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Physicochemical characteristics and electric conductivity of various fruit wines

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Abstract

Quality characteristics of Korean commercial apple wine, Moru wine, red wine, white wine, and raspberry wine were compared in this study. The aim of this study is to improve the quality of fruit wines, based on physicochemical characteristics, fermentation quality, correlation between soluble solid and sugar content, and a relationship between electrical conductivity and other analyzed parameters. Though soluble solid content in fruit wines was proportional to sugar content by HPLC, a soluble solid content did not indicate total sugar content fully in fruit wines. Red wine, white wine, and Moru wine had approximately 0.26-5.83, 1.28-1.51, and 0.20-0.50% of high sugar content as compared to other fruit wines, respectively. In addition, Raspberry wine had approximately 13.4-14.2 and 4.24-5.15% of ethanol and sugar content, respectively. Among four kinds of commercial fruit wines, Moru wine had the highest K content, A_{280}, A_{320}, A_{420}, and A_{520} value, protein content, and electrical conductivity than those of other fruit wines. Electrical conductivity of Moru wine had a similar result, and the electrical conductivity of fruit wines had a linear correlation to chromaticity.

Introduction

Fruit wines are fermented by yeasts using crushed matured fruits (grapes, apples, pears, raspberry, and strawberry) with an additional sugar supplement as occasion demands, and then are aged for some period, and bottled (Margalit, 2004). Sour taste and a mouth-feel by phenolic compounds play an important role for an assessment of fruit wine-tastes. Moru (*Vitis amurensis*) fruits have the extremely high contents of organic acids and anthocyanins, as compared to other grape species, and it causes the thick color and the strong astringent taste of Moru wines (Choi *et al*., 2006; Jeong *et al*., 2007). Although apples and grapes with proper contents of organic acids can be brewed by itself without an adjustment of its contents and nutrition, the raspberries have too much organic acids for brewing wine and should be diluted to appropriate concentration of organic acids for brewing (Ku and Mun, 2008; Kim *et al*., 2012). Characteristics of fruits influence a brewing efficiency and the fermentation.

Korean customers prefer wines with a low alcohol, high sweetness, and low tannins/organic acids (Yoo *et al*., 2008). Korean Moru wine had an extremely high concentration of anthocyanins than imported red wines (Chang *et al*., 2008). Difference in acidity and phenolic compounds content affects a preference of customers for fruit wines. To adjust the phenolic compound content to acceptable level for maintaining nutrition and fermentation characteristics in wines, the cold stabilization, electrodialysis, a treatment of fining agents, and membrane filtration methods are applied to brewing wines (Chung *et al*., 2003; Lee and Kim, 2006; Cabrera *et al*., 2011).

Aim of this study is to evaluate the characteristics of Korean commercial fruit wines, based on physicochemical characteristics, a fermentation quality, a correlation between soluble solid and sugar content, and a relationship between electrical conductivity and other analyzed parameters.

Materials and Methods

Materials

Two brands of Moru wines, a white wine, raspberry wines, and four deferent brands of red wine were purchased from commercial markets at July 2012 in Korea. Market prices of all commercial wines were less than 3 US $/750 ml. For lab-brewed wines, Moru (*Vitis amurensis*) and apple (*Malus pumila*, Fuji) from Jechon, Chunbuk, Korea were used and simply washed for preparation of fermentation

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mixture. Whole Moru and quartersawed apples were crushed and used for fermentation of wines. Sucrose, $K_2S_2O_5$, pectinase (Pectinex 100 L), and *Saccharomyces cerevisiae* were obtained from Cheil-Jedang Co. (Seoul, Korea), Sigma (St. Louis, MO, USA), Novozyme (Bagsvaerd, Denmark), and Red star premier cuvee (Lesaffre, France), respectively.

Preparation of lab-brewed wine

For brewing apple and Moru wine in a laboratory, a 5 l of fruit juice and 150 mg/l of $K_2S_2O_5$ were added to 10 l of a plastic fermentation jar, and its sugar content were adjusted to 24°Brix using sucrose. And then fermentation mixtures were stored at room temperature for 16 hrs. Pectinase (2 ml, Pectinex 100 L) and *S. cerevisiae* (2 g) were added to material mixture, followed the fermentation at 20^{o}C for 2 weeks. Then the fruit wines were filtered to remove solid materials and were matured at 20^{o}C for another 30 days.

Determination of ethanol content

Ethanol concentration in fruit wines were analyzed using an Alcoholyzer (Model AT/DMA 4500M, Anton Paar, GRAZ, Austria).

Determination of pH and acidity

The pH of fruit wines was measured by a pH meter (model 725p, Istek Co., Seoul, Korea). For the determination of acidity, samples (10 ml) were titrated with 1-2 drops of phenolphthalein to pH 8.3 with 0.1N NaOH. Total titratable acidity (TTA) was calculated by the following equation using consumed amounts (ml) of 0.1N NaOH at the end-point (pink color).

Acidity (%) = [(ml of 0.1 N NaOH) x (N NaOH) x 0.067 (malic acid coefficient) x 100] /ml sample

Determination of soluble solid and total sugar content

Total water soluble solids in fruit wines were quantified by a Refractometor (N-1a, ATAGO, Tokyo, Japan). For the measurement of fructose, glucose and sucrose, the fruit wines were cleaned with 0.45 µm-syringe filter, and 20 µl of samples were analyzed using HPLC (1200, Agilent Technologies Inc., Santa Clara, CA, USA) equipped with gel filtration column (300x8 mm, Shodex Ionpack KS-802, Tokyo, Japan). Deionized water was flowed at the rate of 0.4 ml/min as a mobile phase, and a Refractive Index Detector was used for determination of sugar content. Authentic fructose, sucrose, and glucose (Sigma) were used to plot a standard curve at 0.01-5% concentration ranges for a quantification of sugar content. Coefficients (R^2 value) for standard curve of fructose, glucose, and sucrose were 0.97, 0.99, and 0.99, respectively.

Color analysis

Color of fruit wines was determined by a spectrophotometer (UV-visible spectrophotometer UV-1650 PC, Shimadzu, Japan) on 280, 320, 420, and 520 nm using 10 mm quartz cuvette, and the distilled water was used as a blank. Total phenol content, hydroxycinnamate, the brownness, the anthocyanin content, chromaticity, and brightness were expressed as a value of A_{280}, A_{320}, A_{420}, A_{520}, A_{420}+A_{520}, and A_{420}/A_{520}, respectively.

Determination of protein content

Protein content was determined by protein assay kit (Bio-Rad Laboratories, CA, USA) and bovine serum albumin (Bio-Rad Laboratories), according to the manual. Intensity of protein sample was measured on 595 nm by a spectrophotometer (UV-visible spectrophotometer UV-1650 PC, Japan).

Determination of electric conductivity (EC)

For detection of electric conductivity, the temperature of samples was maintained at 25^{o}C. Electric conductivity was measured by a multimeter (S-47K, Metter Toledo, OH, USA), and was expressed as millisimens per centimeter (mS/cm).

Statistical analysis

All results were analyzed using one-way analysis of variance (ANOVA), a multiple and Duncan's multiple comparison test for individual comparisons (Albright *et al*., 1999).

Results and Discussion

Ethanol content of fruit wines

Ethanol contents for ten kinds of commercial fruit wines and two kinds of lab-brewed wines were investigated in this study. Detected ethanol contents of fruit wines had slightly higher values, which were approximately 102.4±7.2% of the labeled ethanol content on bottles of each commercial fruit wines (Table 1). Their ethanol contents for commercial fruit wines and lab-brewed wines were approximately 10.0-14.2 and 12.9-15.6%, respectively, in an order as followings; raspberry wine > Moru wine > white wines > red wines.

Ethanol contents in fruit wines are dependent on the sugar content in fermentation mixture in the early stage. Although theoretically 180 g of sugar produces 92 g of ethanol, practically less amount of ethanol is produced in wine fermentation. Therefore, the ethanol content 10.0-14.2% labeled

Table 1. Ethanol concentration of various wines

	Ethanol content (%)	
	Supplier[1)]	This work
Moru wine	14	14.2±0.4[b,2)]
	12	12.9±0.4[c]
	Lab-brewed	12.9±0.2[c]
White wine	13	13.7±0.4[bc]
	11	11.5±0.0[d]
Red wine	13	12.5±0.4[c]
	11	10.1±0.1[e]
	10	10.0±0.1[e]
	10	10.3±0.1[e]
Apple wine	Lab-brewed	15.7±0.1[a]
Raspberry wine	14	13.4±0.1[b]
	12	14.2±0.2[b]

[1)] Ethanol content written in a label by supplier.
[2)] All values were expressed as the mean ± standard deviation (S.D.).
[a-e]Means with different alphabets are significantly different at 95% level of confidence.

Table 2. Sugar concentration and soluble solid (°Brix) of fruit wines

	Sugar concentration (%)				°Brix
	Fructose	Glucose	Sucrose	Total	
Moru wine	0.33	0.16	0.02	0.50[c1)]	8.4
	0.04	0.13	0.04	0.20[c]	7.1
	0.07	0.22	0.00	0.28[c]	8.1
White wine	0.84	0.67	0.00	1.51[bc]	7.3
	0.45	0.66	0.17	1.28[bc]	7.1
Red wine	0.12	0.07	0.07	0.26[c]	7.3
	2.10	3.10	0.34	5.54[a]	12.3
	2.73	2.53	0.56	5.83[a]	12.4
	2.23	2.70	0.02	4.96[ab]	11.3
Apple wine	0.12	0.59	0.00	0.71[c]	8.1
Raspberry wine	2.76	2.30	0.08	5.15[ab]	13.2
	2.23	1.93	0.40	4.24[ab]	11.0

[1)] Values are the Mean. [a-c]Means with different alphabets are significantly different at 95% level of confidence.

Table 3. Acidity and pH of fruit wines

	Acidity (%)	S/A ratio[2)]	pH
Moru wine	0.67[ab]	12.5	3.82[c]
	0.65[bc]	10.9	3.53[d]
	0.78[a]	10.4	4.01[a]
White wine	0.72[ab]	10.1	3.10[g]
	0.77[ab]	9.2	3.15[fg]
Red wine	0.55[c]	13.3	3.54[d]
	0.42[de]	29.3	3.00[h]
	0.40[e]	31.0	2.80[i]
	0.52[cd]	21.7	3.53[d]
Apple wine	0.55[c]	14.7	3.86[b]
Raspberry wine	0.63[bc]	20.9	3.18[f]
	0.44[de]	25.0	3.31[e]

[1)] Values are the Mean. [a-i]Means with different alphabets are significantly different at 95% level of confidence.
[2)] S/A ratio are from ratio of soluble solids(in Table 2)/acidity(°Brix /%).

on the bottles of commercial wines is obtained from approximately 20.0-28.4°Brix of soluble solid content in fermentation-mixture. Soluble solid contents of apple, raspberry, grape, and Moru were reported to be approximately 15, 6.9-7.8, 15-20, and 16-18°Brix, respectively (Kim *et al*., 2012). Therefore, it is necessary to add the sugar supplement for obtaining approximately 10 % final ethanol level in most fruit wines.

Total sugar content of fruit wines

Soluble solid and sugar content in fruit wines were determined using a Refractometer and a HPLC system, and showed approximately 7.1-13.2°Brix and 0.2-5.8%, respectively (Table 2). Average sugar contents of commercial Moru wine, white wine, red wine, and raspberry wine were 0.35, 1.4, 4.14, and 4.7%, respectively. Raspberry wine and red wine had relatively higher sugar contents than Moru wine ($p < 0.05$). Total sugar was composed of a lot of monosaccharide fructose/glucose and small amount of disaccharide sucrose. Disaccharide sucrose may be degraded to monosaccharide fructose and glucose by the sucrase in brewing yeasts (Lehle *et al.*, 1979).

Generally, though the soluble solids in fruit wines are closely related to sugar content, it is not represent sugar concentration totally. When we plotted the X-Y correlation for Table 2 results, sugar concentration and soluble solid had a linear correlation ($Y = 0.8658X + 7.3446$, $R^2 = 0.860$), and the content of soluble solids in fruit wines had more than 7.0°Brix without sugar. Sugar contents, organic acids, nitrogen, inorganic nutrients, and ethanol contents influence a soluble solid content in fruit wines. In the fruit-fermentation mixture, approximately 5% of sugar is conversed to organic acids, such as glycerol, acetic, lactic, and succinic acid, 2.8% of sugar is utilized as a carbon source for growth of yeasts, and only 0.2% of sugar is remained in fruit wines finally. Therefore, approximately 92% of sugar is utilized for the ethanol fermentation (Kim *et al*., 2012). For this reason, the sugar content, estimated as a soluble solid content, are not reflecting enough the amount of sugar in fruit wines on the brewing process of fruit wines. In consideration of the Korean preference for sweet red wines (Yoo *et al*., 2008), Moru wine with extremely low sugar contents is necessary to raise and maintain a soluble solid content to more than 10°Brix.

Total acidity of fruit wines

Total acidity of commercial raspberry wines and red wines had approximately 0.44-0.63% and 0.40-0.55%, respectively, which were relatively low as compared with those of white wines (0.72-0.77%) and Moru wines (0.65-0.67%) in a significant difference ($p < 0.05$) (Table 3). In case of lab-brewed Moru wine, the total acidity was approximately 0.78%, which was higher than that (0.56%) of apple wine in a significant difference ($p < 0.05$).

Generally, a sweet taste of fruit wines and their acidities were expressed well as the soluble solid/acidity (S/A) ratio, which is usually approximately 16-29, in which a good balance between sweet taste and its acidity were reported (Kim and Kim, 1997). The S/A ratios of commercial Moru wines, white wines, red wines, and raspberry wines were investigated to be approximately 10.9-12.5, 9.2-10.1, 13.3-31.0, and 20.9-25.0, respectively. S/A ratios of commercial red

Table 4. Mineral contents of fruit wines

	Major mineral(mg/l)						
	K	P	Mg	Ca	Na	Si	Se
Moru wine	956$^{b1)}$	193^{b}	95^{a}	75^{b}	3.03^{h}	6.87^{d}	1.50
	953^{b}	174^{bc}	79^{ab}	97^{a}	5.27^{g}	6.15^{d}	1.25
	1224^{a}	281^{a}	80^{ab}	111^{a}	2.14^{h}	12.09^{a}	3.32
White wine	363^{e}	156^{bc}	67^{b}	80^{b}	17.49^{d}	8.30^{cd}	1.92
	286^{e}	127^{bc}	64^{b}	100^{a}	21.63^{c}	10.03^{b}	1.64
Red wine	707^{c}	313^{a}	85^{ab}	70^{bc}	10.32^{f}	9.60^{bc}	1.32
	140^{f}	39^{ef}	16^{c}	23^{d}	108.72^{a}	2.23^{e}	1.54
	121^{f}	28^{ef}	18^{c}	16^{d}	3.88^{gh}	2.06^{ef}	1.57
	572^{d}	125^{cd}	63^{b}	64^{b}	6.68^{g}	7.53^{d}	1.63
Apple wine	699^{c}	64de	24^{c}	26^{d}	3.62^{gh}	0.72^{f}	1.29
Raspberry wine	322^{e}	62de	34^{c}	55^{c}	36.35^{b}	9.60^{bc}	1.86
	170^{f}	21^{f}	21^{c}	22^{d}	14.56^{e}	1.90^{ef}	2.04

	Minor mineral (mg/l)				
	Cu	Zn	Pb	Cd	Ag
Moru wine	0.025	0.663	0.044	ND$^{1)}$	ND
	0.034	0.250	0.038	ND	ND
	0.113	0.312	0.129	ND	ND
White wine	0.026	0.285	0.058	ND	ND
	0.018	0.251	0.073	ND	ND
Red wine	0.043	0.301	0.034	ND	ND
	0.009	0.054	0.068	ND	ND
	0.033	0.046	0.032	ND	ND
	0.025	0.263	0.050	ND	ND
Apple wine	0.047	0.145	0.055	ND	ND
Raspberry wine	0.186	0.384	0.045	ND	ND
	0.396	0.166	0.075	ND	ND

[1)] Values are the Mean. $^{a-h}$Means with different alphabets are significantly different at 95% level of confidence. [1)] ND= not detected.

wines and raspberry wines observed in 16-29 range, however Moru wine and white wine had extremely low S/A ratio.

Apples contain malic acid as a major organic acid and have approximately 0.25-0.67 of total acidity. Raspberries have citric acid and malic acid and its acidity are approximately 1.0-1.5%. Acidities are appeared to be different according to the producing area (Do, 1995; Whang *et al*., 2000; Lee and Ahn, 2009). In addition, the grapes and Moru have commonly malic acid and tartaric acid as a major organic acid. Grapes for white wines and red wines have approximately 0.4-1.4 and 0.5-0.7% of total acidity, respectively, and total acidity of Moru shows approximately 0.8-1.2% (Lee *et al*., 2004; Chang *et al*., 2008; Kim and Kang, 2008).

pH of fruit wines

Concentrations of hydrogen ion in commercial Moru wine, white wine, red wine and raspberry wines showed approximately pH 3.53-3.82, 3.10-3.15, 2.8-3.54, and 3.18-3.31, respectively (Table 3). Moru wines showed the highest pH level among four kinds of fruit wines. Red wine and Moru wine had lower total acidity than material mixture in the early stage of brewing. The reason is that decreasing amounts of tartaric acid and malic acid in fermentation mixture is more than increasing amounts of materials, such as volatile acids, lactic acid, and succinic acid during fruit wine-fermentation (Kim and Kim, 1997; Kim *et al*., 2012). Hydrogen ion concentration of apple juice is approximately pH 4.1-4.4 and changed slightly to acidic pH 3.9-4.1 during brewing apple wines (Choi *et al*., 2011). In this study, the lab-brewed apple wine and Moru wine showed a similar pH changes during brewing wines.

Minerals of fruit wines

In addition, the mineral composition in commercial fruit wines was investigated, as shown in Table 4. Among the several minerals, the potassium (K) and the phosphorus (P) were the highest concentration in fruit wines. Content of K was approximately 953-956, 286-363, 140-707, and 170-322 mg/l in Moru wines, white wines, red wines, and raspberry wines, respectively, and Moru wines had the highest K content among four kinds of fruit wines. Potassium ions are combined to tartaric acid, and form potassium bitartarate ($C_4H_5O_6K$). The solubility of potassium bitartarate is high and is not precipitated easily in water, whereas it has low solubility and is precipitated in ethanol (Jackson, 2008). Tartaric acid is a specific organic acid detected in Moru and grape fruits, and the precipitation of potassium bitartarate causes a problem in brewing process of Moru wine and grape wine. Insufficient removal of K or tartaric acid from fruit wines causes a precipitation of potassium bitartarate in fermentation/aging/clarification/bottling procedure of fruit wines. That's why customers misunderstand the precipitated potassium bitartarate as a broken glasses or sugar particles, and it causes a decline of purchasing needs (Delfini and Formica, 2001; Jackson, 2008).

Average P content was found to be approximately 184, 142, 126, and 41 mg/l in Moru wines, white wines, red wines, and raspberry wine, respectively, and Raspberry wines had the lowest P content among fruit wines. Average magnesium (Mg) was detected to be approximately 87, 66, 45, and 27 mg/l in commercial Moru wines, white wines, red wines, and raspberry wine, respectively, and showed the highest value in Moru wines and the lowest value in raspberry wines. In addition, the calcium (Ca) was measured to be approximately 16-100 mg/l range. Moru wines, white wines, red wines, and raspberry wines had 86, 20, 32, and 26 mg/l of average Ca content, respectively, and Moru wines had the most abundant Ca content among tested fruit wines.

Content of sodium (Na) was approximately 3.03-108.7 mg/l in commercial fruit wines. Moru wines, white wines, red wines, and raspberry wines had an average Na content with 1.6, 2.9, 50.9, and 0.4 mg/l, respectively. Red wines showed the highest Na content specifically among four kinds of fruit wines. In red wines, the abnormally and extremely high Na content indicates the possibility that Na was added in some red wines for prevention of potassium bitartarate-precipitation in a brewing procedure. As compared with potassium bitartarate in ethanol, sodium bitartarate is more soluble and causes less precipitation and stable colloids in ethanol, after bottling (Delfini and Formica, 2001; Jackson, 2008).

Silicon (Si) is an abundant mineral, next to aluminum (Al) in soils, and is closely related with the bone health. Si was detected to be approximately 1.9-10.03 mg/l in commercial fruit wines. Moru wines, white wines, red wines, and raspberry wines had approximately 6.5, 9.2, 5.4, and 5.8 mg/l of average Si content, respectively, and white wines showed the highest Si content among them. Selenium (Se) contents were approximately 1.3-3.3 mg/l range in commercial fruit wines. Average contents of Se were approximately 1.4, 1.8, 1.5, and 2.0 mg/l in Moru wines, white wines, red wines, and raspberry wines, respectively. In addition, approximately 0.009-0.396 mg/l of Copper (Cu) was detected in commercial fruit wines. Moru wine, white wine, red wines, and raspberry wines had approximately 0.03, 0.022, 0.028, and 0.291 mg/l of average Cu content, respectively, and the highest Cu content was found in raspberry wine (Table 4). Zinc (Zn) was detected to be 0.046-0.663 mg/l range in commercial fruit wines, and average Zn contents were approximately 0.457, 0.268, 0.166 and 0.275 mg/l in Moru wine, white wine, red wine and raspberry wine, respectively.

Harmful heavy metal lead (Pb), cadmium (Cd), and silver (Ag) are limited strictly to use in foods (No *et al*., 2010). Average Pb contents in commercial Moru wine, white wine, red wine, and raspberry wine were approximately 0.041, 0.066, 0.046, and 0.060 mg/l, respectively. European Union (EU) and Codex Alimentarius Commission (CODEX) standard define the limit of Pb as the less than 0.2 mg/l in wine. All tested fruit wines had a less content than the international standard for Pb in wines. According to the actual condition survey for heavy metals in Korean alcoholic beverages, the contents of Pb, Cd, and Ag in fruit wines were reported to be approximately 0.013, 0.092, 0.04 mg/l, respectively (No *et al*., 2010). In addition, no Cd and Ag were detected in wines in this study.

Color of fruit wines

Fruit wines contain the polyphenolic compounds, proteins, and minerals as well as ethanol, which affect the sensory values of red wines (Kim *et al*., 2012). Because an intensity of absorbance on the specific wavelength is proportional to content of specific polyphenolic compound in red wines, the total phenolic content, hydroxycinnamate content, and anthocyanins content were expressed as a value of A_{280}, A_{320}, and A_{520}, respectively. Brownness, color intensity, and brightness of fruit wines were expressed as a value of A_{420}, A_{420}+A_{520}, and A_{420}/A_{520}, respectively (Table 5). Total phenolic contents, expressed as a A_{280} value, of Moru wine, white wine, red wine, and raspberry wine had approximately 58.6, 9.1, 29.4, and 19.5 value, respectively. Among them, Moru wine contained the most abundant phenolic content, and white and raspberry wine had relatively low content of phenolic compounds. Contents of hydroxycinnamate, expressed as the A_{320} value, for Moru wine, white wine, red wine, and raspberry wine were approximately 26.2, 5.8, 11.7, and 8.6, respectively. Brownness and anthocyanins content of Moru wine, white wine, red wine, and raspberry wine were approximately 6.7, 1.1, 2.6, and 5.1 of A_{420} value and approximately 9.3, 1.2, 2.2, and 3.5 of A_{520} value, respectively. Color intensity (A_{420}+A_{520}) and brightness (A_{420}/A_{520}) for Moru wine, white wine, red wine, and raspberry wine had approximately 16.0, 2.2, 4.8, and 8.6, and were approximately 0.9, 2.1, 2.3, and 3.5, respectively. Among four kinds of fruit wines, Moru wines had the highest total phenol content, hydroxycinnamate, antocyanins, brownness, and color intensity, whereas white wines had the lowest levels for all color parameters. It was reported that Korean grapes contain approximately 95-345, 26-89, and 0.03-0.28 mg/100 g of total phenolic acid, flavonoids, and content of phenolic compounds such as stibene, respectively (National Academy of Agricultural Science, 2009). Content of tannins and anthocyanidins, a major phenolic compound in Moru, were approximately 400-500 mg/l, which were approximately 4-10 times more than those of Korean grapes. Anthocyanidins are classified to red-colored cyanidins and purple-colored delphinidins.

Table 5. Color parameters of fruit wines

	A_{280}	A_{320}	A_{420}	A_{520}	A_{420}+A_{520}	A_{420}/A_{520}
Moru wine	63.47^{b}	26.47^{b}	7.47^{ab}	12.80^{a}	20.27^{a}	0.60
	53.67^{b}	25.93^{b}	5.87^{ab}	5.80^{ab}	11.67^{ab}	1.11
	111.20^{a}	50.80^{a}	17.93^{a}	7.50^{ab}	25.43^{a}	2.46
White wine	8.67^{d}	5.73^{c}	1.27^{b}	1.13^{b}	2.40^{b}	1.28
	9.53^{d}	5.87^{c}	0.87^{b}	1.20^{b}	2.07^{b}	2.96
Red wine	60.00^{b}	19.40^{b}	3.33^{b}	0.80^{b}	4.13^{b}	5.21
	9.73^{d}	3.80^{c}	1.20^{b}	3.20^{b}	4.40^{b}	0.33
	9.47^{d}	5.20^{c}	1.93^{b}	3.00^{b}	4.93^{b}	0.62
	38.53^{c}	18.20^{b}	4.00^{b}	1.73^{b}	5.73^{b}	3.12
Apple wine	15.13^{d}	7.80^{c}	1.33^{b}	2.13^{b}	3.46^{b}	0.57
Raspberry wine	18.00^{d}	7.87^{c}	1.80^{b}	5.33^{ab}	7.13^{b}	0.31
	20.93^{d}	9.27^{c}	8.33^{ab}	1.67^{b}	10.00^{ab}	6.62

[1)] Values are the Mean. [a-d]Means with different alphabets are significantly different at 95% level of confidence.

Table 6. Protein concentration and electric conductivity of fruit wines

	Protein (mg/l)	EC (mS/cm²)
Moru wine	542b[1)]	2.79[c]
	638[a]	2.97[b]
	508[b]	4.05[a]
White wine	50[e]	1.86[f]
	47[e]	1.74[g]
Red wine	501[b]	2.57[d]
	173[d]	1.36[h]
	172[d]	0.88[k]
	313[c]	1.99[e]
Apple wine	160[d]	1.85[f]
Raspberry wine	163[d]	1.22[i]
	281[c]	0.73[j]

[1)] Values are the Mean. [a-j]Means with different alphabets are significantly different at 95% level of confidence.
[2)] EC indicates electric conductivity.

Table 7. Correlation between electric conductivity and physicochemical parameters of fruit wines

Parameters	Equation	R^2 [2)]
Acidity (%)	Y[1)] = 0.1008X + 0.3901	0.499
pH	Y = 0.2483X + 2.9546	0.498
A_{280}	Y = 32.574X - 31.243	0.869
A_{320}	Y = 14.198X - 13.225	0.882
A_{420}	Y = 4.5639X - 4.5542	0.646
A_{520}	Y = 3.418X - 2.7656	0.542
$A_{420}+A_{520}$	Y = 7.9827X - 7.3204	0.668
A_{420}/A_{520}	Y = -0.04X + 1.5576	0.001
K	Y = 367.04X -162.52	0.913
P	Y = 94.497X - 63.945	0.815
Mg	Y = 24.179X + 1.6429	0.704
Ca	Y = 30.338X - 2.143	0.717
Na	Y = -9.4484X + 36.594	0.144
Si	Y = 2.9324X - 0.0378	0.477
Protein	Y = 152.4X - 9.2175	0.516

n = 12. [1)] Y indicates electric conductivity. [2)] R^2 indicates coefficient of determination.

While raspberry and some grape species show an abundant cyanidins content, Moru species have even more delphinidin than cyanidins (Kim *et al*., 2012). Additionally, it was investigated that raspberry juice had approximately 34.7 mg/100 g of anthocyanins, and its composition was found to be cyanidin 3-O-sambubioside, cyanidin 3-O-xylosambubioside, cyanidin 3-O-rutinoside, pelargonidin 3-O-rutinoside, delphinidin 3-O-rutinoside, and delphinidin 3-O-glucuronide (Ku and Mun, 2008).

Protein characteristics of fruit wines

In fruits, proteins mainly exist as enzymes involved in metabolisms of carbohydrates, lipids, proteins, and nucleic acids (Kim *et al*., 2012). As shown in Table 6, Moru wine had the highest average protein content (590 mg/l), and on the other hand, white wine had the lowest protein content (49 mg/l). Red wine and raspberry wine had approximately 290 and 220 mg/l of average protein content, respectively.

Korean grapes, apples, and raspberries were reported to have approximately 0.3-0.6, 0.2-0.4, and 0.2-0.4 g/100 g depending on the species (National Academy of Agricultural Science, 2011). Fruit wines have a low pH circumstance than isoelectric point (pI) of proteins. Therefore most proteins in fruit wines are charged positively and are not precipitated easily. Main floating materials in fruit wines are proteins, pectin, which is not utilized for fermentation, and phenolic compounds. These floating materials are precipitated very slowly for several years, and cause the expensive storage costs for a long time (Delfini and Formica, 2001; Jackson, 2008).

Electrical conductivity of fruit wines

Electrical conductivity (EC) in fruit wine is dependent upon ion compounds, and is proportional to their contents. Average EC of commercial wines was shown in Table 6. Moru wine, white wine, red wine, and raspberry wine had approximately 2.88, 1.8, 1.7, and 0.98 mS/cm of EC, respectively. Among tested four kinds of wines, Moru wine had the highest EC value, and raspberry wine had the lowest EC value. EC values can be used for a decision of additional clarification-step in fruit wines (Jackson, 2008). The correlation between EC and physicochemical parameters (Table 1-6) was investigated as shown in Table 7. The EC in fruit wines had a high correlation to color-indicating A_{280}, A_{320}, A_{320}, and A_{420}, and mineral K, P, Mg, and Ca, whereas a correlation with protein, pH, and acidity were relatively low.

In this study, we compared the physicochemical characteristics of Korean commercial apple wine, Moru wine, raspberry wine, and white wine. Solid content in fruit wines was proportional to sugar content detected by HPLC, however it was not proper to express the realistic sugar content in fruit wines. Among four kinds of commercial wines, raspberry wine and red wine had the high sugar content, but Moru wine had the low sugar content and very dry taste. S/A ratio, which is closely related with quality of fruit wines, showed approximately 13.3-31.0 and 20.9-25.0 in red wine and raspberry wine, respectively, and was balanced well between sweet taste and acidity. On the other hand, Moru wine and white wine had extremely low S/A ratio. In addition, Moru wine had extremely high level of K, A_{280}, A_{320}, A_{420}, A_{520}, protein, and EC. EC values had a high correlation to A_{280}, A_{320}, A_{320}, A_{420}, minerals K, P, Mg, and Ca content. Taken these results, it is supposed that the additional clarification-step by consideration of EC value will be helped improve quality of fruit wines.

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