5 min, increased to 220℃ at a rate of 3℃/min and finally held at 220℃ for 5 min. The injector and source temperature were set at 250℃ and 230℃, respectively. The mass detector was operated in electron impact ionization mode at a voltage of 70 eV, with the range set at 50-700 m/z. Selected GC-MS peaks were identified based on the comparison of mass spectra with the NIST11 (Agilent, Gaithersburg, MD, USA) mass spectral database. Content of all compounds was quantified relative to the known concentration of 4-nonanol internal standard.

Statistical analysis

A one-way analysis of variance (ANOVA) was performed to identify statistically significant differences between samples. A principal components analysis (PCA) was performed to evaluate and perform a reduction in the number of attributes to a smaller set of underlying variables based on patterns of correlations between original variables. The R Commander (version 2.13.0, A Basic-Statistics GUI for R statistical software package; McMaster University, Ontario, Canada) was employed for this analysis where statistical significance was defined as $p<0.05$.

Results and Discussion

Volatile composition of grape berries

The major volatile compounds found in the juice extracted from the three grape berries were terpenes, C_{13}-norisoprenoids, ketones, alcohols and aldehydes (Fig. 1). However, the % content of the various volatile compounds varied as a function of grape cultivar. The most abundant volatiles in Cheongsoo grapes were terpene compounds, while aldehydes predominated in Chardonnay and Riesling grapes. Terpenes are known to play an important role in grape berries as they are responsible for the floral notes of aromatic grape varieties such as Gewürztraminer, Sauvignon Blanc and the Muscat family (19-21). Currently, about 50 monoterpene compounds that occur in grapes and wines most commonly have been identified (22). Free and bound glycoside terpenes can be found in grapes. Specifically, odorless precursors (bound fraction) present in grapes are transformed into odor-active forms (free fraction) during the winemaking process (23). Therefore, quantification of bound glycosides can be used as a useful index by winemakers for the determination of wine aroma and character (22). Recently, it has been reported that diendiol II (3,7-dimethylocta-1,7-dien-3,6-diol) is generated enzymatically from linalool in grape berries (24). However, the biosynthesis and oxidative transformation of monoterpenes in grapes remain largely unexplored in spite of their importance as a volatile wine compounds. Taking into consideration of the high content of terpene, Cheongsoo wine possesses quite a strong characteristic aroma compared to Chardonnay and Riesling wines.

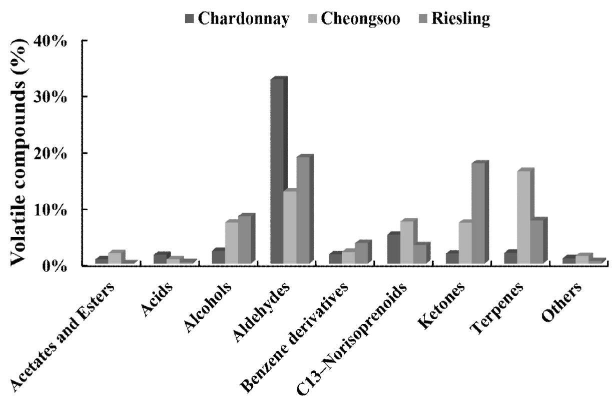

Fig. 1. The % content of different groups of volatile compounds detected as a function of grape cultivar.

Volatile composition of wines

PCA based on GC-MS data was performed to compare the content of volatile compounds as a function of grape cultivar (Fig. 2). PCA is a powerful tool for the interpretation of multivariate statistical analysis. The three white wines examined in this study were found to adopt three overlapping, yet distinct zones. Cheongsoo wine was identified by the presence of isoamyl acetate, ethyl hexanoate, ethyl octanoate and ethyl decanoate. In contrast, Chardonnay wine was distinguished by the ethyl heptanoate, methyl-2-hydroxybenxoate, 3-hexen-1-ol and 1-heptanol content. Finally, Riesling wine was categorised by 2-methyl-hexanoic acid, trans-(2-chlorovinyl)methyldiethoxysilane and 1,1,6,-trimethyl-1,2-dihydronapthalene (TDN).

powerful odorants and key fermentation volatiles of Zalema white wine, 52 young red wines and *Vitis vinifera* cv. Pinotage and Sake (10,25-27). The esters produced enzymatically during yeast fermentation are the most important group of aromatic compounds in wines. In particular, ethyl esters formed from medium-chain fatty acids are responsible for the fruity character of fermented beverages, and thus constitute a vital group of aromatic compounds in both wine and beer (28,29). In our results, ethyl hexanoate and ethyl octanoate exhibited a high OAV of >1 in all three wines

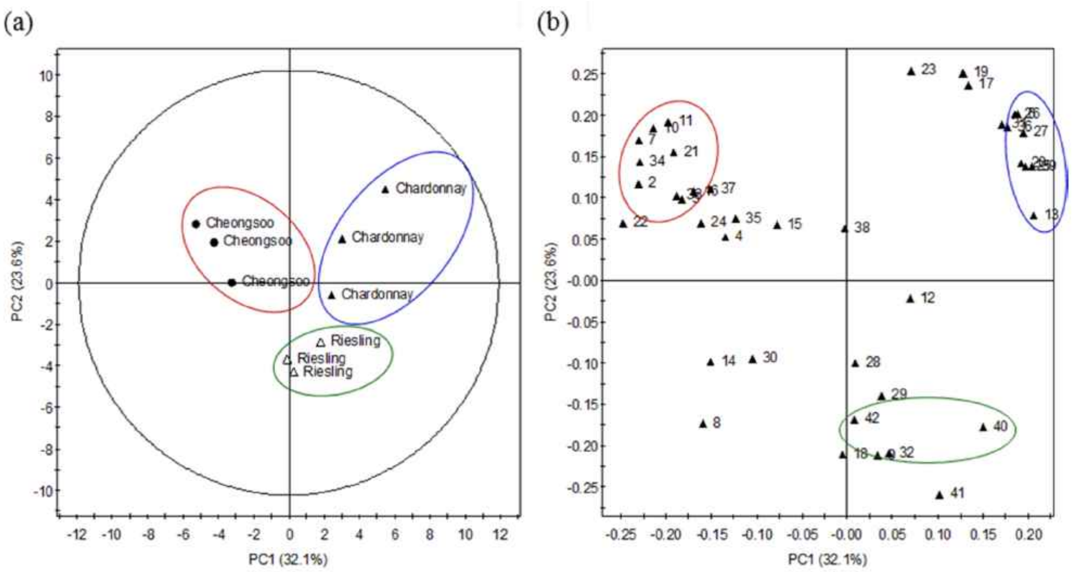

Fig. 2. PC1 *vs.* PC2 scatter plot of the main sources of variability between Cheongsoo, Chardonnay and Riesling white wine varietals, where (a) shows the distinction between different wines (n=3) and (b) the relationship between the 42 volatile compounds* detected.

*Numbers in (b) represent: 1, ethyl acetate; 2, isoamyl acetate; 3, hexyl acetate; 4, ethyl butanoate; 5, ethyl hexanoate; 6, ethyl heptanoate; 7, ethyl octanoate; 8, methyl formate; 9, hexyl propionate; 10, ethyl decanoate; 11, ethyl *trans*-4-decenoate; 12, ethyl-9-decenoate; 13, methyl-2-hydroxybenxoate; 14, methyl N-hydroxybenzenecarboximidoate; 15, phenethyl acetate; 16, ethyl dodecanoate; 17, 1-propanol; 18, isobutyl alcohol; 19, 1-butanol; 20, isoamyl alcohol; 21, isohexyl alcohol; 22, 3-ethyl-1-butanol; 23, 1-hexanol; 24, (E)-3-hexen-1-ol; 25, 3-hexen-1-ol; 26, 3-ethoxy-1-propanol; 27, 1-heptanol; 28, (+)-1,3-butanediol; 29, 3-(methylthio)-1-propanol; 30, 2-phenylethanol; 31, 2-methyl-octanoic acid; 32, 2-methyl-hexanoic acid; 33, hexanoic acid; 34, octanoic acid; 35, n-decanoic acid; 36, benzaldehyde; 37, α-ionene; 38, ethyldihydroxyborane; 39, benzyol bromide; 40, trans-(2-chlorovinyl) methyldiethoxysilane; 41, vanillin; *tert*-butyldimethylsilyl ether; 42, 1,1,6,-trimethyl-1,2-dihydronapthalene (TDN).

In the present study, 16 ester volatile compounds were detected in three white wine varietals (Table 1). The concentration of esters was about four times higher in Cheongsoo than in Chardonnay and Riesling wines. Five esters found in Cheongsoo wine, namely isoamyl acetate, ethyl butanoate, ethyl hexanoate, ethyl octanoate and ethyl decanoate, exhibited a high OAV of >1. In contrast, only four and two esters displayed a high OAV (>1) in Chardonnay and Riesling wines, respectively. Additionally, the isoamyl acetate (OAV=16.28) odorant associated with banana and sweet aroma, was detected only in Cheongsoo wine. In several studies, isoamyl acetate was one of the esters that contribute most significantly to the aroma profile of white and red wines. This compound was also considered to be one of the most

(Table 1). However, the concentration of ethyl hexanoate in Cheongsoo wine was about six and three times higher than its content in Chardonnay and Riesling wines, respectively. Furthermore, the concentration of ethyl octanoate was about five and eight times higher in Cheongsoo wine than in Chardonnay and Riesling wines. While ethyl decanoate was detected in all white wines examined, it exhibited a high OAV of >1 only in Cheongsoo wine. In contrast, ethyl butanoate, which displayed an OAV of above 1 was detected in both Cheongsoo and Chardonnay wines. Finally, ethyl heptanoate was detected with a high OAV (>1) only in Chardonnay wine. In summary, five esters were found to be the predominant fruity and sweet volatile odorant compounds in Cheongsoo wine.

Table 1. Esters detected in Cheongsoo, Chardonnay and Riesling white wines

	Compounds	CAS[1)]	RT[2)]	Cheongsoo		Chardonnay		Riesling		OTV[5)] (μg/L)	Odor descriptor
				Conc.[3)] (μg/L)	OAV[4)]	Conc. (μg/L)	OAV	Conc. (μg/L)	OAV		
	Esters										
1	Ethyl Acetate	141-78-6	2.306	0.00[a6)]	-[7)]	226.61[a]	<1	0.00[a]	-	12,000[y]	pineapple
2	Isoamyl acetate	123-92-2	7.093	488.28[a]	16.28	0.00[b]	-	0.00[b]	-	30[z]	banana, sweet
3	Hexyl acetate	142-92-7	12.372	153.66[a]	<1	16.08[b]	<1	0.00[b]	-	670[x]	fruity, pear
4	Ethyl butanoate	105-54-4	4.634	52.40[a]	2.62	95.08[a]	4.75	0.00[a]	-	20[z]	strawberry
5	Ethyl hexanoate	123-66-0	10.806	885.46[a]	110.68	140.91[b]	17.61	274.56[b]	34.32	8[y]	fruity, apple
6	Ethyl heptanoate	106-30-9	15.402	0.00[a]	-	3.18[a]	1.45	0.00[a]	-	2.2[y]	fruity, apple
7	Ethyl octanoate	106-32-1	19.198	2169.44[a]	433.89	397.22[b]	79.44	274.01[b]	54.80	5[z]	sweet, pear
8	Methyl formate	107-31-3	21.165	96.67[a]	-	36.49[a]	-	198.55[a]	-		
9	Hexyl propionate	2445-76-3	24.501	0.00[a]	-	0.00[a]	-	68.10[a]	-		
10	Ethyl decanoate	110-38-3	27.416	963.99[a]	4.82	185.77[b]	<1	51.42[b]	<1	200[z]	fruity, grape
11	Ethyl trans-4-decenoate	76649-16-6	29.406	100.33[a]	-	21.82[ab]	-	0.00[b]	-		
12	Ethyl 9-decenoate	67233-91-4	29.503	0.00[a]	-	6.97[a]	-	0.00[a]	-	100[y]	rose
13	Methyl 2-hydroxybenzoate	119-36-8	32.109	0.00[b]	-	8.95[a]	-	3.42[b]	-	Nf[8)]	minty, sweet
14	Methyl N-hydroxybenzenecarboximidoate	NIST[8)],222866	33.419	500.87[a]	-	171.25[a]	-	653.94[a]	-		
15	Phenethyl acetate	103-45-7	33.831	105.79[a]	-	63.81[a]	-	62.76[a]	-	250[w]	pleasant, floral
16	Ethyl dodecanoate	106-33-2	34.857	60.11[a]	-	0.00[a]	-	10.75[a]	-	3,500[y]	sweet, fruity
	Subtotal			5577.02		1374.14		1597.51			

[1)]CAS, chemical abstract service.
[2)]RT, retention time.
[3)]Conc., concentration.
[4)]OAV was calculated by dividing the concentration by odor threshold value of the compound.
[5)]OTV: [z]Ferreira et al., 2000 (27); [y]Welke et al., 2014 (32); [x]Jiang & Zhang, 2010(33); [w]Li et al., 2008 (34).
[6)]Different letters within each rows indicates statistical differences (n=3, p<0.05).
[7)]Not found.
[8)]National institute of standards and technology.

Fourteen alcohol volatile compounds were detected in three white wine varietals (Table 2). At a concentration of 6.0-10.5 mg/L, alcohols represented the largest group of volatile compounds in the three examined white wine varietals. Nevertheless, the influence of alcohols as odorants in wine was lower than those of esters as a result of their high odor threshold value (OTV). In fact, with the exception of 1-hexanol, the alcohols were detected lower than their OTVs in quantities. In addition, alcohols with six carbon atoms, which supply vegetal and herbaceous nuances to wine, usually exert a negative effect on wine quality when present at concentration above their OTV (30). In our work, 3-hexan-1-ol with an OAV <1 was detected in Chardonnay wine only, and can be thus used to distinguish Chardonnay wine from others.

Five acids and 7 other volatile compounds were detected in three white wine varietals (Table 3). C_6-C_{10} fatty acids at a concentration of 4 to 10 mg/L impart mild and pleasant aroma to wine. At levels beyond 20 mg/L, however, their impact on wine becomes negative (31). In this study, fatty acids were found to be present in the wine samples only in trace amounts. C_{13}-norisoprenoid components such as α-ionene were detected with high OAV (>1) only in Cheongsoo wine. In contrast, 2-methyl-hexanoic acid and TDN were detected in Riesling wine only. These volatile compounds may contribute to the distinction of Riesling wine from non-Riesling wines (12).

This is the first study comparing the volatile compounds found in white grape varieties grown in Korea. The obtained analytical results allowed us to determine the content of major volatile components in Cheongsoo, Chardonnay and Riesling grape cultivars. The differences detected in the content of volatile components were successfully used to distinguish grapes and wines associated with the three varietals. The

Table 2. Alcohol compounds detected in Cheongsoo, Chardonnay and Riesling white wines

	Compounds	CAS[1)]	RT[2)]	Cheongsoo		Chardonnay		Riesling		OTV[5)] (μg/L)	Odor descriptor
				Conc.[3)] (μg/L)	OAV[4)]	Conc. (μg/L)	OAV	Conc. (μg/L)	OAV		
	Alcohols										
17	1-Propanol	71-23-8	5.461	182.00[a6)]	<1	212.57[a]	<1	208.93[a]	<1	306,000[z]	ripe fruit
18	Isobutyl alcohol	78-83-1	7.520	32.87[a]	<1	0.00[b]	-[7)]	292.55[ab]	<1	75,000[z]	alcohol
19	1-Butanol	71-36-3	9.351	6.10[a]	<1	23.39[a]	<1	0.00[a]	-	150,000[z]	medicinal
20	Isoamyl alcohol	123-51-3	12.012	3,846.71[a]	<1	4,510.33[a]	<1	7,056.47[a]	<1	30,000[x]	harsh, bitter
21	Isohexyl alcohol	626-89-1	15.406	19.77[ab]	<1	2.31[a]	<1	0.00[b]	-	50,000[z]	almond
22	3-Ethyl-1-butanol	589-35-5	15.872	51.32[a]	-	16.70[b]	-	47.55[b]	-		
23	1-Hexanol	107-02-8	16.881	160.20[ab]	1.46	221.79[a]	2.02	179.33[b]	1.63	110[z]	herbaceous
24	(E)-3-Hexen-1-ol	928-97-2	17.267	7.35[a]	<1	0.00[a]	-	0.00[a]	-	400[y]	green, floral
25	3-Hexen-1-ol	544-12-7	17.354	0.00[b]	-	15.64[a]	-	0.00[b]	-		
26	3-Ethoxy-1-propanol	111-35-3	17.750	0.00[a]	-	6.11[a]	<1	0.00[a]	-	100[z]	fruity
27	1-Heptanol	111-70-6	20.828	3.46[b]	<1	36.80[a]	<1	2.84[b]	<1	1,000[y]	grape, sweet
28	(+)-1,3-Butanediol	24621-61-2	24.327	51.26[a]	-	70.75[a]	-	58.62[a]	-		
29	3-(Methylthio)-1-propanol	505-10-2	30.722	0.00[a]	-	5.15[a]	<1	8.84[a]	<1	500[y]	rubber
30	2-Phenylethanol	60-12-8	37.225	1,700.98[a]	<1	1,240.25[a]	<1	2,632.84[a]	<1	200,000[z]	rose, honey
	Subtotal			6,062.01		6,361.80		10,487.96			

[1)]CAS, chemical abstract service.
[2)]RT, retention time.
[3)]Conc., concentration.
[4)]OAV was calculated by dividing the concentration by odor threshold value of the compound.
[5)]OTV: [z]Welke et al., 2014 (32); [y]Jiang & Zhang, 2010(33); [x]Li et al., 2008 (34).
[6)]Different letters within each rows indicates statistical differences (n=3, p<0.05).
[7)]Not found.

Table 3. Acid and other compounds detected in Cheongsoo, Chardonnay and Riesling white wines

	Compounds	CAS[1)]	RT[2)]	Cheongsoo		Chardonnay		Riesling		OTV[5)] (μg/L)	Odor descriptor
				Conc.[3)] (μg/L)	OAV[4)]	Conc. (μg/L)	OAV	Conc. (μg/L)	OAV		
	Acids										
31	2-Methyl-octanoic acid	3004-93-1	29.411	0.00[a6)]	-[7)]	22.32[a]	-	0.00[a]	-		
32	2-Methyl-hexanoic acid	4536-23-6	29.536	0.00[a]	-	0.00[a]	-	53.49[a]	-		
33	Hexanoic acid	142-62-1	35.415	122.55[a]	<1	0.00[a]	-	0.00[a]	-	420[z]	cheese, fatty
34	Octanoic Acid	124-07-2	42.335	247.02[a]	<1	17.39[b]	<1	0.00[b]	<1	500[z]	fatty, rancid
35	n-Decanoic acid	334-48-5	48.704	7.74[a]	1.29	0.00[a]	-	0.00[a]	-	6[y]	fatty, rancid
	Subtotal			377.31		39.70		53.49			
	Others										
36	Benzaldehyde	100-52-7	23.041	0.00[a]	-	3.45[a]	<1	0.00[a]	-	2,000[y]	almond
37	α-Ionene	475-03-6	18.658	4.21[a]	1.62	0.00[a]	-	0.00[a]	-	2.6[z]	sweet, fruity
38	Ethyldihydroxyborane	4433-63-0	7.023	98.19[a]	-	76.95[a]	-	0.00[a]	-		
39	Benzoyl bromide	618-32-6	14.551	27.42[a]	-	69.91[a]	-	70.50[a]	-		
40	*trans*-(2-Chlorovinyl)methyldiethoxysilane	NIST[8)],139969	18.981	0.00[b]	-	28.50[ab]	-	118.91[a]	-		
41	Vanillin, tert-butyldimethylsilyl ether	NIST,352846	23.637	12.57[a]	-	17.61[a]	-	62.92[a]	-		
42	TDN	NIST,357258	30.957	0.00[a]	-	0.00[a]	-	19.44[a]	9.72	2[x]	kerosene
	Subtotal			142.39		196.43		271.78			

[1)]CAS, chemical abstract service.
[2)]RT, retention time.
[3)]Conc., concentration.
[4)]OAV was calculated by dividing the concentration by odor threshold value of the compound.
[5)]OTV: [z]Ferreira et al., 2000; [y]Welke et al., 2014; [x]Sacks et al., 2012.
[6)]Different letters within each rows indicates statistical differences (n=3, p<0.05).
[7)]Not found.
[8)]National institute of standards and technology.

concentration of terpenes, which are known to determine the wine aroma after fermentation, was found to be about eight and two times higher in Cheongsoo grapes than in Chardonnay and Riesling grapes, respectively. Furthermore, the quantity of odorants in Cheongsoo wine exceeded those found in Chardonnay and Riesling wines. In particular, esters such as isoamyl acetate, ethyl butanoate, ethyl hexanoate, ethyl octanoate and ethyl decanoate were detected in Cheongsoo wine with an OAV of >1. These ester components are key odorants in wine associated with fruity and sweet aroma. Therefore, we anticipate that Cheongsoo grape variety can be employed in Korea as a new wine grape for winemaking owing to its high content of sweet and fruity odorants.

요 약

본 연구는 청수 품종의 과실과 와인의 향기 성분을 주요 화이트 와인 품종인 샤르도네와 리슬링 품종과 비교하기 위해 향기성분을 headspace-solid phase microextraction 분석법으로 확인하였다. 세 포도 품종 모두 과실의 주된 향기의 구성 성분은 terpenes, C_{13}-norisoprenoids, ketones, alcohol과 aldehydes였다. 청수 품종의 과실에서는 향기성분 중 terpenes이 가장 많았으며 샤르도네와 리슬링 품종의 과실에서는 aldehydes의 함량이 높게 나타났다. 세 품종의 와인에서는 42 종류의 향기성분이 검출되었다. 청수 와인에서는 샤르도네와 리슬링 와인보다 ester의 함량이 약 4배 이상 높았으며 주된 ester 물질은 isoamyl acetate, ethyl butanoate, ethyl hexanoate, ethyl octanoate과 ethyl decanoate였으며 이 물질들은 OAV 값(odor activity value)이 1 이상으로 나타났다. 그 중에서 isoamyl acetate는 청수 와인에서만 확인된 물질로 odor descriptor가 바나나 향 및 달콤한 향을 나타낸다. 따라서 청수 와인의 과일 향과 달콤한 향은 다양하고 높은 ester 화합물 함량에 의한 것으로 판단된다.

Acknowledgment

This work was carried out with the support of the Cooperative Research Programme for Agriculture Science & Technology Development (Project No. 01272902), Rural Development Administration, Republic of Korea.

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