



Characteristics of aroma compounds of 11 red wines from international grape cultivars grown in Korea

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국내에서 재배된 세계 주요 와인 포도 품종으로 제조된 적포도주 11종의 향기 성분 특성

김현일 · 허윤영 · 정성민 · 임동준 · 정경호 · 김수진*

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Abstract

The aroma compounds of 11 red wines grown and produced in Wanju region were characterized by headspace-solid phase microextraction combined with gas chromatography-mass spectrometry. Seventy-five aroma compounds were identified in the 11 red wines. The aroma compounds were grouped into five aroma series and their odor activity values were calculated to determine the aroma impact compounds in 11 wines. Alcohols, esters and C₆ compounds were the main contributors to the aroma in the 11 wines. Isoamyl alcohol and phenylethyl alcohol obtained from the 11 red wines contributed to the floral, sweet, and fatty odorants in the wine. Octanoic acid ethyl ester, and hexanoic acid ethyl ester contributed to the fruity, floral, and sweet odorants of all the red wines. 1-Hexanol was detected all the wines, which contributed to the green odorant. The major aroma contribution of Chancellor, Malbec, Marchel, Narsha, Pinot Meunier, and Sangiovetto wines were the fruity series. The green series was the major contribution of the Cabernet Franc, Cabernet Sauvignon, and Sauvignon Vert wines. The floral series was the major contribution of the MBA and Narsha wines. Based on the results of these studies, aroma component analysis could be used as a selection criterion for developing wine cultivars.

Key words : aroma, headspace-solid phase microextraction, gas chromatography-mass spectrometry, red wine

Introduction

Wine aroma is one of the most important factors in determining wine character and quality. Wine aroma was determined by more than 1,300 volatile compounds, including alcohols, esters, acetates, acids, aldehydes, isoprenoids, lactones and ketones, with a wide concentration range (1). The aroma profiles are the results of complex interactions

among several factors: grape variety (2), vineyard geographical origin (3), soil and climate characteristics (4) and winemaking techniques (5). Wine aroma contents may be used as a tool for characterization and differentiation of wines from varieties and for establishing criteria to improve the quality of the wines. In particular, attention has been devoted recently to the analytical characterization and the quality improvement of the varietal aroma of wines. Previous studies have focused on the identification of volatile components and on the establishment of character impact odorants of different varieties (6-8).

Korean winemakers made wine using table grape cultivars, such as 'Campbell Early', 'Muscat Bailey A' and 'Kyoho' (9,10). Korea wines are produced using the most cultivated

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Campbell Early, however, these wines have the limitations of containing low levels of sugar, high malic acid concentration and negatively foxy aroma content (11). Therefore, development of wine cultivar with good wine aptitude and aroma is desperately required.

The present study was aimed to characterize aroma compounds of cultivated 11 wine grape cultivars to accumulate basic data for making red wine cultivars by aroma using headspace-solid phase microextraction (HS-SPME) combined with gas chromatography-mass spectrometry (GC-MS).

Materials and methods

Reagents

Benzyl alcohol, 1-heptanol, Isoamyl alcohol, phenylethyl alcohol, Isobutyl alcohol, benzaldehyde, acetic acid hexyl ester, hexadecanoic acid ethyl ester, 1-hexanol, α -terpineol, 4-nonanol and sodium chloride (NaCl) were purchased from Sigma-Aldrich Korea Ltd. (Seoul, Korea). Fatty acid ethyl esters were purchased from Sigma-Aldrich Korea Ltd. (Supelco, Seoul, Korea). Calcium chloride (CaCl_2) was purchased from Kanto Chemical Co., INC. (Tokyo, Japan). All used reagents were analytical grade.

Plant material

Eleven grape cultivars, Cabernat Franc, Cabernet Sauvignon, Chancellor, Malbec, Marchel, MBA, Merlot, Narsha, Pinot Meunier, Sangiovetto and Sauvignon Vert were obtained from experimental vineyards of the National Institute of Horticultural and Herbal Science, Wanju, Korea. All grape varieties used for winemaking were harvested at August in 2016. Samples were frozen at -20°C prior to analysis.

Winemaking procedure

The winemaking process followed a modified Chang's method (12) and micro-vinification method. Grapes were removed from grape bunches and potassium metabisulfite ($\text{K}_2\text{S}_2\text{O}_5$) was added at a concentration of 200 mg kg^{-1} . Before fermentation, grape must (800 g) was adjusted to 22°Brix using table sugar. Five hours after the addition of potassium metabisulfite, active yeasts were inoculated into grape at a ratio of 0.02% (w/w). The yeast strain *Saccharomyces cerevisiae* (Fermivin, France) was used for fermentation in all winemaking processes. The grapes were first fermented for two weeks at a constant temperature of 25°C in a 1,000 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°C for 1 week, after which the prepared wine samples were analysed.

Total soluble solids and total acidity of grape

The total soluble solids (TSS) of wine was determined using a digital refractometer (PAL-1; Atago, Tokyo, Japan). For measurement of the total acidity (TA), 20 mL of wine sample was titrated using 0.1 N NaOH to an end point of pH 8.2. The TA value was then converted to tartaric acid equivalents.

HS-SPME conditions

An SPME fibre 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 (13). Fermentation-finished wine (15 mL) was transferred into a capped 50 mL solid-phase microextraction vial, and 1.8 g of NaCl and 2 μL of internal standard (4-nonanol in EtOH, 1 mg/mL) were added. Samples were heated at 70°C in an automated heating block (Wise Therm®, HB-48P). After 20 min of equilibration, the SPME fibre was manually inserted into the sample vial headspace. After 20 min, the fibre was withdrawn and introduced into the GC injection port for desorption at 250°C and maintained for 10 min in splitless mode. All samples were examined in triplicate.

GC-MS analysis

An Agilent gas chromatograph model 6890N coupled to an Agilent 5975 series mass selective detector was used to perform the analysis. Volatile compounds were separated on an HP-INNOWAX capillary column (30 m \times 0.32 mm \times 0.25 μm ; Agilent technologies, Santa Clara, CA, USA), with purified helium as the carrier gas, at a constant flow rate of 2 mL/min. Desorption of the DVB/CAR/PDMS fibre was carried out for 10 min in the GC injection port at 250°C . The oven temperature was held at 40°C for 5 min, increased to 220°C at a rate of 3°C min^{-1} and finally held at 220°C for 5 min. The injector and source temperature were set at 250°C and 230°C , respectively. The mass detector was operated in electron impact ionisation 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. 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

Characteristics of 11 red wine grapes

To compare the characteristic of eleven red wine grapes, the titratable acid (TA), the total soluble solids (TSS) and the total soluble solids/titratable acid (TSS/TA) were identified (Table 1). In all grapes, the TA range from 5.50 to 10.80 g/L, and TSS value were higher than 18.40 °Brix in all grapes. The TSS/TA ranged from roughly 1.98 to 4.15. An outstanding parameter to evaluate the maturity of grape is the total soluble solids, predominantly sugars, measured as °Brix (13). These results, all harvested grapes in Wanju region were reached their appropriate maturity times, with the exception of Cabernet Franc and Pinot Meunier grapes.

Identification and characterization of the aroma compounds in wines

Seventy five compounds were identified as follows 16 alcohols, 11 volatile acids, 3 aldehydes, 28 esters and acetates, 4 ketones, 3 C₁₃-norisoprenoids, 2 C₆-compounds, 1 furan, 1 phenolic acid derivative, 1 terpene and 5 others in 11 wines by HS-SPME and GC/MS analysis (Table 2).

Higher alcohols are secondary products of yeast metabolism and have been related with pungent, sweet and fruity odors (14). Alcohols was the most abundant component

in the aroma compounds of all wines like previous studies (15-18). 1-heptanol, isoamyl alcohol, 2,3-butanediol, [R-(R*,R*)]-, 2,3-butanediol,[S-(R*,R*)]-, 3-ethyl-1-butanol, phenylethyl alcohol, 1-propanol and isobutyl alcohol were identified in the all red grape wines. Isoamyl alcohol was largest aroma compound in all wine samples without Cabernet Sauvignon, Chancellor and Sauvignon Vert wines. Largest aroma compound of those 3 wines is isobutyl alcohol. 1-butanol and 2-ethyl-1-butanol were detected only in Chancellor and Marchel wines. And, benzyl alcohol was found in several wines, such as Cabernet. The alcohol profile of Chancellor wine was the most diverse in the all wines, containing 14 types of alcohols. However, Cabernet Sauvignon wine was shown in highest concentration of alcohol component. Franc, Cabernet Sauvignon, Chancellor, Marchel and Merlot wines. Studies performed by Tao et al. (19), Cheng et al. (20) and Vilanova et al. (21) reported high values for higher alcohols and ethyl esters in Cabernet Sauvignon wines.

Volatile acid compounds are mainly produced during fermentation and their concentration has been reported to depend on the initial composition of the must and fermentation conditions. The low concentration of these compounds had a positive contribution to the quality of the wine by increasing aroma complexity. However, at levels beyond 20 mg/L, these acids have been associated with negative odors (22). In present study, the total volatile acid concentration was less than 1.1 mg/L in all red wines.

Ester and acetate were identified largest number of the aroma component in 11 red wines, and this result is consistent with previous data for different red wine varieties (17,18). Ethyl esters of the fatty acid were formed from ethanolsysis of acyl-CoA during fatty acid synthesis or degradation and appeared mainly at the first phase of the alcoholic fermentation of fatty acid (23,24). In the present study, octanoic acid ethyl ester, hexanoic acid ethyl ester and ethyl acetate were major esters identified in the aroma compounds of the 11 red wines. Ethyl acetate and Lactic acid ethyl ester

Table 1. Total soluble solids and titratable acid content in fruits of 11 grape cultivars

Cultivars	Cabernet Franc	Cabernet Sauvignon	Chancellor	Malbec	Marchel	MBA	Merlot	Narsha	Pinot Meunier	Sangiovetto	Sauvignon Vert
TA ¹⁾ (g/L)	5.6	8.1	10.8	6.0	8.5	5.9	10.3	9.0	9.3	5.5	9.2
TSS ²⁾ (°Brix)	19.9	22.9	23.8	20.5	22.6	20.6	21.8	22.0	18.4	22.8	21.0
TSS/TA	3.6	2.8	2.2	3.4	2.7	3.5	2.1	2.4	2.0	4.2	2.3

¹⁾Titratable acid.

²⁾Total soluble solids.

Table 2. Concentration of aroma compounds determined in 11 red wines

No.	RI ¹⁾	Compounds	Cabernet Franc	Cabernet Sauvignon	Chancellor	Malbec	Marchel	MBA	Merlot	Narsha	Pinot Meunier	Sangiovetto	Sauvignon Vert	ID ²⁾
Alcohols														
1	4544	Benzyl Alcohol	1,494.48 ^{bc}	3,167.25 ^a	607.79 ^{dc}	0.00 ^d	1,859.74 ^{bc}	0.00 ^d	1,274.42 ^{bc}	0.00 ^d	0.00 ^d	0.00 ^d	0.00 ^d	S/MS
2	2603	1-Heptanol	46.03 ^{de}	79.61 ^{de}	95.43 ^{de}	351.89 ^b	266.19 ^{bc}	202.72 ^{ce}	196.49 ^{cd}	157.40 ^c	204.69 ^{cd}	163.85 ^{ce}	562.39 ^c	S/MS
3	1653	Isoamyl alcohol	264,472.81 ^{ab}	219,102.42 ^{ab}	209,535.85 ^{ab}	332,626.75 ^{ab}	197,936.04 ^{ab}	337,254.82 ^{ab}	285,922.91 ^{ab}	253,026.53 ^{ab}	274,735.60 ^{ab}	294,962.74 ^{ab}	237,243.39 ^b	S/MS
4	1603	2-Methyl-1-butanol	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	51.99 ^f	0.00 ^f	0.00 ^f	61.23 ^f	MS
5	3060	2,3-Butanediol, [R-(R*,R*)]-	173.78 ^b	777.40 ^f	431.50 ^{ab}	207.31 ^b	325.32 ^b	187.44 ^b	184.52 ^b	275.26 ^b	196.86 ^b	193.14 ^b	214.57 ^b	MS
6	3242	2,3-Butanediol, [S-(R*,R*)]-	36.82 ^{bc}	212.53 ^d	174.00 ^f	46.18 ^{bc}	99.53 ^{ab}	40.45 ^{bc}	36.74 ^c	66.33 ^{bc}	42.94 ^{bc}	43.34 ^{bc}	41.98 ^c	MS
7	4083	2-Octen-1-ol, 3,7-dimethyl-	0.00 ^f	0.00 ^{bc}	17.40 ^f	0.00 ^f	7.09 ^{bc}	6.10 ^{bc}	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
8	4347	1,2,3-Butanetriol	0.00 ^f	6.19 ^f	6.73 ^f	1.96 ^f	4.50 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
9	6104	2,3-Dihydrofarnesol	0.00 ^f	0.00 ^f	3.26 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
10	2024	3-Ethyl-1-butanol	8.15 ^{ac}	14.45 ^{ac}	9.28 ^{ac}	4.19 ^{ac}	3.31 ^{bc}	10.52 ^{ac}	10.56 ^{bc}	9.54 ^{ac}	7.34 ^{ac}	5.16 ^c	13.52 ^c	MS
11	4677	Phenylethyl Alcohol	162,570.99 ^{ce}	260,521.24 ^{ab}	149,694.79 ^{de}	231,597.03 ^{ac}	128,119.23 ^c	180,350.31 ^{bd}	297,388.95 ^a	149,424.61 ^{de}	153,301.73 ^{de}	173,095.78 ^{ce}	152,864.89 ^{de}	S/MS
12	1966	4-Methyl-1-pentanol	0.00 ^f	0.00 ^f	0.00 ^f	0.57 ^f	0.00 ^f	2.94 ^f	0.00 ^f	2.99 ^f	0.00 ^f	3.22 ^f	1.48 ^f	MS
13	1085	1-Propanol	24.38 ^b	34.92 ^b	154.64 ^a	16.71 ^b	146.80 ^f	15.36 ^b	28.18 ^b	17.38 ^b	15.18 ^b	6.04 ^b	23.79 ^b	MS
14	1420	1-Butanol	0.00 ^f	0.00 ^f	99.10 ^f	0.00 ^f	13.59 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
15	1220	Isobutyl alcohol	199,954.87 ^{ab}	462,540.19 ^{ab}	257,257.41 ^{ab}	220,455.27 ^{ab}	169,629.07 ^b	220.77 ^b	176,872.41 ^b	162,439.08 ^b	127,824.95 ^b	221,874.59 ^{ab}	308,023.55 ^b	S/MS
16	1950	2-Ethyl-1-butanol	0.00 ^f	0.00 ^f	117.55 ^a	0.00 ^f	7.98 ^b	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
		Total	628,782.33	946,456.21	618,204.75	785,307.85	498,418.40	518,291.45	761,915.17	565,471.11	556,329.29	690,347.85	699,050.80	
Volatile acids														
17	7904	Pentadecanoic acid	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	19.26 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
18	5731	Nonanoic acid	0.00 ^f	3.47 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	5.89 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
19	5398	Octanoic Acid	0.00 ^f	3.72 ^a	0.00 ^f	0.00 ^f	0.00 ^f	11.92 ^a	4.99 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
20	4454	Hexanoic acid	0.00 ^f	5.74 ^a	0.00 ^f	3.17 ^a	0.00 ^f	0.00 ^f	0.00 ^f	5.34 ^a	0.00 ^f	0.00 ^f	2.19 ^f	MS
21	6197	n-Decanoic acid	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	5.20 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
22	3673	2-Methylhexanoic acid	0.00 ^f	43.66 ^a	0.00 ^f	12.27 ^a	6.32 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	20.81 ^a	MS
23	7584	Tetradecanoic acid	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	18.04 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
24	8212	n-Hexadecanoic acid	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	160.35 ^a	5.87 ^a	0.00 ^f	0.00 ^f	0.00 ^f	MS
25	3378	4-Hydroxybutanoic acid	0.00 ^f	15.94 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
26	2710	Acetic acid	35.47 ^f	999.77 ^a	222.75 ^{cc}	167.03 ^{bc}	54.97 ^{fe}	134.78 ^{cd}	82.38 ^{de}	48.26 ^{ge}	0.00 ^f	269.29 ^b	33.10 ^{ef}	MS
27	3205	Isobutyric acid	0.00 ^d	103.88 ^a	7.14 ^{cd}	23.20 ^b	8.45 ^{cd}	10.89 ^{cd}	0.00 ^d	0.00 ^d	0.00 ^d	18.44 ^{bc}	27.36 ^{cd}	MS
		Total	35.47	1176.18	229.89	205.67	69.75	157.59	296.10	59.47	0.00	287.73	83.46	
Aldehydes														
28	2844	Benzaldehyde	0.00 ^f	0.00 ^{bc}	1,272.94 ^a	0.00 ^f	0.00 ^f	252.93 ^{bc}	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	450.74 ^b	S/MS
29	788	Acetaldehyde	61.21 ^{de}	974.69 ^f	811.41 ^a	173.02 ^c	396.69 ^b	21.86 ^c	170.27 ^{cd}	75.10 ^{de}	69.49 ^{ce}	131.45 ^{de}	67.47 ^{de}	MS
30	809	Isobutanal	0.00 ^f	3.14 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
		Total	61.21	977.82	2,084.35	173.02	396.69	274.79	170.27	75.10	69.49	131.45	518.21	
Esters and acetates														
31	2823	Propanoic acid, 3-methoxy-, methyl ester	0.00 ^f	16.28 ^a	10.14 ^a	5.67 ^a	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
32	4118	Benzeneacetic acid, ethyl ester	0.00 ^b	0.00 ^b	4.24 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.48 ^{bc}	0.00 ^b	MS
33	4238	Acetic acid, 2-phenylethyl ester	0.00 ^f	4.59 ^{bc}	14.52 ^{cc}	21.56 ^{cd}	19.64 ^{ce}	49.62 ^a	35.08 ^{bc}	59.97 ^{ab}	2.89 ^{bc}	14.76 ^{cc}	8.69 ^{de}	MS
34	1013	Butanoic acid, ethyl ester	0.00 ^b	0.00 ^b	0.00 ^b	138.78 ^{bc}	208.85 ^{ab}	15.86 ^{ab}	0.00 ^b	219.70 ^{bc}	0.00 ^b	207.69 ^{ab}	0.00 ^b	S/MS
35	1888	Heptanoic acid, ethyl ester	0.00 ^b	0.00 ^b	0.00 ^b	4.29 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.52 ^b	0.63 ^b	MS
36	2377	Octanoic acid, ethyl ester	116.20 ^{bc}	25.06 ^c	159.42 ^{bc}	236.84 ^{cc}	176.16 ^{cc}	1,024.38 ^a	283.93 ^{cd}	672.98 ^b	372.22 ^c	257.23 ^{cd}	295.66 ^{cc}	S/MS
37	4374	Dodecanoic acid, ethyl ester	0.00 ^b	0.00 ^b	0.00 ^b	0.58 ^b	2.31 ^b	1.69 ^a	0.00 ^b	0.72 ^a	0.00 ^b	0.00 ^b	0.00 ^b	S/MS
38	6523	Ethyl hydrogen succinate	0.00 ^b	7.88 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
39	4270	Isovaleric acid, ethyl ester	3.72 ^{cc}	38.44 ^d	25.65 ^{ab}	12.86 ^{cc}	38.44 ^{cc}	8.46 ^{ccc}	13.41 ^{acd}	0.00 ^f	0.00 ^f	2.89 ^{bc}	11.94 ^c	MS
40	3428	Decanoic acid, ethyl ester	15.75 ^{cb}	0.00 ^f	21.96 ^{cd}	20.32 ^{cc}	13.34 ^{bc}	159.62 ^a	29.62 ^{bcd}	130.70 ^b	46.03 ^b	14.87 ^{bc}	13.01 ^{bc}	S/MS
41	1533	Hexanoic acid, ethyl ester	61.54 ^c	7.98 ^c	189.30 ^{bc}	800.68 ^a	370.21 ^{cc}	60.66 ^{ab}	181.80 ^{bc}	424.02 ^{cc}	392.37 ^{cc}	554.27 ^{cc}	395.41 ^c	S/MS
42	1221	Isoamyl acetate	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	30.98 ^a	0.00 ^f	0.00 ^f	157.02 ^a	0.00 ^f	0.00 ^f	MS
43	844	Ethyl Acetate	312.71 ^{ab}	1,717.55 ^{ab}	492.17 ^{ab}	368.56 ^{ab}	769.93 ^{ab}	296.50 ^{ab}	424.25 ^{ab}	433.09 ^{ab}	401.22 ^{ab}	432.89 ^{ab}	168.36 ^b	MS
44	1683	Acetic acid, hexyl ester	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	1.42 ^a	0.00 ^f	S/MS
45	4649	Butanedioic acid, ethyl 3-methylbutyl ester	1.59 ^f	0.00 ^f	2.11 ^a	12.43 ^a	0.00 ^f	7.74 ^a	8.37 ^a	9.94 ^a	1.66 ^a	5.31 ^a	6.33 ^a	MS

No.	RI ¹⁾	Compounds	Cabernet Franc	Cabernet Sauvignon	Chancellor	Malbec	Marchel	MBA	Merlot	Narsha	Pinot Meunier	Sangiovetto	Sauvignon Vert	ID ²⁾
46	2921	Butanoic acid, 3-hydroxy-, ethyl ester	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.97 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
47	6969	Linoleic acid, ethyl ester	0.00 ^b	0.00 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	2.60 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
48	6128	9-Hexadecenoic acid, ethyl ester	0.00 ^a	0.00 ^a	3.12 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
49	7423	Hexadecyl 2-ethylhexanoate	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	17.94 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
50	6818	(E)-9-Octadecenoic acid, ethyl ester	0.00 ^b	0.00 ^b	5.54 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
51	1345	trans-2-Butenoic acid, ethyl ester	0.00 ^b	0.00 ^b	25.21 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
52	6042	Hexadecanoic acid, ethyl ester	0.00 ^b	0.00 ^b	5.54 ^b	1.27 ^b	0.98 ^b	31.41 ^a	0.00 ^b	46.74 ^a	0.00 ^b	15.36 ^{ab}	5.35 ^b	S/MS
53	6814	9-Octadecenoic acid, ethyl ester	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	1.16 ^c	3.49 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
54	3685	4-Decenoic acid, ethyl ester, (E)-	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	12.14 ^d	4.41 ^a	0.00 ^a	11.51 ^a	0.00 ^a	14.31 ^a	MS
55	816	Acetic acid, methyl ester	1.94 ^d	0.00 ^a	7.19 ^a	0.00 ^a	2.07 ^a	2.09 ^a	0.61 ^a	2.12 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
56	6396	Diethyl Phthalate	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	8.84 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
57	2107	Lactic acid, ethyl ester	16.67 ^{ab}	0.00 ^b	5.73 ^b	15.22 ^b	7.93 ^b	12.93 ^b	44.70 ^{ab}	21.47 ^{ab}	16.44 ^b	20.91 ^{ab}	7.04 ^{ab}	MS
58	4213	Methyl N-hydroxybenzencarboximidate	86.55 ^a	0.00 ^a	5.09 ^a	24.46 ^a	11.90 ^a	4.29 ^a	0.00 ^a	43.40 ^a	106.16 ^a	69.50 ^a	6.12 ^a	MS
		Total	616.68	1,817.78	976.94	1,663.53	1,622.92	1,722.85	1,052.94	2,067.44	1,507.52	1,598.09	932.83	
		Ketones												
59	1981	Acetol	0.00 ^f	0.00 ^f	15.16 ^d	0.00 ^f	2.34 ^b	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	0.00 ^f	MS
60	1928	Acetoin	10.27 ^{abf}	32.66 ^{ce}	465.40 ^f	15.24 ^{ce}	177.90 ^b	0.00 ^f	32.35 ^c	7.54 ^{ef}	5.30 ^{ce}	16.94 ^{ce}	0.00 ^{cd}	MS
61	811	Acetone	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	2.16 ^{ab}	0.00 ^b	1.95 ^{ab}	0.00 ^{ab}	3.98 ^{ab}	0.00 ^b	MS
62	2754	3-Isopropyl-7a-methyl-1,4,5,6,7,7a-hexahydro-2H-inden-2-one	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	7.81 ^a	0.00 ^a	0.00 ^a	0.00 ^a	6.22 ^a	0.00 ^a	MS
		Total	10.27	32.66	480.56	15.24	180.24	9.97	32.35	9.48	5.30	27.14	0.00	
		C13-norisoprenoids												
63	2308	α-Ionene	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	4.67 ^a	0.00 ^a	MS
64	2774	Ionone	0.00 ^b	0.00 ^{ab}	0.00 ^b	0.00 ^b	0.00 ^b	11.67 ^a	0.00 ^b	0.00 ^b	0.00 ^b	3.63 ^{ab}	0.00 ^b	MS
65	3826	TDN	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	8.55 ^a	0.00 ^a	MS
		Total	0.00	0.00	0.00	0.00	0.00	11.67	0.00	0.00	0.00	16.85	0.00	
		C6-compounds												
66	2135	1-Hexanol	6,246.35 ^{ce}	6,933.31 ^{ce}	4,492.25 ^{ce}	1,6418.01 ^a	8,381.96 ^{cd}	3,577.18 ^{bc}	6,162.38 ^{ce}	4,951.91 ^{ce}	9,386.92 ^{bc}	5,728.51 ^{ce}	14,397.96 ^c	S/MS
67	2261	(Z)-3-Hexenol	0.97 ^{bc}	0.00 ^{bc}	0.00 ^b	0.00 ^b	0.00 ^b	23.99 ^a	0.00 ^b	15.16 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
		Total	6,247.32	6,933.31	4,492.25	1,6418.01	8,381.96	3,601.17	6,162.38	4,967.07	9,386.92	5,728.51	14,397.96	
		Furans												
68	2629	Furfural	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	3.07 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
		Total	0.00	0.00	0.00	0.00	0.00	3.07	0.00	0.00	0.00	0.00	0.00	
		Phenolic acid derivatives												
69	4001	Methyl Salicylate	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	2.27 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	2.99 ^a	0.00 ^a	MS
		Total	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.00	2.99	0.00	
		Terpenes												
70	3725	α-Terpineol	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	40.67 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	S/MS
		Total	0.00	0.00	0.00	0.00	0.00	40.67	0.00	0.00	0.00	0.00	0.00	
		Others												
71	8631	Squalene	0.00 ^a	31.26 ^c	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	42.20 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
72	1169	1-(1-Ethoxyethoxy)pentane	0.00 ^b	0.00 ^{ab}	13.03 ^{ab}	2.73 ^{ab}	1.72 ^{ab}	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b	MS
73	4339	1,3,6-Trioxocane	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.61 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.49 ^a	0.00 ^a	MS
74	6246	Glycerin	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	11.74 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	MS
75	1761	Butylcyclopropane	0.59 ^a	0.00 ^a	1.24 ^a	0.00 ^a	1.18 ^a	0.84 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	1.18 ^a	MS
		Total	0.59	31.26	14.27	2.73	3.50	12.58	42.20	0.00	0.00	0.49	1.18	

¹⁾Retention index on a HP-1Innowax column.

²⁾S, identified with standard compounds; MS, mass spectra database performed using NIST 11 spectral database, considering fit and retrofit values >70%.

³⁾Different letters within each rows indicates statistical differences (n=3, p<0.05).

increases its concentration with the malolactic fermentation (25). This compound was the most abundant ester in 11 redwines, in agreement with published data for Cabernet Sauvignon and Merlot wines (19-21) and new wine grape cultivar Meili (26). While, lactic acid ethyl ester was detected in 10 red wines, with the exception of Cabernet Sauvignon wine. Other ethyl ester, such as butanoic acid ethyl ester, heptanoic acid ethyl ester decanoic acid ethyl ester, dodecanoic acid ethyl ester and hexadecanoic acid ethyl ester were presented in some wines. Dodecanoic acid ethyl ester was found in 10 red wines, with the exception of Cabernet Sauvignon wine. In previous study, dodecanoic acid was

found in only Pinot noir among 4 red wines (21). Butanoic acid ethyl ester was shown with high concentration in the Marchel, Narsha and Sangiovetto wines. Only two C₆-compounds were identified from 11 red wines. 1-hexanol was found in every red wines, while (Z)-3-hexenol was found Cabernet Franc, MBA and Narsha wines. These C₆-compounds were derived from fatty acid by the action of grape-derived lipoxygenase (LOX) and hydroperoxide lyase (HPL), and associated with negative green and herbaceous odors when their concentration is above their odor threshold values (27-28).

Benzaldehyde and acetaldehyde were only detected in

Table 3. Odor active values (OAVs) of active aroma compounds detected in 11 red wines

No.	Compounds	Odor descriptor	Odor Series ¹⁾	OTV ²⁾ ($\mu\text{g/L}$)	Odor activity value (OAV) ³⁾										
					Cabernet Franc	Cabernet Sauvignon	Chancellor	Malbec	Marchel	MBA	Merlot	Narsha	Pinot Meunier	Sangiovetto	Sauvignon Vert
<i>Alcohol</i>															
1	Isoamyl alcohol	alcohol, harsh, bitter	4, 5	30,000b	8.82	7.30	6.98	11.09	6.60	11.24	9.53	8.43	9.16	9.83	7.91
2	Phenylethyl Alcohol	rose, honey	2	200,000d	5.42	8.68	4.99	7.72	4.27	6.01	9.91	4.98	5.11	5.77	5.10
3	Isobutyl alcohol	alcohol	5	75,000d	1.00	2.31	1.29	1.10	0.85	0.00	0.88	0.81	0.64	1.11	1.54
	total				15.23	18.30	13.26	19.91	11.72	17.25	20.33	14.23	14.91	16.71	14.54
<i>Aldehyde</i>															
4	Acetaldehyde	pungent	5	500d	0.12	1.95	1.62	0.35	0.79	0.04	0.34	0.15	0.14	0.26	0.13
	total				0.12	1.95	1.62	0.35	0.79	0.04	0.34	0.15	0.14	0.26	0.13
<i>Ester and acetate</i>															
5	Acetic acid, 2-phenylethyl ester	flowery	2	1.9d	0.00	2.41	7.64	11.35	10.34	26.12	18.46	31.56	1.52	7.77	4.57
6	Butanoic acid, ethyl ester	strawberry, apple	1	20a	0.00	0.00	0.00	6.94	10.44	0.79	0.00	10.98	0.00	10.38	0.00
7	Heptanoic acid, ethyl ester	fruity, green apple	1	2.2d	0.00	0.00	0.00	1.95	0.00	0.00	0.00	0.00	0.00	0.24	0.29
8	Octanoic acid, ethyl ester	sweet, fruity, pear	1, 2, 4	5a	23.24	5.01	31.88	47.37	35.23	204.88	56.79	134.60	74.44	51.45	59.13
9	Hexanoic acid, ethyl ester	fruity, green apple	1	8d	7.69	1.00	23.66	100.09	46.28	7.58	22.73	53.00	49.05	69.28	49.43
10	Isoamyl acetate	banana, fruity, sweet	1, 4	30a	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	5.23	0.00	0.00
	total				30.93	8.42	63.19	167.69	102.29	240.40	97.97	230.15	130.25	139.12	113.41
<i>C₁₇-norisoprenoid</i>															
11	α -Ionene	fruity, sweet	1, 4	2.6d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00
12	TDN	kerosene	1, 5	2c	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00
	total				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.07	0.00
<i>C₆-compound</i>															
13	1-Hexanol	herbaceous, grass, woody	3	110d	56.79	63.03	40.84	149.25	76.20	32.52	56.02	45.02	85.34	52.08	130.89
	total				56.79	63.03	40.84	149.25	76.20	32.52	56.02	45.02	85.34	52.08	130.89
<i>Terpene</i>															
14	α -Terpineol	floral, sweet	2, 4	1.1d	0.00	0.00	0.00	0.00	0.00	36.97	0.00	0.00	0.00	0.00	0.00
	total				0.00	0.00	0.00	0.00	0.00	36.97	0.00	0.00	0.00	0.00	0.00

¹⁾1, fruity; 2, floral; 3, green; 4, sweet; 5, fatty.

²⁾Odor threshold value: a, Ferreira et al., 2000; b, Li et al., 2008; c, Sacks et al., 2012; d, Welke et al., 2014.

³⁾OAV, concentration/odor threshold.

aldehyde group. Acetaldehyde was shown in 11 red wines, however, benzaldehyde was detected only in Chancellor and MBA wines. Acetone aroma compound of ketone group was identified in 9 red wines without MBA and Sauvignon Vert wines. Terpene compounds belong to the secondary plant constituents, of which biosynthesis begins with acetyl-coenzyme A (Co A) (29). In this study, α -terpineol and furfural were detected only MBA wine. C_{13} -norisoprenoids have low odor threshold values and these compounds play an important role in the varietal typicality of wines (8) in this study, α -ionene, ionene and TDN were detected only Sangiovetto wine. MBA wine was shown only ionene.

Odor activity values (OAVs) and aroma series

The aroma compounds of wine depend on both concentration and threshold. However, only a limited number of aroma compounds can be found at concentration high enough to be perceived ($OAV \geq 1$) and considered as flavor contributors as well as active odorants (30). The OAV values for the 14 aroma compounds with $OAV \geq 1$ are shown in Table 3. Alcohol, aldehyde, ester and C_6 -compounds were the main contributors to aroma in 11 red wines. Phenylethyl alcohol obtained from 11 red wines was contributed to the floral odorant. While, isoamyl alcohol and isobutyl alcohol were contributed to sweet and fatty odorant in wines, the

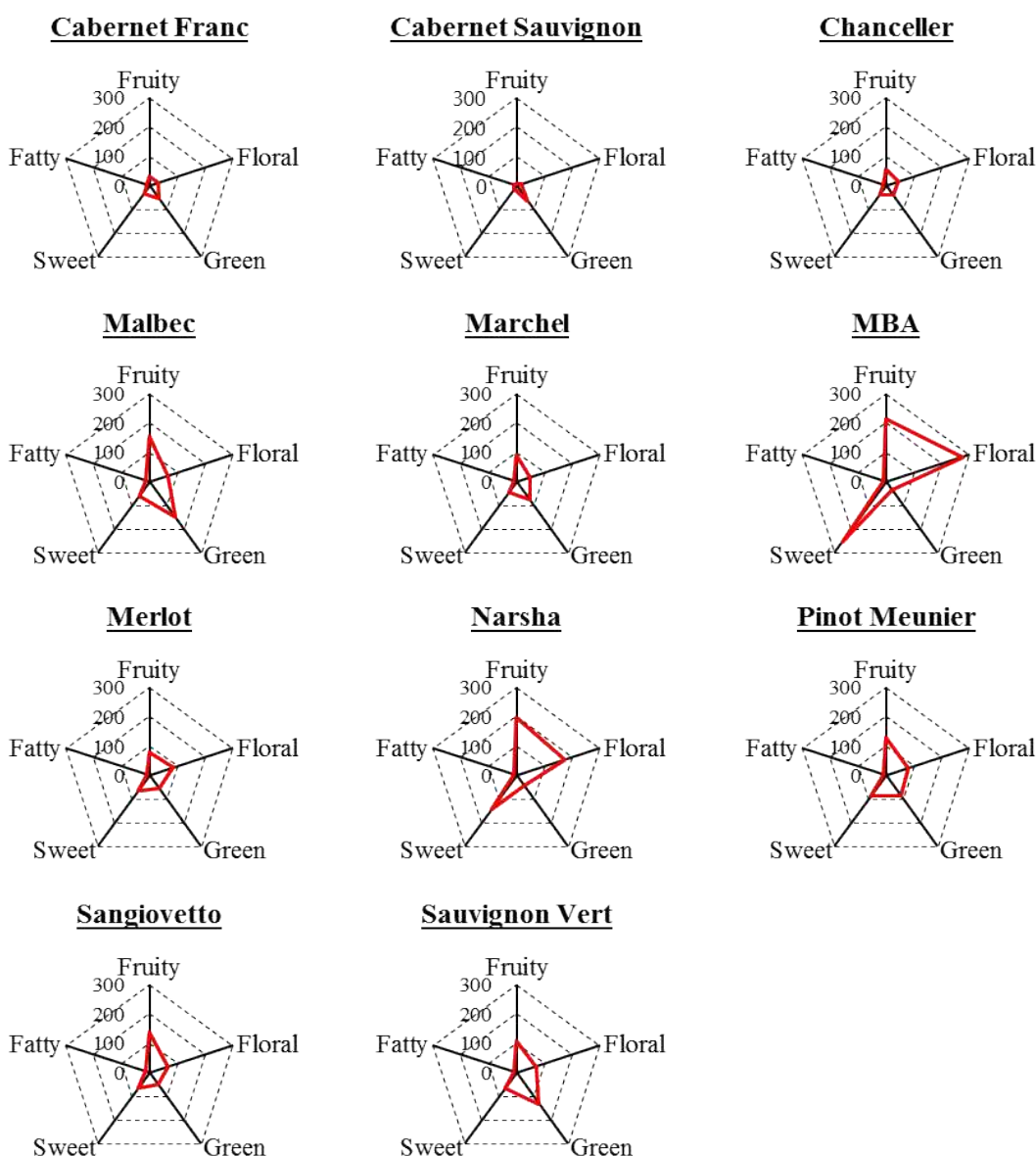


Fig. 1. Aromatic series of aroma contributors of 11 red wines.

aroma of wines contributed by these compounds was weak, because they have a high odor threshold. Acetaldehyde was detected only Cabernet Sauvignon and Chaceller wines. Ester and acetate were contributed to fruity, floral and sweet odorant in wines. Octanoic acid ethyl ester and hexanoic acid ethyl ester were most active esters, and they contributed to the fruity, floral and sweet odorant of all red wines. 1-hexanol was detected all wines, it was contributed to green odorant. C₁₃-norisoprenoids and terpene were detected only Sangiovetto and MBA wines, respectively. Although present at low concentrations C₁₃-norisoprenoids and terpene made significant contributions to the aroma of wines due to their low thresholds.

To evaluate the global fermentative aroma of the wines, all aroma compounds were grouped into five aroma series and each compound was assigned to one or more aromatic series based on their similar odor descriptors. Aroma series were represented the main constituents of the aroma profile of the wine: 1-fruity, 2-floral, 3-green, 4-sweet, 5-fatty odors bearing in mind their descriptions in previous papers (31-33). The total intensities for each aromatic series were calculated as the sum of the OAV of each of the compounds assigned to this series and the results are shown in Fig. 1. The highest aroma contribution in Chancellor, Malbec, Marchel, Narsha, Pinot Meunier and Sangiovetto wines were fruity series. While, the green series was present in the highest level in Cabernet Franc, Cabernet Sauvignon and Sauvignon Vert wines. The floral series were higher in MBA and Narsha wines, probably it is due to the high quantity of ester and acetate compounds in these wines. In present study, fruity series were major aroma categories in all red wines, and similar result was reported in previous studies (30,34).

Based on the results of these studies, aroma component analysis could be used as a selection criterion developing wine cultivars.

요 약

본 연구는 완주에서 재배된 세계 주요 11개 적포도 품종으로 제조된 적포도주의 향기 성분을 headspace-solid phase microextraction 분석법으로 확인하였다. 향기성분은 총 75 종이 확인되었다. 아로마화합물은 그들의 OAV 값에 의해 5 그룹으로 나뉘었다. 알콜, 알데하이드, 에스테르, C₆ 화합물이 11개 적포도주의 주요한 향기성분이었다. Isoamy alcohol 알콜과 phenylethyl 알콜은 11개 포도주에서 공통적으로 꽃향기, 달콤한 향을 나타내는데 중요한 물질이었다.

Octanoic acid, ethyl ester, hexanoic acid ethylester은 모든 레드와인에서 과실향과 꽃향, 달콤한 향을 내는 중요한 성분이었다. 1-Hexanol은 모든 포도주에서 분석되었으나 풀향을 나타내는 향으로 나타났다. Chancellor, Malbec, marchel, Nsrsha, Pinot Meunier, Sangiovetto 포도주의 주요 향기 성분은 과실 향인 것으로 나타났으며 Cabernet Franc, Cabernet Sauvignon, Sauvignon Vert 포도주의 주요 향기 성분은 풀향인 것으로 조사되었다. 또한, MBA와 Narsha 포도주의 경우 꽃향이 주요 향인 것으로 조사되었다. 본 연구 결과를 바탕으로 적포도주용 품종을 육성할 때 선발 기준으로 향기성분 분석을 활용할 수 있을 것으로 판단되었다.

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References

1. Villamor RR, Ross CF (2013) Wine matrix compounds affect perception of wine aromas. *Annu Rev Food Sci Technol*, 4, 1-20
2. Armanino C, Casolino MC, Casale M, Forina M (2008) Modelling aroma of three Italian red wines by headspace-mass spectrometry and potential function. *Anal Chim Acta*, 614, 134-142
3. Koundouras S, Marinos V, Gkoulioti A, Kotseridis Y, Leeuwen C (2006) Influence of vineyard location and vine water status on fruit maturation of nonirrigated cv. Agiorgitiko (*Vitis vinifera* L.) effects on wine phenolic and aroma components. *J Agric Food Chem*, 54, 5077-5086
4. Sabon I, de Revel G, Kotseridis Y, Bertrand A (2002) Determination of volatile compounds in Grenache wines in relation with different terroirs in the Rhone valley. *J Agric Food Chem*, 50, 6341-6345
5. Esti M, Tamborra P (2006) Influence of winemaking techniques on aroma precursors. *Anal Chim Acta*, 563, 173-179
6. Cortes-Dieguez S, Rodriguez-Solana R, Dominguez JM, Diaz E (2015) Impact odorants and sensory profile of young red wines from four Galician (NW of Spain)

- traditional cultivars. *J Inst Brew*, 121, 628-635
7. Ferreira V, Saenz-Navajas MP, Campo E, Herrero P, de La Fuente A, Fernández-Zurbano P (2016) Sensory interactions between six common aroma vectors explain four main red wine aroma nuances. *Food Chem*, 199, 447-456
 8. Guth H (1997) Identification of character impact odorants of different white wine varieties. *J Agric Food Chem*, 45, 3022-3026
 9. Ahn SY, Kim SH, Choi SJ, Yun HK (2012) Characteristics of cold hardiness and growth of grapevines grown under rain shelter type cultivation system in the vineyard. *Korean J Horticult Sci Technol*, 30, 626-634
 10. Yang E, Drosou F, Dourtoglou EG, Chatzilazarou A, Dourtoglou VG (2017) Approaches to outline the aromatic profile of Kyoho wines from South Korea. *BIO Web Conf*, 9, 1-4
 11. Park YS, Heo JY, Um NY, Hong DK, Park SM (2015) Development of a new wine grape cultivar 'Cheongpung'. *J Am Pomol Soc*, 69, 222-225
 12. Chang EH, Jung SM, Hur YY (2014) Changes in the aromatic composition of grape cv. Cheongsoo wine depending on degree of grape ripening. *Food Sci Biotechnol*, 23, 1761-1771
 13. Barros EP, Moreira N, Pereira GE, Ferreir-Leite SG, Rezende CM, Guedes de Pinho P (2012) Development and validation of automatic HS-SPME with a gas chromatography-ion trap/mass spectrometry method for analysis of volatiles in wines. *Talanta*, 101, 177-186
 14. Arana I, Jaren C, Arazuri S (2005) Maturity, variety and origin determination in white grapes (*Vitis vinifera* L.) using near infrared reflectance technology. *J Near Infrared Spectrosc*, 13, 349-357
 15. Li H, Tao YS, Kang WH, Yin CL (2006) Wine aroma analytical investigation progress on GC. *J Food Sci Biotechnol*, 25, 99-104
 16. Domingues AM, Agosin E (2010) Gas chromatography coupled with mass spectrometry detection for the volatile profiling of *Vitis vinifera* cv. Carmenere wines. *J Chil Chem Soc*, 55, 385-391
 17. Farina L, Villar V, Ares G, Carrau F, Dellacassa E, Boido E. (2015) Volatile composition and aroma profile of Uruguayan Tannat wines. *Food Res Int*, 69, 244-255
 18. Gomez Garcia-Carpintero E, Sanchez-palomo E, Gomez Gallego MA, Gonzalez-Vinas MA (2012) Free and bound volatile compounds as markers of aromatic typicalness of Moravia Dulce, Rojal and Tortosi red wines. *Food Chem*, 131, 90-98
 19. Tao Y, Li H, Wang H, Zhang L (2008) Volatile compounds of young Cabernet Sauvignon red wine from Changli contry (China). *J Food Compos Anal*, 21, 689-694
 20. Cheng G, Liu Y, Yue TX, Zhang ZW (2015) Comparison between aroma compounds in wines from four *Vitis vinifera* grape varieties grown in different shoot positions. *Food Sci Technol*, 35, 237-246
 21. Vilanova M, Genisheva Z, Grana M, Oliveira JM (2013) Determination of odorants in varietal wines from international grape cultivars (*Vitis vinifera*) grown in NW Spain. *S Afr J Enol Vitic*, 34, 212-222
 22. Gomez Garcia-Carpintero E, Sanchez-palomo E, Gonzalez-Vinas MA (2011) Aroma characterization of red wines from cv. Bobal grape variety grown in La Manch region. *Food Res Int*, 44, 61-70
 23. Shinohara T (1985) Gas chromatographic analysis of volatile fatty acids in wines. *Agric Biol Chem*, 49, 2211-2212
 24. Lee SJ, Rathbone D, Asimont S, Adden R, Ebeler SE (2004) Dynamic changes in ester formation during chardonnay juice fermentations with different yeast inoculation and initial brix conditions. *Am J Enol Vitic*, 55, 346-354
 25. Gil M, Cabellos MJ, Arroyo T, Prodanov M (2006) Characterization of the volatile fraction of young wines from the denomination of origin "Vinos de Madred" (Spain). *Anal Chim Acta*, 563, 145-153
 26. Vilanova M, Cortes S, Santiago JL, Martinez C, Fernandez E (2007) Aromatic compounds in wines produced during fermentation: effect of three red cultivars. *Int J Food Prop*, 10, 867-875
 27. Song JQ, Li H, Liang YY, Tao YS, Mi CQ, Qian MC, Wang H (2013) Characterisation of volatile components of red and sparkling wines from a new wine grape cultivar 'Meili' (*Vitis vinifera* L.). *Vitis* 52, 41-48
 28. Ferreira B, Hory C, Bard MH, Taisant C, Olsson A, Fur YL (1995) Effects of skin contact and settling on the level of the C18:2, C18:3 fatty acids and C6 compounds in burgundy Chardonnay musts and wines. *Food Qual Prefer*, 6, 35-41
 29. Lopez de Lerma N, Bellincontro A, Mencarelli F, Moreno J, Peinado RA (2012) Use of electronic nose, validated by GC-MS, to establish the optimum off-vine dehydration time of wine grapes. *Food Chem*, 130, 447-452

30. Mateo JJ, Jimenez M (2000) Monoterpenes in grape juice and wines. *J Chromatogr A*, 881, 557-567
31. Genovese A, Gambuti A, Lamorte SA, Gambuti A, Moio L (2013) Aroma of Agilanico and Uva di Troia grapes by aromatic series. *Food Res Int*, 53, 15-33
32. Gomez Garcia-Carpintero E, Sanchez-palomo E, Gonzalez-Vinas MA (2014) Volatile composition of Babal red wines subjected to alcoholic/malolactic fermentation with oak chips. *LWT-Food Sci Technol*, 55, 586-594
33. Lorenzo C, Pardo F, Zalacain A, Alonso GL, Salinas MR (2008) Differentiation of co-winemaking wines by their aroma composition. *Eur Food Res Technol*, 227, 777-787
34. Sacks GL, Gates MJ, Ferry FX, Lavin EH, Kurtz AJ, Acree TE (2012) Sensory threshold of 1,1,6-trimethyl-1,2-dihydronaphthalene (TDN) and concentrations in young Riesling and non-Riesling wines. *J Agric Food Chem*, 60, 2998-3004
35. Peinado GA, Mauricio JC, Moreno J (2006) Aromatic series in sherry wines with gluconic acid subjected to different biological aging conditions by *Saccharomyces cerevisiae* var. *capensis*. *Food Chem*, 94, 232-239
36. Ferreira V, Lopez R, Cacho JF (2000) Quantitative determination of the odorants of young red wines from different grape varieties. *J Sci Food Agric*, 80, 1659-1667
37. Li H, Tao YS, Wang H, Zhang L (2008) Impact odorants of Chardonnay dry white wine from Changli County (China). *Eur Food Res Technol*, 227, 287-292
38. Welke JE, Zanusi M, Lazzarotto M, Zini CA (2014) Quantitative analysis of headspace volatile compounds using comprehensive two-dimensional gas chromatography and their contribution to the aroma of Chardonnay wine. *Food Res Int*, 59, 85-99