Food Sci. Biotechnol. Vol. 16, No. 3, pp. 374 ~ 380 (2007)

Food Science and Biotechnology

Chemical and Sensory Characterization of Korean Commercial Rice Wines (*Yakju*)

Seung-Joo Lee*, Young-Hee Kwon, Hye-Ryun Kim, and Byung-Hak Ahn
Traditional Food Research Division, Korea Food Research Institute, Seungnam, Gyeonggi 463-420, Korea

Abstract Chemical and sensory profiles of 5 Korean commercial rice wines (*yakju*) were developed using descriptive, physicochemical, and volatile analyses. Color, 6 aroma, and 5 taste attributes of these rice wines were evaluated by a panel of 13 judges. Sample wines were analyzed for titratable acidity, ethanol content, pH, Hunter colorimeter value, organic acids, and free sugars. Volatile analysis of the samples revealed the presence of 2 acids, 7 alcohols, 19 esters, and 5 miscellaneous compounds. Based on principal component analysis of the descriptive data, rice wines were primarily separated along the first principal component, which accounted for 57% of the total variance between the rice wines with high intensities of 'color' and 'sweet aroma' versus 'ginseng' aroma.

Keywords: Korean rice wine, sensory analysis, physicochemical analysis, volatile analysis

Introduction

Korean traditional rice wines and liquors have long been consumed and produced using *nuruk* (Korean-style mold bran), cooked rice, yeasts, and some medicinal plants or herbs. However, the traditional methods of making rice wines and liquors were largely discontinued as a result of the Japanese invasion (1910) and changes in national grain policy after liberation. After the 1988 Seoul Olympics, a strong interest in perpetuating traditional culture had risen in Korean society, including a renewed interest in traditional production methods for rice wines and liquors. Recently, there have been many studies about Korean rice wines and liquors in various areas such as fermentation science, chemistry, and microbiology (1).

The general characteristics of Korean traditional rice wines and liquors have been categorized by their ingredients, fermenting methods, and regions (2, 3). For example, the microflora present in Korean traditional *nuruk* was recently isolated and classified (4). Changes in microbes and enzyme activities during the *nuruk* fermentation process were investigated (5-7). The physico-chemical characteristics of rice wines fermented with different types of *nuruk* have also been studied (8). The fermentation characteristics and quality changes of the typical Korean traditional alcoholic beverages have also been investigated during fermentation and after aging (9). Kim *et al.* (9) have suggested that traditional brewing methods with multiple input steps of seed mash and raw materials increased the fermentation efficiency.

The flavor components of Korean distilled liquors, *soju* were also compared with Chinese and Japanese liquors using gas chromatography-mass spectrometry (GC-MS) analysis (10). The flavor and sensory characteristics of *soju* fermented by the co-culture of isolates from *nuruk* and brewing mashes have been investigated using GC-MS (11). There were no significant differences in overall preferences among brewing mashes for *soju* fermented with traditional *nuruk* and co-cultures of isolates from *nuruk*. The physiological characteristics of such as angiotensin I-converting enzyme (ACE) inhibitory activity, superoxide dismutase (SOD) like activity, and electron donating ability have also been investigated in 31 Korean traditional liquors (3). Recently, many different types of rice wines using medicinal plants and herbs were developed and their physico-chemical, sensory, and functionality were investigated (12-15).

Sensory tests of these 'supplemented' rice wines have mainly been simple preference tests or cursory descriptive analyses (9, 11, 12, 14). However, no comprehensive sensory and volatile analysis of traditional rice wines (*yakju*) has yet been attempted. Comprehensive investigation and analysis of the physical properties and characteristics of commercial products are essential to improve quality of traditional rice wines and liquors. In this study, we investigated the chemical and sensory profiles using descriptive, physico-chemical, and volatile analyses of 5 widely consumed rice wines.

Materials and Methods

Materials Initially, commercial fermented rice wines (total alcohol level ranged from 12-18%) were selected by postal shopping services for traditional Korean liquors (www.koreapost.go.kr). The rice wines were informally evaluated using blind taste tests by experienced drinkers, who also described the sensory characteristics, and identified defective samples. Defective samples were eliminated from further consideration and among samples that were extremely similar; one representative sample was selected for further study. Finally, 5 fermented rice wines were selected for descriptive analysis and subsequent instrumental tests. The ingredients and alcohol level of the samples were shown in Table 1.

*Corresponding author: Tel: 82-31-780-9303; Fax: 82-31-709-9876
E-mail: sejlee@kfri.re.kr
Received October 16, 2006; accepted February 9, 2007

Instrumental analysis ***General chemical analysis***: The pH of the selected wines was measured with a Beckman model 250 pH meter (Beckman Coulter, Inc., Fullerton, CA, USA). Titratable acidity (tartaric acid in g/L) was measured by placing 5 mL of sample into 125 mL of deionized water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2. Soluble solids (°Bx) were measured using an Atago hand refractometer (model N-1E; Atago, Tokyo, Japan). Reducing sugar was analyzed with the dinitrosalicylic acid (DNS) reagent, using D-glucose as a standard, both being obtained from Sigma Chemical Co. (St. Louis, MO, USA) by Miller method (16). A calibration curve was prepared and the results were expressed as mg D-glucose equivalents/mL. All chemical measurements were repeated 3 times and the average values were reported.

Organic acid analysis: Organic acid composition was analyzed using high performance liquid chromatography (HPLC) procedures adapted from McCord *et al.* (17). A 10-tube vacuum manifold (Supelco Co., Bellafonte, PA, USA) was used for initial stages of sample preparation; Bio-rex 5 (Bio Rad Laboratories, Inc., Hercules, CA, USA) 200-400 mesh size in the chloride form was used as a resin. After the sample was adjusted to pH 8-9 with concentrated ammonium hydroxide, a 2 mL aliquot was pipetted into a 5 mL syringe and applied to the resin bed. The resin bed was washed with distilled water until a final volume of 15 mL was collected. The collected eluate contained the neutral compounds. Two mL of 10% sulfuric acid was then applied to the resin bed with the syringe. The resin bed was then washed with distilled water until a final volume of 10 mL was collected. This fraction contained the acidic compounds. Each fraction was membrane filtered (0.45 μm) before analysis by HPLC (Jasco, Tokyo, Japan).

HPLC (Jasco) was equipped with a Bio-Rad HPLC organic acid analysis Aminex HPX-87H ion exclusion column (300×7.8 mm). A Bio-Rad Micro-Guard Cation-H-refill cartridge (30×4.5 mm) was used as a guard column. Columns were maintained at 65±0.1°C using a temperature control unit. The mobile phase consisted of a 0.01 N sulfuric acid solution with 0.65 mL/min flow rate. Injection volumes were 10 μL for all samples, and run time for completion was 32 min. Organic acids were detected at 210 nm using a UV detector. Commercial standards were used for identification. The standard solutions consisted of organic acids (citric acid, L-(+) tartaric acid, L-(-) malic acid, succinic acid, L-(+) lactic acid) in various concentrations typical of the range found in rice wines. Components were identified by a comparison of their retention times with those of external standards. The peaks were quantified using external standard calibration curve. A 10 μL amount of standard solution was injected into the HPLC to determine the linearity of response and to develop standard curves for the HPLC method.

Free sugar analysis: To analyze free sugar content and composition, the procedures were adapted from Frayne (18) and Walker *et al.* (19). Each sample, before analysis by HPLC, was membrane filtered (0.45 μm) and injected to the HPLC (Jasco) equipped with a Bio-Rad YMC-pack polyamine II column (250×4.6mm i.d.). The mobile phase consisted of acetonitrile and deionized water (75:25) with a 1 mL/min flow rate. Injection volumes were 10 mL for all samples, and free sugars were detected at refractive index detector. Commercial standards were used for identification and calibration curve generation as described in organic acid analysis.

Color measurement: CIELAB L^* (lightness), a^* (redness), and b^* (yellowness) tri-stimulus values were obtained with a scanning spectrophotometer using a Hunter colorimeter (Dp-9000; Hunter Lab, Reston, VA, USA). Coloring degree and ultraviolet absorption were obtained by absorbance measurement at 430 and 280 nm, respectively using Unicam Helios Beta UV-Vis spectrophotometer (Unicam, Cambridge, UK).

Volatile analysis: Polydimethylsiloxane (PDMS; 100 μm) coated solid phase microextraction (SPME) fibers were purchased from Supelco Co. Ten mL of rice wine sample was placed in a 30-mL glass vial, which was sealed with a screw-capped top containing a Teflon-lined septum. A conditioned SPME fiber was exposed to the headspace of the sample at 40°C for 30 min. The fiber was then retracted and immediately injected into the gas chromatography (GC) inlet on a Hewlett-Packard (HP) gas chromatograph model 6890 (Palo Alto, CA, USA) equipped with a split/splitless injector and a DB-Wax bonded fused capillary column (30 m × 0.25 mm i.d. × 0.25 μm film thickness: J & W Scientific, Folsom, CA, USA). Volatile compounds absorbed in the SPME fiber were thermally desorbed at 250°C for 5 min (splitless mode for 1 min).

Compounds were identified using a mass spectrometer (MS 6890 series; Mass selective detector, Hewlett-Packard). 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/sec. The oven temperature was held at 50°C for 5 min and programmed at 10°C/min to 200°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, with the HP Wiley 275 library or with reference compounds. The quantification of each volatile component identified was made based on their relative peak areas obtained from GC-MS total ion chromatogram.

Sensory descriptive analysis (DA) The sensory evaluation was conducted with 13 judges (9 female, 4 male) drawn from the Korea Food Research Institute. Six training sessions were held and consensus was reached on one color, 9 aromatic, and 7 taste attributes (Table 1). Standards used to define these aroma and taste descriptors were present during training and formal sessions. A descriptive analysis of 5 rice wines was performed in triplicate after one practice session. The presentation order of samples

Table 1. Rice wines and their ingredients

Code	Ingredient	Alcohol content (%)
A	Sweet rice, *nuruk*, chrysanthemum flower, malt, ginger, pepper, fermented soybean	18
B	Rice, sweet rice, wild chrysanthemum flower	13
C	Sweet rice, flour, *gugija* (*Lycii fructus*), *omija* (*Schizandra chinensis fructus*), ginseng	13
D	Sweet rice, chrysanthemum flower, *gugija* (*Lycii fructus*), *Rehmanniae radix*	16
E	Rice, sweet rice, *gugija* (*Lycii fructus*)	15

Table 2. Sensory attributes, definitions, and physical standards

Attribute	Code	Written definition	Physical standard
Color	Color	Intensity of yellow color in the rice wine	No physical standards
Pungent	Pungent	Nose feel of pungentness	0.2 mL Vinegar/100 mL DW
Alcohol	Alcohol	Alcohol	25%(w/v) Ethanol
Floral	Floral	General flower aroma	Ten pedals of chrysanthemum
Fruity	Fruity	Ripe fruit aroma similar to pears	Crushed pear 15 g/100 mL DW
Sweet aroma	Saroma	Caramel, sweet	Starch syrup 15 g/150 mL DW
Ginseng aroma	Ginseng	Ginseng	2 g Crushed ginseng/50 mL 25% ethanol solution
Medicinal herb aroma	M-herb	Bitter medicinal plants aroma	*Ssanghwatang* 50 g/100 mL DW
Yeasty	Yeasty	Yeasty, moldy	*Nuruk* 80 g/100 mL DW
Earthy aroma	Earthy	Earthy soil aroma	Crushed Arrowroot 100 g/100 mL DW
Alcohol taste	Altas	Alcohol taste	25%(w/v) Ethanol
Sweet	Sweet	Sweet taste	Sucrose 6%(w/v)
Sour	Sour	Sour taste	Tataric acid 0.25%(w/v)
Astringent	Astringent	Mouth feel of dryness	Aluminium sulfate 0.1%(w/v)
Bitter	Bitter	Bitter taste	Anhydride caffeine 0.1%(w/v)
Medicinal herb taste	M-herb taste	Bitter medicinal plants taste	*Ssanghwatang* 50 g/100 mL DW
Yeasty taste	Ystas	Yeasty, moldy taste	*Nuruk* 80 g/100 mL DW

was randomized for each session. Samples were presented in clear plastic cups marked with three-digit numbers and covered with petri dishes. The judges scored each attribute on a scale of 0 to 9, where 9 was the highest possible score (i.e., most intense).

Statistical analysis Statistical analysis of all GC and sensory tests were performed using SAS version 6.12 (SAS Institute, Cary, NC, USA). 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®.

Results and Discussion

General composition The general composition of rice wine samples is shown in Table 3. The pH level of the 5 samples ranged from 3.89 to 4.58. In another study of 22 Korean traditional fermented rice wines, the pH levels similarly ranged widely from 3.43-4.5 (8). Because malt was added before fermentation, the Brix and reducing sugar levels in A were elevated and highest among 5 rice wine samples. The titratable acidity of A was also highest among those of other rice wines. As seen in the dark brown color of E compared to other samples, L* and a* values reflected these color differences of samples. The color values reflected the yellow coloration level of the liquor from the ingredients such as rice, *nuruk*, and other medicinal herbs and plants (8). If the wine color is too strong, the overall wine quality was typically judged to be lower. Coloring values were relatively higher in samples A and E which also showed higher yellowness b* values, 29.43 and 27.68, respectively.

Ultraviolet absorption was widely used as an index for the aromatic amino acids which contribute an earthy and yeasty taste in these fermented rice wines and liquors (8). The values for ultraviolet absorption ranged widely from 11.22-25.53 in the 5 samples. Sample A showed the highest value ultraviolet absorption value, 25.53. The high ultraviolet absorption values correlated with high intensities of 'yeasty aroma' and 'yeasty taste' in sample A. Succinic acid was the major organic acid in the 5 rice wine samples. High volatile acidity is objectionable and indicates

Table 3. General composition of 5 commercial rice wine samples[1)]

	Rice wines				
	A	B	C	D	E
pH	4.58	4.22	3.89	4.21	4.58
Brix	18.4	12.2	10.6	8.0	10.8
Titrable acidity (g/L tartaric acid)	7.2	4.9	4.8	4.1	2.8
Color					
L^*	79.93	85.11	88.01	82.88	74.08
a^*	-1.17	-1.53	-1.13	-0.8	0.46
b^*	29.43	19.56	16.98	20.34	27.68
Coloring degree (430 nm)	0.49	0.19	0.14	0.22	0.4
Ultraviolet absorption (280 nm)	25.53	13.11	11.22	17.56	20.54
Reducing sugar (mg/mL)	0.79±0.02	0.39±0.06	0.44±0.02	0.07±0.00	0.19±0.01
Organic acids (mg/mL)					
Citric acid	0.63±0.04	0.68±0.06	1.53±0.13	0.65±0.14	0.19±0.03
Malic acid	0.24±0.10	0.5±0.06	-	0.15±0.02	-
Succinic acid	1.00±0.66	0.57±0.18	4.04±0.21	3.66±0.09	0.61±0.41
Lactic acid	0.02±0.01	0.02±0.00	-	-	0.01±0.00
Acetic acid	0.31±0.16	-	-	-	0.19±0.05
Free sugars (mg/mL)					
Sucrose	3.42±0.64	5.98±1.56	1.19±0.39	-	1.84±0.17
Glucose	54.97±1.80	11.88±2.96	24.98±2.00	2.02±0.37	4.57±0.42
Fructose	48.33±3.82	48.58±9.15	46.93±2.43	54.04±2.24	47.88±2.90

[1)]Mean±SD of 3 replications.

spoilage or incorrect storage of the alcoholic beverages (20). The concentration of acetic acid formed during fermentation is usually less than 0.5 g/L, depending largely on yeast strain. Higher amounts may be formed by bacterial or oxidative yeast activity during after fermentation. Thus, monitoring changes in acetic acids and/or volatile acidity is important to detect the onset of spoilage. In this study, acetic acid was detected in samples A and E, in which the concentrations were lower than 0.5 g/L. The major free sugar detected was fructose in all 5 samples ranged from 46.93-54.04. It was suggested that fructose was added in the blending process after aging.

Aroma composition The relative peak areas of volatile compounds are shown in Table 4. A total of 33 volatile compounds were detected, including 16 esters, 5 alcohols, 2 acids, and 10 miscellaneous compounds. Alcohols and esters were the largest groups among the quantified volatiles. The most abundant compounds were alcohols such as isoamyl alcohol and 2-phenylethanol. Over 60% of the total volatile material was comprised of three compounds; isoamyl alcohol, diethyl malate, and 2-phenylethanol. All of these major compounds were yeast fermentation products and might contribute to the background or base flavor of these rice wine samples rather than to differentiate among the samples. In a study of volatile compounds in heat-sterilized *yakju* using a static head space technique (21), ethyl acetate and fusel alcohols such as isoamyl alcohol, 2-methyl-1-popanol, and *n*-propyl alcohol were detected as major volatile compounds. Those compounds were also found as major volatiles in this study. Also in the analysis of volatile compounds of *soju* (11, 22), fusel alcohols and esters were the major components of the flavor compounds.

Among esters, ethyl acetate, isoamyl acetate, ethyl hexanoate, and ethyl octanoate were the major compounds detected in the samples tested. Overall, those compounds were considered to be the major source of fruitiness in alcoholic beverages (23). The majority of these esters are formed by esterification by yeast during fermentation. In sample A which had both high reducing sugar content and Brix levels, relatively higher amounts of fruity ester compounds were detected. In comparison to sample A, the relative content of esters was the lowest in sample D which exhibited a high medicinal herb note than fruitiness. Limonene, which exhibited a pleasant balsamic odor, was identified in chrysanthemum added to both samples A and D. In samples C and D, which included varieties of medicinal herbs such as ginseng and *gugija* (*Lycii fructus*), relative peak areas of 2-methyl 1-propanol and isoamyl alcohol were greater than those in the remaining samples. However, among the many esters and alcohols were identified in this study, volatile phenols were not detected, which might contribute the medicinal herb-related aromas

Table 4. Volatile compounds isolated from 5 commercial rice wines

RI[1)]	Tentative compound	Relative peak area[2)]					ID[3)]
		A	B	C	D	E	
<900	Ethyl acetate	8.754	1.844	2.49	0.188	1.91	A
<900	Diethyl acetal	-	0.271	-	-	-	A
938	Ethyl isobutylate	0.114	0.060	-	-	0.681	A
978	Isobutyl acetate	0.119	0.189	0.497	-	0.214	A
998	Ethyl butylate	0.274	0.645	0.508	0.058	1.477	A
1053	Isobutyl alcohol	1.532	1.734	3.098	3.832	1.936	A
1083	Isoamyl acetate	0.788	3.147	5.465	0.193	2.553	A
1095	Ethyl valeate	0.096	0.096	0.429	0.023	0.483	A
1159	Isododecane	0.061	0.096	0.053	0.048	-	B
1162	Limonene	1.329	-	-	0.067	-	A
1170	Isoamyl alcohol	10.656	12.911	16.684	16.752	8.943	A
1196	Ethyl hexanoate	3.078	2.743	2.986	-	-	A
1261	Tridecane	0.244	0.07	0.012	0.023	-	B
1273	Propanedionic acid	1.607	3.007	0.322	0.481	0.323	B
1300	Ethyl heptanoate	0.290	0.165	0.235	-	0.111	A
1310	Ethyl lactate	0.239	0.073	0.068	0.107	0.234	A
1320	Hexyl alcohol	0.148	0.244	-	0.050	-	A
1365	Tetradecane	0.056	0.024	0.018	-	0.013	B
1406	Ethyl octanoate	6.370	4.395	5.059	0.270	4.276	A
1432	Isoamyl hexanoate	0.241	-	-	-	-	B
1511	Ethyl nonanoate	0.293	0.249	-	0.195	-	A
1599	Unknown	0.276	0.242	-	-	0.606	
1617	Ethyl decanoate	4.171	1.196	0.978	0.114	3.041	A
1639	Isoamyl octanoate	0.075	0.095	-	-	0.155	B
1657	Diethyl succinate	2.581	0.587	0.773	0.52	0.153	A
1812	Phenethyl acetate	0.114	0.572	0.936	0.193	0.435	A
1830	Ethyl dodecanoate	1.555	2.925	0.400	0.052	2.086	B
1892	Ethyl 3-methylbutyl butanedioate	0.154	-	-	-	-	B
1912	2-Phenylethanol	3.982	7.415	2.986	2.465	1.395	A
2037	Diethyl malate	9.000	10.92	5.367	0.887	2.583	A
2157	Pentadecanoic acid	0.571	0.98	-	0.114	1.091	B
>2100	Ethoxy triglycol	4.655	3.222	2.561	1.603	0.089	C
>2100	Ethyl palmitate	-	0.606	-	0.303	2.774	B

[1)]Linear retention index calculated on the DB-Wax capillary column using C9-C21 as external reference.
[2)]Average relative peak areas (%) of 2 replicates obtained from GC-MS total ion chromatograms.
[3)]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.

in the investigated samples. Because a SPME procedure is a more effective for the extraction of relatively low molecular weight (Mw) volatile compounds, solvent extraction and other extraction methodology will likely be applied for the extraction of higher Mw volatile compounds in future studies.

Sensory characteristics by DA To profile the sensory characteristics of each rice wine samples, the samples were evaluated by DA. Mean intensity ratings and Fisher least significant difference (LSD) are given in Table 5. 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 'floral', 'fruity', 'earthy aroma', and 'astringent' attributes. However, significant judge*sample interactions were found ($p<0.05$), the samples differed significantly in intensity for all attributes except for the above 4 attributes. When examining the mean intensities of color and aroma related attributes, overall mean sensory attributes for the samples A, B, and C were similar for the most part, except differences in 'color', 'pungent', and 'yeasty' attributes. Samples D and E showed different profiles compared to the sample A, B, and C. Sample E showed the highest intensities in 'color' and 'sweet aroma' while being lowest in other attributes except 'floral' and 'fruity'. Sample D had a dominating 'ginseng' and 'medicinal herb' aroma. We suggest that those sensory characters originated from various medicinal plants and herbs used in the production of this sample. Those typical sensory characters of Korean commercial rice wines were also observed in other studies of Korean alcoholic beverages (11, 12). In the sensory attributes related to taste, overall differences among samples were smaller than those in the color and aroma attributes. Sample D showed significantly higher intensities in the 'medicinal herb taste', while sample C showed the highest level in 'sour taste'. Sample A had the highest alcohol (18%) and sugar levels among samples, and showed the highest intensities in 'alcohol taste' and 'sweet' attributes.

The biplot of PC 1 vs. PC 2 from the principal components analysis (PCA) of the matrix of significant sensory attributes across the samples is shown in Fig. 1. The first dimension in this plot, which accounts for 57% of the variance, was a contrast between a 'color' and 'sweet aroma' vs. 'ginseng' sensory attributes. The second principal component, which accounts for 28% of the variance, seemed to show contrast between medicinal plant/herb related attributes ('medicinal herb', 'medicinal herb taste', and 'ginseng') and highly correlated 'alcohol', 'pungent', and 'sour' attributes. The distribution of samples on this PCA plot (Fig. 1) was related to the mean intensities of the investigated samples (Table 4). Sample E was located far right along the PC 1, indicating high in 'color' and 'sweet aroma'. In the other upper side of PC 1,

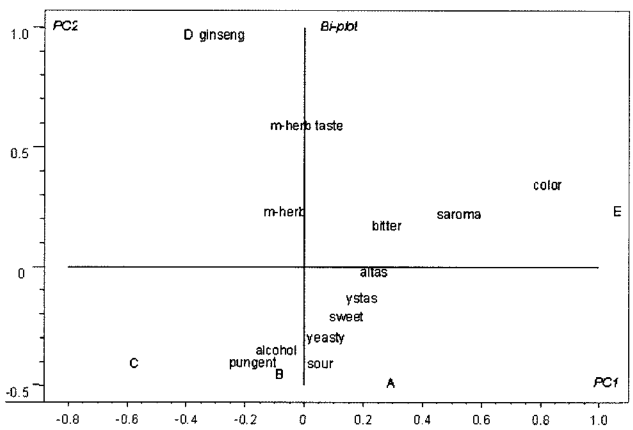

Fig. 1. Principal component analysis of descriptive data for five rice wines. (PC 1 and PC 2 are 57 and 28% of variation, respectively; Letters correspond to sensory attributes as shown in Table 1).

Table 5. Mean sensory attribute ratings of the 5 rice wines. (n = 13 judges × 3 replications)

Attribute[1)]	LSD[2)]	Rice wine[3)] A	B	C	D	E
Color****	0.38	6.36[b]	4.51[d]	3.23[e]	5.05[c]	7.90[a]
Pungent****	0.66	4.90[a]	3.79[b]	5.31[a]	3.95[b]	3.36[b]
Alcohol****	0.50	5.38[a]	5.08[ab]	4.64[bc]	4.56[c]	3.72[d]
Floral	ns	3.21	3.26	3.28	2.97	3.79
Fruity	ns	3.46	3.15	3.33	2.95	3.72
Sweet aroma****	0.44	4.36[b]	4.00[b]	4.23[b]	4.28[b]	6.61[a]
Ginseng aroma****	0.52	2.18[c]	2.10[c]	3.08[b]	5.44[a]	1.79[c]
Medicinal herb****	0.52	2.59[b]	2.82[b]	3.46[a]	3.74[a]	2.62[b]
Yeasty****	0.49	4.77[a]	3.72[bc]	4.03[b]	3.64[bc]	3.36[c]
Earthy aroma	ns	2.23	2.41	2.03	2.38	2.20
Alcohol taste****	0.44	6.10[a]	5.31[b]	4.64[c]	5.27[b]	5.62[b]
Sweet****	0.45	4.92[a]	4.59[ab]	3.97[c]	4.23[bc]	3.97[c]
Sour****	0.57	4.87[b]	4.77[b]	5.67[a]	4.18[c]	4.38[bc]
Astringent	ns	4.18	4.15	3.97	3.95	4.62
Bitter****	0.51	4.90[b]	4.49[bc]	4.31[c]	4.90[b]	5.56[a]
Medicinal herb taste****	0.53	3.72[b]	3.77[b]	4.23[b]	5.64[a]	3.95[b]
Yeasty taste*	0.46	4.79[a]	4.10[b]	4.33[b]	4.18[b]	4.46[ab]

[1)]ns, Not significant; *$p<0.05$; **$p<0.01$; ***$p<0.001$; ****$p<0.0001$.
[2)]Fisher's LSD among samples in a given attribute at 5% level.
[3)]Means with different letters across the line are significantly different at 5% level by Fisher's LSD test.

sample D was located closely with 'ginseng' and 'medicinal herb taste', and sample D showed the highest intensities among tested samples. Along the PC 2, samples A, B, and C were located in proximity with high intensities in 'alcohol' and 'pungent' attributes. These three samples showed overall similarities in sensory analysis.

When examining the relationships between sensory and physicochemical data, the sensory 'color' attribute, which showed yellowness in the sample, was significantly correlated with instrumental b* value (yellowness) and coloring degree ($r = 0.89$ and 0.97, respectively). The sensory bitterness level also significantly correlated with b* value and coloring degree (r = 0.88 and 0.88, respectively). In cases where the yellow color was darker in the sample, it also demonstrated stronger bitterness in sensory analysis. However, organic acids and free sugars didn't show significant correlations with sensory attributes.

In this study, 5 commercial rice wines were characterized using sensory and physico-chemical analysis. Three samples (A, B, and C) were similar in sensory characteristics with a medium range of medicinal plants note and high in 'alcohol' and 'pungent' attributes. On the other hand, sample D showed the highest intensities in aroma and taste attributes related to medicinal plants and herbs ('ginseng', 'medicinal herb', and 'medicinal herb taste'). Sample E had a strong yellow color and sweet aroma. These sensory and chemical characterizations are an important first step for understanding and improving the quality of Korean rice wines, *yakju*. These findings will help guide further consumer studies that will enable us to more clearly understand the consumer preferences based on the different sensory and instrumental characteristics of rice wines.

Acknowledgements

This work was supported by research grant from the Ministry of Agriculture and Fishery, Korea.

References

1. Kim HR, Ahn BH. Research trend of Korean traditional alcoholic beverage. Food Ind. Nutr. 6: 5-10 (2001)
2. Yoon SJ, Jang MS. Study on traditional folk wine of Korea in the central region of Korea - Seoul, Gyeonggi-do, Chungchung-do. Korean J. Diet. Culture 9: 341-353 (1994)
3. Yoon SJ, Jang MS. Study on traditional folk wine of Korea - In the southern region of Korea - Jeolla-do, Gyeongsang-do, and Jeju-do. Korean J. Diet. Culture 9: 355-367 (1994)
4. Yu TS, Kim J, Kim HS, Hyun JS, Ha HP, Park MG. Bibliographical study on microorganims of traditional Korean *nuruk* (Since 1945). J. Korean Soc. Food Sci. Nutr. 27: 789-799 (1998)
5. Kim JH, Lee DH, Choi SY, Lee JS. Characterization of physiological functionalities in Korean traditional liquors. Korean J. Food Sci. Technol. 34: 118-122 (2002).
6. Yang JY, Shin KR, Kim BC, Kim YD. Characterization of *yakju* prepared with yeasts from fruits 1. Volatile components in *yakju* during fermentation. J. Korean Soc. Food Sci. Nutr. 28: 794-800 (1999)
7. Yang JY, Shin KR, Kim BC, Kim YD. Characterization of *yakju* prepared with yeasts from fruits 2. Quality characteristics of *yakju* during fermentation. J. Korean Soc. Food Sci. Nutr. 28: 801-804 (1999)
8. Lee MK, Lee SW, Yoon TH. Quality assessment of *yakju* brewed with conventional *nuruk*. J. Korean Soc. Food Sci. Nutr. 23: 78-89 (1994)
9. Kim IH, Park WS, Koo YJ. Comparison of fermentation characteristics of Korean traditional alcoholic beverages prepared by different brewing methods and their quality changes after aging. Korean J. Diet. Culture 11: 497-506 (1996)
10. Lee DS, Park HS, Kim K, Lee TS, Noh BS. Determination and multivariate analysis of flavour components in the Korean folk *soju* using GC - MS. Korean J. Food Sci. Technol. 26: 750-758 (1994).
11. Hong Y, Choi EH. Flavor and sensory characteristics of *soju* fermented by the co-culture of isolates from *nuruk* and brewing mashes. Food Sci. Biotechnol. 11: 700-703 (2002)
12. Kim JH, Lee DH, Lee SH, Choi SY, Lee JS. Effect of *Ganoderma lucidum* on the quality and functionality of Korean traditional rice wine, *yakju*. J. Biosci. Bioeng. 97: 24-28 (2004)
13. Lee IS, Yang EJ, Jeong YJ, Seo JH. Fermentation process and physiochemical characteristics of *yakju* (Korean cleared rice wines) with addition of ginseng powder. Korea J. Postharvest Sci. Technol. 6: 463-468 (1999)
14. Lee DH, Kim JH, Kim NM, Lee JS. Manufacture and physiological functionality of Korean traditional liquor by using chamomile (*Matricaria hamomile*). Korean J. Food Sci. Technol. 34: 109-113 (2002).
15. Yu HE, Lee DH, Lee JH, Choi SY, Lee JS. Quality characteristics and cardiovascular activities of Korean traditional wines and liquors. Food Sci. Biotechnol. 14: 772-777 (2005)
16. Miller GL. Use of dinitrosalycilic acid reagent for the determination of reducing sugar. Anal. Chem. 31: 426-428 (1959)
17. McCord JD, Trousdale E, Ryu DY. An improved sample preparation procedure for the analysis of major organic components in grape must and wine by high performance liquid chromatography. Am. J. Enol. Viticult. 35: 28-29 (1984)
18. Frayne RF. Direct analysis of the major organic components in grape must and wine using high performance liquid chromatography. Am. J. Enol. Viticult. 37: 281-287 (1986)
19. Walker T, Morris J. Threlfall R, Main G. Analysis of wine components in Cynthiana and Syrah wines. J. Agr. Food Chem. 51: 1543-1547 (2003)
20. Nurgel C, Pickering GJ, Inglis DL. Sensory and chemical characteristics of Canadian ice wines. J. Sci. Food Agr. 84: 1675-1684 (2004)
21. Kang MY, Yoo SS, Park YS, Mok C, Chang HG. Analysis of flavors in heat-sterilized *yakju*. Food Eng. Prog. 3: 170-175 (1999)
22. In HY, Lee TS, Lee DS, Noh BS. Volatile components and fusel oils of *soju* and mashes brewed by Korean traditional method. Korean J. Food Sci. Technol. 27: 235-240 (1995).
23. Etievant PX. Wine. pp. 483-546. In: Volatile Compounds of Food and Beverages. Maarse H (ed). Dekker, New York, NY, USA (1991)