Available online at www.sciencedirect.com

SCIENCE DIRECT®

Food Chemistry 94 (2006) 385–393

Food Chemistry

www.elsevier.com/locate/foodchem

Development of Korean red wines using *Vitis labrusca* varieties: instrumental and sensory characterization

Seung-Joo Lee [a], Jang-Eun Lee [a], Hyeon-Wee Kim [b], Sung-Soo Kim [a], Kyung-Hee Koh [c,*]

[a] *Korea Food Research Institute, San 46-1, Baekhyun-dong, Bundang-gu, Seongnam-si, Kyonngi-do, Republic of Korea*
[b] *Ottogi Research Center, Anyang-si, Kyonngi-do, Republic of Korea*
[c] *Department of Food Science and Nutrition, The Catholic University of Korea, 43-1, Yokkok 2-dong, Wonmi-gu, Pucheon-si Kyonngi-do, Republic of Korea*

Received 23 August 2004; received in revised form 16 November 2004; accepted 16 November 2004

Abstract

In this study, two red wines were developed, with and without sugar addition, from a mixture of two different grape varieties, Gerbong (*Vitis labrusca* L.) 60% and Campbell Early (*V. labrusca* B.) 40%. Their chemical and sensory profiles were determined and compared with a French Beaujolais Nouveau wine of Chateau Talance using descriptive, physicochemical and volatile analyses. Colour, six aroma, and five taste attributes were evaluated by an expert panel of nine judges. Sample wines were analyzed for titratable acidity, ethanol, pH, Hunter colorimeter value, phenolic compounds, and organic acids. From the volatile analysis of sample wines, 10 acids, 12 alcohols, 10 esters, 7 volatile phenols, 5 furans, and 3 miscellaneous compounds were identified. From the principal component analysis of the descriptive data, wines were primarily separated along the first PC, which explained 93% of the total variance between the Korean wines with high intensities of "ripe-fruit aroma", "caramel aroma", and "sour" attributes and the French wine that was high in "woody aroma", "astringent", "mineral aroma", and "colour" attributes.

Keywords: Korean wines; Sensory analysis; Physicochemical analysis; Volatile analysis

1. Introduction

In 2000, the total wine consumption in Korea was about 6,850,200 l; accordingly, 0.24 l of wine was consumed per person (Korea Alcohol Liquor Industry Association, 2001). Despite the minimal share (0.24%) of wine in the Korean alcoholic beverage market, wine is the one of the fastest growing commodities among alcoholic beverages and liquors. However, most wines consumed in Korea are imported from France, Italy, Chile, and the USA because the Korean wine industry has had difficulties in the production of Korean wines, due to various geographical and technical problems. The quality of wine is mainly governed by the quality of grapes and wine production technology. Varieties of grapes and geological-environmental conditions of grape-growing areas are important factors for the quality of grapes. Traditionally, *Vitis vinifera* varieties have been mostly used in most wine production areas in the world. However, the cultivation of the *V. vinifera* varieties in Korea has been unsuitable because of the conditions of the monsoon before the summer and the cold winters. Thus, recently, many Korean wine makers are trying to use *Vitis labrusca* varieties, which are mainly planted in Korea. Campbell early and Gerbong are major table grapes in Korea and these grapes are cultivated

* Corresponding author. Tel.: +82 2 2164 4313; fax: +82 2 2164 4111.
E-mail address: verokoh@catholic.ac.kr (K.-H. Koh).

0308-8146/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2004.11.035

in 69.8% (Campbell early) and 10.5% (Gerbong) of the total grape cultivated area. In this study, these two grape varieties were used for the development of Korean red wines. These grapes have relatively higher sugar levels than other table grapes and wines made with these varieties have an intense grape flavour.

In Europe, USA, Australia, and other western countries, there have been numerous studies about wines made with *V. vinifera* varieties across disciplines and in specialities such as chemistry, microbiology, beneficial functionality and sensory evaluation (Bisson, Waterhouse, Ebeler, Walker, & Lapsley, 2002; Boulton, Singleton, Bisson, & Kunkee, 1996). However, research studies related to wines are in the initial stages in Korea, with its short history of wine consumption and industry. There have been several studies about wines made with *V. labrusca* varieties using various fermentation conditions and processing techniques in Korea. Kim, Kim, Han, Yoon, and Yook (1999) monitored the °Brix and total acidity of Campbell Early grapes by harvest time and observed the fermentation progress and stability of wines made with and without yeast inoculation. Kim, Sim, and Yook (2001) investigated the effects of different types of sugar addition on the fermentation progress and quality of red wines made with Campbell Early. Sucrose, xylitol, glucose, corn syrup, and high fructose corn syrup were added to the must, to make 21 °Bx and the fermentation progress was monitored. The fermentation rate of the wine with added glucose was the fastest, compared to those of other wines made with different types of sugars, with the final ethanol content of 12% (v/v). The wine with added xylitol showed the highest rating in the preference test. For the study, selected processing techniques were used; reverse osmosis (RO) was applied to improve the quality of wine made with Sheridan grapes (Lee, Lee, Chang, & Lee, 2000). The sensory and volatile profiles of wines made with and without the reverse osmosis system were determined using sensory and Gas chromatography–olfactometry–mass spectrometry (GC–O–MS) analysis. Wines using the RO system showed higher FD values of fruity aromas and also higher intensities of sweet/fruity flavour in sensory analyses. There have been few studies of volatile compositions of wines made with non-*V. vinifera* varieties. Volatile compositions of three *V. labrusca* variety grapes (Blackolympia, Campbell Early, and Dellaware) were analyzed by GC/FID and GC/MS analyses (Park & Kim, 2000). The total concentration of esters, such as ethyl acetate, ethyl butanoate, and ethyl hexanoate, was the highest in the Campbell Early grape. The Dellaware grape was high in fusel alcohol content, comprising ca. 40% of quantified volatiles. In another study, volatile profiles were monitored during the alcoholic fermentation of Seibel grape must, inoculated with different types of yeast strains (*Saccharomyces cerevisiae* and *Schizosaccharomyces pombe*) (Koh & Chang, 1999). In the sensory area, wines were prepared using Campbell Early grapes from different areas in Korea; and the sensory profiles of wines were determined and compared with French wine (Park, Park, Rhee, Yoon, & Lee, 2002). The sensory characteristics of red wines made with various non-*V. vinifera* varieties, such as Gerbong (*V. labrusca* L.), Campbell Early (*V. labrusca* B.), and Morou (*Vitis amurensis*) were evaluated by a descriptive analysis, and the overall acceptabilities of developed wines were also measured by a ranking test (Lee, Hong, Sim, Kim, & Koh, 2003). However, no comprehensive sensory and volatile analysis of wines made with Gerbong (*V. labrusca* L.) and Campbell Early (*V. labrusca* B.) has previously been attempted.

In this study, two red wines were developed from a mixture of two different grapes, Gerbong (*V. labrusca* L.) and Campbell Early (*V. labrusca* B.) and their chemical and sensory profiles were determined and compared with a 2002 French Beaujolais Nouveau wine of Chateau Talance using descriptive, physicochemical and volatile analyses.

2. Materials and methods

2.1. Vinification of wines

Gerbong (*V. labrusca* L.) and Campbell Early (*V. labrusca* B.), grown at Anseong-si, Kyonngi-do, Republic of Korea, were transported to the experimental winery at the agricultural research centre at Anseong-si in 2002. Two Korean wines prepared in this study were referred to as (+) and (−) sucrose in the following text. The total weight of 200 kg of grapes (Gerbong 60% + Campbell Early 40%) was crushed using a crusher/de-stemmer and the resulting 150 l of must was transported to a 200-l stainless steel fermenter. Soluble solids content, pH and titratable acidity of the must were 15.5 ± 0.4 °Bx, 3.5 ± 0.05, and 6.0 ± 0.5 g tartaric acid/l, respectively. The ratio of two grapes used for winemaking was determined from previous studies according to the sensory qualities of wines (Lee et al., 2003; Lee, Won, Kim, & Koh, 2002). The must was treated with 200 ppm SO_2 with subsequent stirring, and settled for 20 h before inoculation. Before inoculation, 1.5 g/l of tartaric acid and 0.3 g/l of fermentation aid (Gist-brocades, France) were added. The fermentation was carried out using a rehydrated inoculum of Fermivin 7013 dry yeast – *S. cerevisiae* (Gist-brocardo, France) in a stainless steel fermenter at room temperature. Yeast was inoculated at 0.2 g dry yeast per litre. For the (+) sucrose treatment wine, sucrose (CJ Co., Korea) was added before inoculation to make 21 °Brix of the must. The wine reached dryness in approximately 18–21 days. Clinitest tablets (Bayer Inc., Elkhart, IN) were used to estimate the residual reducing sugar in the wine at the end of the fermentation (Ough & Amerine, 1988). The fermentation was considered complete when the Clinitest showed less than 0.25% reducing sugar in the finished wine. The wine was racked after fermentation and aged in an oak barrel (50 l). Wines were stored at 11 °C for 6 months. The finished wines were clarified with 80 mg/l of gelatin and filtered with 0.5 and 1.5 μm of filter paper (Buon vino MGF. Inc, Ontario, Canada). The finished wines were stored in a 750-ml glass bottle at 11 °C before analysis. As a control, a commercial 2002 French Beaujolais Nouveau wine of Chateau Talance (BN), with a light aroma and taste was, selected for a comparison with Korean wines.

2.2. Instrumental analysis

2.2.1. Standard chemical analysis

The wine pH was measured with a Beckman model 250 pH meter (Beckman Coulter, Inc., Fullerton, CA, USA). Titratable acidity (tartaric acid in grammes per litre) was measured by adding 5 ml of wine sample to 125 ml of deionized water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2. Soluble solids (°Brix) were measured using an ATAGO hand refractometer (model N-1E, ATAGO, Japan). Ethanol, malic and lactic acid were enzymatically determined using Boehringer–Mannheim GmbH Kits (Manheim, Germany) (Ough & Amerine, 1988). The total phenolic content of the wine was measured by a spectrophotometric method using the Folin–Ciocalteu reagent (Ough & Amerine, 1988). All chemical measurements were replicated three times and the average values were reported.

2.2.2. Colour measurement

CIELAB L^* (lightness), a^* (redness) and b^* (yellowness) tri-stimulus values were obtained with a scanning spectrophotometer and using a Hunter colorimeter (Hunter Lab, Dp-9000, Reston, USA). Absorbance measurements were made at 420 and 520 nm for browning and red colour, respectively, using a Unicam Helios Beta UV–Vis spectrophotometer (Unicam, Cambridge, UK). The colour hue (OD_{420}/OD_{520}) and intensity ($OD_{520} + OD_{420}$) were calculated using absorbance measurements.

2.2.3. Volatile analysis

A 100 ml portion of wine was transferred into a 500-ml Erlenmeyer flask and 0.1 ml of internal standard stock solution was added. The IS stock solution (100 ppm, w/v) was prepared by adding 100 mg of β-pinene to 1 l of absolute ethanol. The aliquot was then liquid–liquid extracted three times with 50 ml of dichloromethane. The organic extracts were combined, dried over sodium sulfate and concentrated to a volume of 1 ml by distilling off the solvent on a Vigreux column (40×2 cm). The solvent was further removed under a purified nitrogen stream until the volume was reduced to 0.2 ml. Each sample was extracted in duplicate and the concentration of a volatile, such as a β-pinene equivalent, was obtained as a mean of two replications.

Two μl of extracts of the wines were analyzed in duplicate on a Hewlett–Packard (HP) gas chromatograph, model 6890, equipped with a split/splitless injector and a INNOWax (cross-linked polyethylene) bonded fused capillary column (60.0 m $\times$ 0.25 mm i.d., film thickness = 0.25 μm, J&W scientific Inc., Folsom, CA). The detector was a mass spectrometer (MS 6890 series Mass selective detector, Hewlett–Packard, Palo Alto, CA). The temperature of the inlet was 250 °C. The splitless time was 1 min. The purge flow to split vent was 50 ml/min for 1 min. The column head pressure was 14.14 psi and the helium carrier gas flow rate was 1.3 ml/min. The average helium gas velocity was 30 cm/s. The oven temperature was held at 40 °C for 4 min and programmed at 4 °C/min to 230 °C and held for 20 min isothermally. Mass spectra in the electron impact mode (MS-EI) were generated at 70 eV and ion source temperature was 230 °C. Mass spectra were taken over the m/z range 45–300. The total ion chromatogram (TIC) acquired by GC–MS was used for peak area integration. HP MS chemstation software G1701BA ver.B.01.00 was used for data acquisition. Volatile compounds were tentatively identified on the basis of the retention index and the comparison of EI mass spectra with published data, Wiley 275 library or with reference compounds.

The recovery of an internal standard during volatile analysis (extraction and GC analysis) was evaluated for three wines to determine the recovery of the method. Average recovery of the internal standard was 74%. Reproducibility of the volatile analysis method was examined in one wine (BN) which was extracted in duplicate, with each extract analyzed in duplicate by GC. A two-way analysis of variance (extraction, injection) for each peak showed no significant differences due to extraction for all but two peaks and no significant differences due to injection for all but three peaks.

2.3. Descriptive analysis

The sensory evaluation of three wines was conducted with nine judges drawn from wine class students at Gana art centre, Seoul, Republic of Korea. Two training sessions were held and consensus was reached on one colour, six aroma, and five taste attributes (Table 1). Standards used to define these aroma and taste descriptors were present during training and formal sessions. A descriptive analysis of three wines was performed in duplicate after one practice session. The presentation order of wines was randomized for each session. Wines were presented in clear tulip-shaped glasses marked with three-digit numbers and covered with Petri-dishes. The

Table 1
Sensory attributes, definitions and physical standards

Attributes	Written definitions	Physical standards
Colour	Intensity of violet colour in the wine	No physical standards
Ripe-fruit aroma	Ripe grape, pear	5 Bunches of grapes (Campbell Early), 20 ml grape juice (Campbell Early) and 10 ml pear juice in 100 ml wine
Caramel aroma	Caramel, sweet	1 crushed caramel in wine
Woody aroma	Oak, cedar tree	No physical standards
Yeast aroma	Yeasty, brown	0.5 g dry yeast in 100 ml sugar solution after overnight
Alcohol aroma	Alcohol	10 ml 95% ethanol
Mineral aroma	Metallic	No physical standards
Sweet	Sweet taste	Mix 2 g sucrose in 1 l base wine
Sour	sour taste	Mix 2 g citric acid in 1 l base wine
Astringent	Mouth feel of dryness	Mix 1 g aluminum sulfate with 1 l distilled water
Bitter	Bitter taste	0.75 g caffeine to 500 ml base wine
Full-body	Full-bodiness while tasting	No physical standards

judges scored each attribute on a scale of 0–9, in which 9 was the highest intensity and 0 was none.

2.4. Statistical analysis

All GC and sensory analyses were performed using SAS version 6.12 (SAS Institute, Cary, NC). The descriptive analysis data were analyzed by mixed model three way analysis of variance (ANOVA) to determine the effects of wine, judge, replication, and the two-way interactions. The means were used to perform a principal component analysis using the covariance matrix with no rotation on SAS®.

3. Results and discussion

3.1. General wine composition

The general compositions of wines are shown in Table 2. With the addition of sugar, a (+) sucrose wine showed a higher alcoholic level (11%) than that of a (−) sucrose wine (8%). The titratable acidity of wine BN was lower than those of Korean wines, (+) and (−) sucrose. As seen by the darker violet colour of wine BN compared to the two Korean wines, colour intensity, L^*, a^*, and total phenolic content reflected these colour differences of wines. This weak colour of Korean wines may be attributed by the skin colour of the Gerbong (*V. labrusca* L.) grapes. As shown in Table 2, malic and lactic acid contents also showed a contrast between the Korean and French wines. The concentration of malic acid was 0.18 g/l in wine BN, while the concentrations were 1.86 and 2.28 g/l in Korean wines H and L, respectively. In contrast, the concentration of lactic acid was 2.35 g/l in wine BN, but the concentrations were minimal (0.48 g/l) in both Korean wines. From this result, the wine BN was considered to undergo malo-lactic fermentation. This vinification technique should be considered in Korean wine-making to lower the acidity of wines.

Table 2
General compositions of three wine samples[a]

	Wines[b]		
	(+) sucrose	(−) sucrose	BN
pH	3.2 ± 0.06	3.3 ± 0	3.3 ± 0.03
Total acidity (g/l tartaric acid)	5.01 ± 0.02	4.93 ± 0.1	3.85 ± 0.06
Alcohol (%, v/v)	11 ± 0.1	8 ± 0.12	12.4 ± 0.2
Total phenolic content (mg/l GAE)	1172.2 ± 61.72	1159.4 ± 62.21	1576.79 ± 7.4
Malic acid (g/l)	1.86 ± 0.01	2.28 ± 0.05	0.18 ± 0.01
Lactic acid (g/l)	0.48 ± 0.1	0.48 ± 0.1	2.35 ± 0.26
Colour			
Hue	0.64 ± 0.02	0.65 ± 0.01	0.14 ± 0.02
Intensity	7.23 ± 0.04	7.88 ± 0.02	14.6 ± 0.05
L^*	49.1 ± 0.02	48.1 ± 0.01	44.3 ± 0.02
a^*	15.39 ± 0.02	17.0 ± 0.01	16.2 ± 0.02
b^*	−1.20 ± 0.02	−1.53 ± 0.01	−5.3 ± 0.02

[a] Average of three replications. Standard deviations shown after ±
[b] (+) Sucrose, Korean wine made with sugar addition; (−) sucrose, Korean

3.2. Aroma composition of wines

The mean concentrations of volatile compounds are given in Table 3 by chemical classes. In all 47 volatile compounds were identified, including 10 esters, 12 alcohols, 10 acids, 7 volatile phenols, 6 furans, and 3 miscellaneous compounds. To determine which peaks varied across wines, one way analyses of variance were performed for each volatile. All volatile compounds varied highly significantly across wines except three compounds (3-ethoxy-1-propanol, propanoic acid, and butanoic acid).

Volatiles were inspected by their chemical classes. Alcohols and esters were the largest groups among quantified volatiles. The most abundant compounds were the higher alcohols, such as isoamyl alcohol and 2-phenylethanol, in accordance with the literature (Ebeler, 2001; Etievant, 1991; Rapp, 1998; Schreier, 1979). Over 60% of the total volatile material was contributed by three compounds: isoamyl alcohol, diethyl succinate,

Table 3
Average concentrations of volatile compounds in three wine samples

Compounds (mg/l)	LRI[a]	Wines			ID[b]
		(−) Sucrose	(+) Sucrose	BN	
Esters					
2-Methyl butanoate	986	0.03	0.03	0	B
Ethyl hexanoate	1230	0.03	0.04	0.01	A
Methyl 3-hydroxy butanoate	1475	0.01	0.01	0	B
Ethyl 3-hydroxy butanoate	1524	0.08	0.09	0.03	A
Methyl benzoate	1600	0.29	0.09	0	B
Ethyl decanoate	1630	0.03	0.05	0.23	A
Diethyl succinate	1690	2.5	5.45	8.5	A
2-Phenylethyl acetate	1809	0.05	0.07	0.03	A
Diethyl malate	2041	0.25	0.4	0.15	B
Allyl phenylacetate	2175	0.03	0.07	0.07	B
Total		3.3	6.3	9.02	
Alcohols					
2-Methyl-1-propanol	1085	0.17	0.18	0.25	A
Isoamyl alcohol (3-methyl butanol)	1210	4.79	5.28	4.45	A
1-Hexanol	1343	0.06	0.05	0.28	A
3-Hexen-1-ol (*E*)	1351	0.34	0.61	0.28	A
3-Ethoxy-1-propanol	1364	0.01	0.01	0.01	A
3-Hexen-1-ol (*E*)	1379	0.02	0.01	0	A
3-Hexen-1-ol (*Z*)	1384	0.03	0.03	0	A
3-Methylthio-1-propanol	1714	0.14	0.26	0.13	A
Benzyl alcohol	1889	0.02	0.03	0.08	B
2-Phenylethanol	1905	3.35	4.94	3.56	B
3-Methyl acetate-1-butanol	–	0.04	0.06	0.03	C
2-Amino-1-butanol	–	0.06	0.08	0.08	C
Total		9.03	11.54	9.15	
Acids					
Propanoic acid	1523	0.02	0.02	0.02	A
Butanoic acid	1614	0.06	0.05	0.06	A
3-Methyl butanoic acid	1686	0.16	0.19	0	A
Pentanoic acid	1730	0.16	0.14	0.1	A
Hexanoic acid	1838	0.25	0.21	0.18	A
2-Methoxy benzoic acid	2010	0.03	0.03	0	A
Octanoic acid	2060	0.28	0.3	0.31	A
Decanoic acid	2357	0.05	0.0	0	A
Hexadecanoic acid	2886	0.16	0.16	0.07	A
Benzene acetic acid	–	0	0.18	0	C
Total		1.17	1.28	0.74	
Volatile phenols					
Eugenol	2164	0.01	0.0	0	A
4-Allyl-2,6-dimethoxyphenol	2186	0.03	0.03	0	C
4-Ethylphenol	2195	0.01	0.02	0	B
2,6-Dimethoxy phenol	2273	0.02	0.03	0.03	B
Methyl vanillate	2600	0.03	0.04	0.04	B
(1,1-Dimethylethyl)-4-methyl-phenol	–	0.03	0.05	0	C
2,4-bis(1,1-dimethylethyl)-phenol	–	0.35	0.35	0.26	C
Total		0.48	0.52	0.33	
Furans					
2-Ethyl-furan	815	0.01	0.0	0	A
Furfural	1458	0.02	0.02	0	A
2-Acetyl furan	1500	0.1	0.16	0	A
Furfuryl alcohol	1660	0.14	0.05	0	A
2-Furancarboxylic acid	–	0.23	0.0	0	C
Total		0.5	0.23	0	

(*continued on next page*)

Table 3 (*continued*)

Compounds (mg/l)	LRI[a]	Wines			ID[b]
		(−) Sucrose	(+) Sucrose	BN	
Miscellaneous					
2-Methyl-2-butenal	1012	0.66	0.86	0	B
γ-Butyrolactone	1635	0.06	0.07	0.56	A
2-Methyltetrahydrothiophen-3-one	–	0.04	0.03	0.02	C
Total		0.76	0.96	0.58	

[a] LRI: Linear retention index calculated in the INNOWAX capillary column.
[b] Identification: A = GC retention and MS data in agreement with that of authentic reference; B = GC retention and MS data in agreement with spectra found in library; C = tentatively identified by MS matching with library spectra only. Results are the means of duplicate analyses.

and 2-phenylethanol in three wine samples. Especially, over 80% of the quantified volatiles were accounted for by the above three compounds in wine BN. All of these major compounds were yeast fermentation products and might contribute to the background or base flavour of these wines rather than differentiate among the wines. In contrast to these major substances, minor classes, such as volatile phenols, furans, and esters (except diethyl succinate), may contribute to the subtle flavour differences among these wines.

The total concentration of esters was greater in wine BN (9.02 mg/l) than in (+) and (−) sucrose wines (6.30 and 3.30 mg/l, respectively). Among esters, ethyl hexanoate, ethyl decanoate, and 2-phenylethylacetate were detected in the investigated wines. Overall, those compounds were considered to be the major source of fruitiness in wines (Ebeler, 2001; Etievant, 1991; Rapp, 1998). Although some of the esters identified in wines are also found in grapes (Schreier, 1979), the majority of these esters are formed by esterification by the yeast during fermentation. Wines, which have finished fermentation, undergo hydrolysis or esterification, until the ester concentration has reached a stable equilibrium with the corresponding level of acyl and allyl moieties involved (Etievant, 1991; Ramey & Ough, 1980; Schreier, 1979). When examining the concentration of volatile phenols across wines, total concentrations in Korean wines were higher than that of French wine (BN). In addition, major volatile phenols, such as eugenol and 4-ethyl phenol, were not detected in the wine BN. This might be explained by the oak barrel aging of Korean wines compared to the wine BN which was only stored for 4–6 weeks in a stainless steel or glass container. Volatile phenols in a wine mainly arise from chemical degradation of lignin in barrels. This group includes naturally occurring wood constituents, thermal degradation products of wood, formed by toasting and charring of wood barrels, and products from ethanolysis of lignin (Nishimura, Ohnishi, Masuda, Koga, & Matsuyama, 1983). However, volatile phenols can also be produced by a biochemical degradation of grape phenolic acids by yeast and bacteria (Chatonnet, Dubourdieu, Boidron, & Lavigne, 1993; Chatonnet, Dubourdieu, Boidron, & Pons, 1992; Etievant, 1991). Likewise, volatile phenols, furfural and related furans can be directly extracted from the wood of the barrels. Thus, furans were only detected in the Korean wines. Among 10 organic acids detected in the investigated wines, hexanoic and octanoic acids were major constituents, comprising ca. 50% of total quantified acids. Free fatty acids occur only as traces in grapes (Roufet, Bayonove, & Cordonnier, 1986), but they are biosynthesized during fermentation by yeasts and bacteria. Considering the compounds' unpleasant odours and similar ranges of concentrations across wines, these acids are not considered to be important contributors to the flavour of these wines.

3.3. Sensory characteristics of wines by DA

To profile the sensory characteristics of each wine, the wines were evaluated by Descriptive analysis (DA). From the results of the analysis of variance (ANOVA), conducted on the descriptive data, all attributes were significantly different across wines ($p < 0.05$) except caramel aroma, yeast aroma, and sweet attributes Table 4. Significant judge*wine interactions were found for ripe-fruit aroma, caramel aroma, woody aroma, alcohol aroma, astringent, bitter, and full-body attributes ($p < 0.05$), indicating that these terms were not used in the same way by all of the judges. However, despite the lack of agreement among judges in the use of the terms, the wines differed significantly in intensity for all attributes except caramel aroma, yeast aroma, and sweet attributes. Replications (rep), rep*judge interactions, and rep*wine interactions were not a significant source of variation except for the astringent attribute.

To illustrate the sensory differences of the wines, the mean intensity ratings of the three wines with Fisher Least Significant Difference (LSD) are plotted on a cob-web graph in Fig. 1. In this diagram, the centre of the Figure represents low intensity with the intensity of each attribute increasing to an intensity of nine at the perimeter. Because the (+) and (−) sucrose wines were made with the same grapes (*V. labrusca* L. and *V. labrusca* B.) and the only difference was the alcohol content by sugar addition, the mean sensory attributes for these Korean wines were similar for the most part, with only small differences in alcohol aroma, bitter,

Table 4
Matrix of correlations for sensory attributes of wines profiled by descriptive analysis ($n = 9$ judges × 2 replications)

Attributes	Attributes 1	2	3	4	5	6	7	8	9	10	11	12
1. Colour	1											
2. Ripe-fruit	−0.206	1										
3. Caramel	0.291	0.347(*)	1									
4. Woody	0.494(**)	−0.232	0.147	1								
5. Yeast	0.293(*)	−0.117	0.591(**)	−0.11	1							
6. Alcohol	0.13	0.122	0.484(**)	−0.007	0.505(**)	1						
7. Mineral	0.484(**)	−0.294(*)	0.125	0.379(**)	0.267	0.276(*)	1					
8. Sweet	0.233	0.224	0.326(*)	0.04	0.244	0.530(**)	0.435(**)	1				
9. Sour	0.034	0.436(**)	0.279(*)	−0.315(*)	0.216	0.374(**)	−0.05	0.388(**)	1			
10. Astringent	0.649(**)	−0.376(**)	0.152	0.371(**)	0.322(*)	0.093	0.560(**)	0.335(*)	0.01	1		
11. Bitter	0.402(**)	−0.333(*)	−0.011	0.21	0.192	−0.091	0.363(**)	0.154	0.037	0.705(**)	1	
12. Full-body	0.540(**)	−0.350(**)	0.363(**)	0.593(**)	0.287(*)	0.118	0.477(**)	0.175	−0.149	0.608(**)	0.470(**)	1

* $p < 0.05$.
** $p < 0.01$.

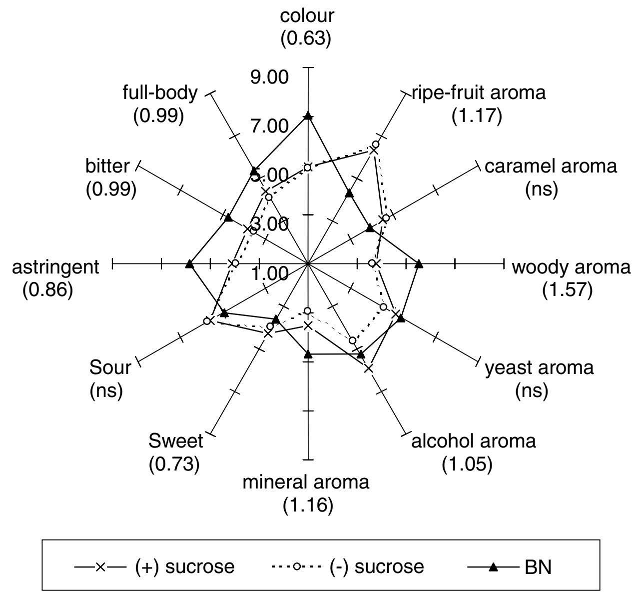

Fig. 1. Mean intensity ratings of the three wines, (+) sucrose, (−) sucrose, and BN. ($n = 9$ judges × 2 replications). At the origin intensity = 1. The perimeter intensity = 9. Least Significant Difference (LSD) at $p < 0.05$ for each term is shown in parenthesis, ns denotes no significant difference.

and full-body sensory attributes. However, wine BN differed from the other two wines most distinctively in the intensities of ripe-fruit aroma, woody aroma, astringency, and colour. Wine BN was high in colour, woody aroma, mineral aroma, astringency, bitterness, and full-body attributes, while being low in the ripe-fruit aroma. In contrast, Korean wines had a dominating ripe-fruit aroma, with a high sourness and weak colour, astringency, bitterness, and full-body attributes. These sensory characteristics are considered to have originated from the strong grape aroma and weak colour of *V. labrusca* varieties such as Campbell Early and Gerbong. These typical sensory characters of Korean wines were also observed in other studies (Lee et al., 2003; Park et al., 2002). In the sensory analysis of Korean wines made with various *V. labrusca* varieties, the Korean wines were, overall, high in the fruitiness, grapiness, sweetness, and sourness, while the French wine showed high intensities of colour, oak aroma, astringency and bitterness. Accordingly, sensory profiles of Korean wines in this study were consistent with those in previous studies in which wines were prepared with *V. labrusca* varieties. Even though concentrations of volatile phenols in Korean wines were higher than those of wine BN, the intensity of woody aroma in DA was much lower in (+) and (−) sucrose wines than in wine BN. Hence, it could be speculated that the dominating grape aroma in Korean wines might mask the woody aroma in these wines.

The correlation coefficients between the sensory attributes are shown in Table 4. In both Korean and French wines, the ripe-fruit, caramel, and sour sensory

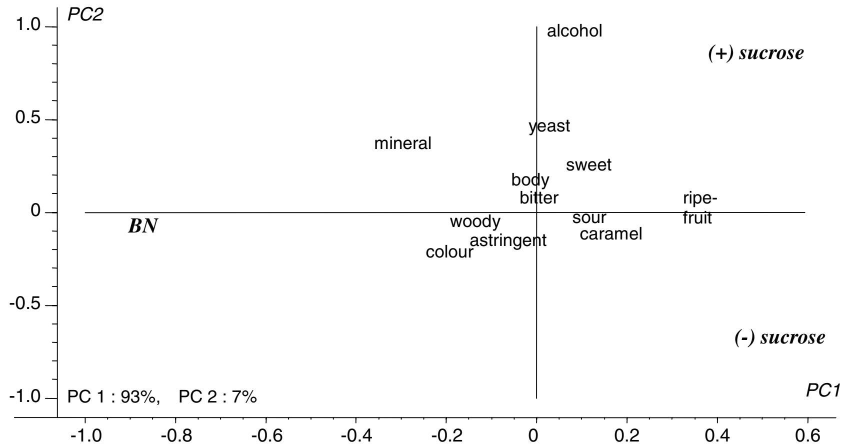

Fig. 2. Principal component analysis of descriptive data for three wines. (PC 1 and 2 are 93% and 7% of variation, respectively; small letters correspond to the sensory attributes as shown in Table 1).

descriptors were significantly positively correlated with each other. On the other hand, colour, mineral, woody, astringent, and full-body descriptors were also significantly and positively correlated and there were inverse correlations between these two groups of highly correlated variables (colour, mineral, woody, astringent, and full-body versus ripe-fruit, caramel, and sour). The overall sensory configuration of these wines was one-dimensional, as shown in Fig. 2, which summarised the results from the principal component analysis (PCA). The first dimension in this plot, which explains 93% of the variance, was a contrast between a ripe-fruit aroma and mineral/colour sensory attributes. The second principal component, which explains 7% of the variance, seemed to show contrast between high and low intensities in alcohol aroma. The distribution of wines on this PCA plot (Fig. 2) was related to the cobweb diagram of the investigated wines. Wine BN was located far left along the PC 1, indicating high values of mineral, woody, astringent, and colour sensory attributes. On the other side of PC 1, (+) and (−) sucrose wines were located with ripe-fruit, sour, and caramel sensory attributes. Along the PC 2, (+) and (−) sucrose wines were separated by alcohol aroma in which (+) sucrose wine showed significantly higher intensity than (−) sucrose wine.

In examining the relationships between sensory and physicochemical data, total phenolic content was significantly correlated with colour, woody aroma, astringent, and ripe-fruit aroma attributes ($r = 0.99$, 0.99, 0.98, and −0.99, respectively). In addition, lactic acid content was significantly correlated with colour and ripe-fruit aroma ($r = 0.99$ and −0.98). The French wine, with an intense woody aroma and astringency, had the highest concentration of the total phenolics and lactic acid, while these were far lower in the Korean wines with a strong grape aroma. Thus DA of the wines' sensory qualities corresponded well with what is expected from these chemical analyses.

4. Conclusion

The differences between Korean red wines ((+) and (−) sucrose wines) vinified with *V. larusca* varieties and French Beaujolais Nouveau wine (BN) were characterized by sensory and physicochemical analyses. Korean wines showed a distinctive ripe-fruit aroma and were also high in sour taste. On the other hand, wine BN was high in colour, woody aroma, full-body, astringent and bitter sensory attributes. Lactic acid content was much higher in wine BN, resulting from malo-lactic fermentation. Thus the intensity of sour taste of wine BN was significantly lower than those of Korean wines in DA. To overcome the overpowering fruit aroma and sourness in Korean wines, malo-lactic fermentation and addition of other varieties of grapes with neutral aroma should be considered for the vinification of *V. labrusca* grapes in the future. Korean wines were high in volatile phenols from oak barrel storage. Sensory and chemical characterizations are an important first step toward understanding and improving the quality of Korean wines using non-*V. vinifera* varieties. With greater understanding of both domestic and imported wines, Korean wines of higher quality can be produced in the future.

Acknowledgement

This work was supported by research Grant (2001–2003) from the Ministry of Agriculture & Fishery, Republic of Korea.

References

Bisson, L. F., Waterhouse, A. L., Ebeler, S. E., Walker, M. A., & Lapsley, J. L. (2002). The present and future of the international wine industry. *Nature, 418*, 696–699.

Boulton, R. B., Singleton, V. L., Bisson, L. F., & Kunkee, R. E. (1996). *Principles and practices of winemaking*. Gaithersburg, MD, USA: Aspen Publishers, Inc.

Chatonnet, P., Dubourdieu, D., Boidron, J. N., & Lavigne, V. (1993). Synthesis of volatile phenols by *Saccharomyces cerevisiae* in wines. *Journal of the Science of Food and Agriculture, 62*, 191–202.

Chatonnet, P., Dubourdieu, D., Boidron, J. N., & Pons, M. (1992). The origin of ethylphenols in wines. *Journal of the Science of Food and Agriculture, 60*, 165–178.

Ebeler, S. E. (2001). Analytical chemistry: unlocking the secrets of wine flavor. *Food Reviews International, 17*, 45–64.

Etievant, P. X. (1991). Wine. In H. Maarse (Ed.), *Volatile compounds of food and beverages* (pp. 483–546). New York, USA: Dekker.

Kim, J. S., Kim, S. H., Han, J. S., Yoon, B. T., & Yook, C. (1999). Effects of sugar and yeast addition on red wine fermentation using campbell early. *Korean Journal of Food Science & Technology, 31*, 516–521.

Kim, J. S., Sim, J. Y., & Yook, C. (2001). Development of red wine using domestic grape campbell early. *Korean Journal of Food Science & Technology, 33*, 319–326.

Korea Alcohol Liquor Industry Association (2001). Alcoholic beverage News (pp. 11), March.

Koh, K. H., & Chang, W. Y. (1999). Changes of chevolatile flavor compounds of Siebell grape must during alcohol fermentation and aging. *Korean Journal Applied Microbiology and Biotechnology, 27*, 491–499.

Lee, J. E., Hong, H. D., Sim, J. K., Kim, S. S., & Koh, K. H. (2003). Study on the sensory characteristics of Korean red wines. *Korean Journal of Food Science & Technology, 35*, 841–848.

Lee, J. E., Won, Y. D., Kim, S. S., & Koh, K. H. (2002). The Chemical characteristics of Korean red wine with different grape varieties. *Korean Journal of Food Science & Technology, 34*, 151–156.

Lee, S. Y., Lee, K. H., Chang, K. S., & Lee, S. K. (2000). The changes of aroma in wine treated with reverse osmosis system. *Korean Journal of Food Science & Technology, 32*, 17–24.

Nishimura, K., Ohnishi, M., Masuda, M., Koga, K., & Matsuyama, R. (1983). Reactions of wood components during maturation. In J. R. Piggott (Ed.), *Flavor of distilled beverages: Origin and Development* (pp. 241–255). London, UK: Society of Chemical Industry.

Ough, C. S., & Amerine, M. A. (1988). *Methods for analysis of musts and wines* (2nd ed.). New York: John Wiley and Sons.

Park, E. R., & Kim, K. S. (2000). Volatile flavor components in various varieties of grapes. *Korean Journal of Postharvest Science & Technology, 7*, 366–372.

Park, W. M., Park, H. G., Rhee, S. J., Yoon, K. E., & Lee, C. H. (2002). Suitability of Domestic Grape, Cultivar Campbell's Early, for Production of Red Wine. *Korean Journal of Food Science & Technology, 34*, 590–596.

Ramey, D., & Ough, C. (1980). Volatile ester hydrolysis or formation during storage of model solutions and wines. *Journal of Agricultural and Food Chemistry, 28*, 928–934.

Rapp, A. (1998). Volatile flavour of wine: correlation between instrumental analysis and sensory perception. *Nahrung, 42*, 351–363.

Roufet, M., Bayonove, C. L., & Cordonnier, R. E. (1986). Changes in fatty acids from grape lipidic fractions during crushing exposed to air. *American Journal of Enology and Viticulture, 37*, 202–205.

Schreier, P. (1979). Flavor composition of wines: a review. *CRC Critical Review of Food Science & Nutrition, 12*, 59–111.