PAPER

INFLUENCE OF DIFFERENT PRETREATMENTS AND CHAPTALIZATION TYPES ON THE PHYSIOLOGICAL CHARACTERISTICS AND ANTIOXIDANT ACTIVITY OF APRICOT (*PRUNUS ARMENIACA* L.) WINE

K.-T. CHOI[1], S.-B. LEE[1], J.-S. CHOI[1] and H.-D. PARK*[1,2]

[1]School of Food Science and Biotechnology, Kyungpook National University, 80 Daehakro, Daegu 41566, South Korea

[2]Institute of Fermentation Biotechnology, Kyungpook National University, 80 Daehakro, Daegu 41566, South Korea

*Corresponding author: hpark@knu.ac.kr

ABSTRACT

The effects of pretreatment (pectinase and $CaCO_3$) and chaptalization (sugar and puree concentrate) on the quality of apricot wine were investigated. Pectinase-treated apricot wines had increased amounts of total phenolics, flavonoid compounds, as well as antioxidant activities. The apricot wine chaptalized with puree concentrate and treated with pectinase (PCP) showed the highest total acidity and some organic acid contents, which resulted in the strongest sourness. In contrast, the apricot wine treated with pectinase and $CaCO_3$ (SCPC and PCPC) showed the lowest total acidity and least sourness. Antioxidant activities of PCP and PCPC wines were higher than other wines, and other pectinase-treated wines were also higher than the control wine. Volatile higher alcohols and terpenes increased in all the pectinase-treated wines, whereas volatile ester compounds were decreased. Sensory evaluation showed that SCPC, PCP, and PCPC wines obtained significantly high flavor scores, and SCPC and PCPC wines obtained the highest overall preference scores.

Keywords antioxidant, apricot wine, aroma profile, fruit wine, pretreatment

1. INTRODUCTION

Apricot (*Prunus armeniaca* L.) is a stone fruit mainly grown in China, the Mediterranean European countries, Turkey, and the USA (SOLIMAN, 2013). Consumption of apricot has shown human health benefits because of its antioxidant, anti-inflammatory, and immune-stimulating properties, which might be attributed to the presence of various phytochemicals, such as carotenoids, polyphenols, vitamins, and fiber (DRAGOVIC-UZELAC *et al*., 2007; HEGEDŰS *et al*., 2010; MADRAU *et al*., 2009). Due to the various advantages of apricot, the development of apricot wine has good potential for commercialization.

Despite the excellent functionality, the strong sourness of apricot, associated with its notably high acidity, has still not been acceptable, which prevents the development of apricot wine. Pretreatment of high-acid wines by deacidification offers a suitable resolution to this issue, and it is commonly carried out by physicochemical methods, such as carbonic amelioration, blending, chemical neutralization, and precipitation, and by biological methods, such as malolactic fermentation (LOIRA *et al*., 2018; VOLSCHENK *et al*., 2006). Among these methods, chemical neutralization by the addition of salts ($CaCO_3$) to deacidify fruit wines is usually preferred because it reduces the risk of increasing the pH levels and, additionally, prevents microbial problems (COSME *et al*., 2018; MATTICK *et al*., 1980).

Pectinases are enzymes that are generally added to maximize juice yield and act by degrading the pectins that interfere with extraction and clarification of most fruit juices (SHARMA *et al*., 2017). In addition, treatment of fruit juice with pectinase has been reported to increase the amounts of phenolics and anthocyanins, facilitate filtration, and contribute to the release of the molecules responsible for aroma and color, two of the major components that characterize a wine (PARDO *et al*., 1999; PINELO *et al*., 2006; WATSON *et al*., 1999).

Some fruits with low sugar content must be chaptalized to obtain sufficient sugar content for making wine (JARVIS, 1996; MIYAWAKI *et al*., 2016). Several researchers have used various technologies, such as freeze-concentration and nanofiltration, to decrease the levels of available water in fruits deficient in sugar content, thereby concentrating the sugar content (BANVOLGYI *et al*., 2006; CLARY *et al*., 2006; MIYAWAKI *et al*., 2016). Puree concentrate can also be a suitable alternative instead of chaptalization because of its concentrated sugar content and using the apricot puree concentrate could reduce labors and enhance productivity by skipping the process of washing the fruit and removing the seed for the industrial mass production of apricot wine.

This study aimed to improve the quality of apricot wine. Apricot wines were prepared following different types of pretreatments, including pectinase and $CaCO_3$, and chaptalization, by the addition of sugar and puree concentrate, and their physicochemical parameters, volatile aromatic profiles, antioxidant activities, and sensory characteristics were investigated.

2. MATERIALS AND METHODS

2.1. Chemicals and reagents

2,2-Diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), Trolox, Folin–Ciocalteu reagent, methanol (HPLC grade), potassium

metabisulfite ($K_2S_2O_5$), organic acids, and all other standards were obtained from Sigma–Aldrich (St Louis, MO, USA). White table sugar (CJ Co., Seoul, South Korea), used to adjust the sugar content of the must, was bought from the local market. Apricot puree concentrate (30.7°Bx, pH 4.1, and acidity 1.31%) was procured from Aftun Gida Ltd. (Yenisehir, Mersin, Turkey). Rapidase® X-Press L (pectinase+hemicellulase, 180,000 AVJP/g) was purchased from DSM Food Specialties (Delft, Netherlands). The fermentation agent *Saccharomyces cerevisiae* var. *bayanus* EC-1118 yeast was purchased from Lallemand Inc. (Montreal, Canada). $CaCO_3$ was acquired from Daejung Co. (Siheung, South Korea).

2.2. Apricot fruit samples

Fully-ripened apricot fruit (*P. armeniaca* L.) were bought from local farms in Yeongcheon (Gyeongsangbuk-do, South Korea) during the 2017 harvest season. "Harcot" apricot fruit was selected for uniformity of size, color, and absence of decay or rot. Fruit was stored at –18°C until further use.

2.3. Apricot fruit must preparation and pretreatment conditions

Apricot fruit was washed with tap water, the seeds removed manually. The deseeded fruit was blended using a household juicer (NJ-9300A, NUC Juicer, Daegu, South Korea) and then combined immediately with 0.02% (w/v) $K_2S_2O_5$ to prevent bacterial contamination and oxidation. To determine the most suitable amount of enzyme and $CaCO_3$ (for deacidification), a part of the apricot fruit pulp was divided into four portions of 300 mL each. The first portion was used as the control while the three remaining portions were treated with pectinase (Rapidase® X-Press L) at 0.05%, 0.1% and 0.2% (v/w), respectively. For the deacidification process, $CaCO_3$ was added at 0.1%, 0.2%, and 0.3% (w/w), respectively. Pectinase treatment or deacidification occurred for 2 h under constant agitation using a shaking incubator (30°C, 200 rpm). The pulp samples were centrifuged at 3,578 × g for 10 min, and the obtained juices were analyzed and compared for pH level, total acidity, total soluble solids, and reducing sugars.

2.4. Apricot wine-making

Apricot fruit pulp was divided into five wine-making trial batches (5 kg), from which wines were prepared in triplicate and, subsequently, treated before fermentation. The chaptalization and pretreatment conditions are listed in Table 1. In the first batch, namely, the control batch (SC), the apricot pulps were chaptalized with white sugar to obtain 22°Bx. In the second batch (SCP), the apricot pulps were chaptalized to 22°Bx with white sugar and then treated with 0.1% (v/w) pectinase. In the third batch (SCPC), the apricot pulps were chaptalized to 22°Bx with white sugar, treated with 0.1% (v/w) pectinase, and then deacidified with 0.3% $CaCO_3$. In the fourth batch (PCP), the apricot pulps were chaptalized to 22°Bx with apricot puree concentrate and then treated with 0.1% (v/w) pectinase. In the fifth batch (PCPC), the apricot pulps were chaptalized to 22°Bx with apricot puree concentrate, treated with 0.1% (v/w) pectinase, and then deacidified with 0.3% (w/w) $CaCO_3$. Each treatment process lasted for 2 h under constant agitation (30°C, 200 rpm), 200 mg/L of $K_2S_2O_5$ was added to prevent bacterial contamination, and then the batches were centrifuged at 3,578 × g for 10 min. The apricot wine was fermented with 1–2 × 10^6 CFU mL^{-1} *S. cerevisiae* var. *bayanus* EC-1118 that was rehydrated by sterile distilled

water at 40°C for 30 minutes, according to the manufacturer's instruction. Each sample was fermented without shaking at 20°C for 7 days until complete fermentation. The final wine samples were filter-sterilized, poured into wine bottles with 50 mg/L of $K_2S_2O_5$, and stored at 4°C for further analysis and sensory assessment.

Table 1. List of ingredients used in apricot wine-making.

Ingredients (g)	Chaptalization and pretreatment conditions				
	SC	SCP	SCPC	PCP	PCPC
Apricot pulp	4,472.5	4,472.5	4,472.5	2,430	2,430
Sugar	527.5	527.5	527.5		
Apricot puree concentrate				2,570	2,570
Pectinase		1	1	1	1
$CaCO_3$			15		15

SC sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$

2.5. Physicochemical parameters

The physicochemical analysis was undertaken on the supernatant obtained from centrifugation of the wine samples at 3,578 × g for 10 min. The pH was measured using a pH meter (MP225K, Mettler-Toledo CH, Seoul, South Korea). Soluble solids (°Bx) were determined using a refractometer (RA250, Atago, Tokyo, Japan). A vinometer was used to evaluate the alcohol content at 15°C. Titratable acidity was assayed using NaOH solution (0.1 N) until neutralization of the organic acids to pH 8.2-8.3, and the results were expressed as a percentage of citric acid/100 g.

2.6. Total phenolic compounds

The total phenolic compounds in the apricot wine samples were estimated, as detailed by OUGH and AMERINE (1988), with some modifications. Wine samples (2 mL) were mixed with 2 mL of 1:1 (v/v) Folin–Ciocalteu reagent and incubated at room temperature for 3 min. Afterward, each tube was added with 2 mL of 10% Na_2CO_3, vortexed, and allowed to stand at room temperature for 1 h. The absorbance was measured at 700 nm. The results were expressed as gallic acid equivalents in mg/mL of apricot wine.

2.7. Total flavonoid content

The total flavonoid contents of the apricot wines were determined, as described by ZHISHEN *et al*. (1999) with minor modifications. The wine samples were examined spectrophotometrically at 510 nm against a blank solution containing all reagents and 200 µL of distilled water instead of wine samples using a spectrophotometer (UV-1601, Shimadzu Co.). First, 430 µL of 50% ethanol, 70 µL of wine sample, and 50 µL of 5% $NaNO_2$ were combined in a test tube. After 30 min of incubation, samples were combined with 50 µL of 10% $Al(NO_3)_3 \cdot 9H_2O$. Six minutes later, 500 µL of NaOH (1 N) was added,

and the solutions vortexed. The results were expressed as rutin equivalents in mg/mL of apricot wine.

2.8. DPPH radical scavenging activity

DPPH radical scavenging activity was measured according to the method previously described by OSZMIAŃSKI *et al*. (2011). Here, 100 μM of DPPH was dissolved in pure ethanol (96%). The radical stock solution was prepared just before experimentation. Then, 1 mL of DPPH was added to 1 mL of apricot wine sample and 3 mL of 96% ethanol. The mixture was thoroughly shaken and placed at room temperature in the dark for 10 min. The decrease in absorbance of the resulting solution was observed at 517 nm at 10 min. The results were corrected for dilution and expressed in μM of Trolox/mL of apricot wine. Absorbance was measured using a spectrophotometer (UV-1601, Shimadzu Co.).

2.9. ABTS radical scavenging activity

ABTS radical scavenging activity was measured based on the method previously reported by OSZMIAŃSKI *et al*. (2011). ABTS was dissolved in water to make a 7 μM concentration. ABTS radical cation ($ABTS^{\cdot+}$) was produced by reacting the ABTS stock solution with 2.45 of μM potassium persulfate (final concentration) and kept in the dark at room temperature for 12–16 h before use. The radical was stable in this form for more than 2 days when stored in the dark at room temperature. The samples containing $ABTS^{\cdot+}$ solution were diluted with redistilled water to an absorbance of 0.700±0.02 at 734 nm and equilibrated at 30°C. After adding 3.0 mL of diluted $ABTS^{\cdot+}$ solution ($A_{734\ nm}$ = 0.700±0.02) to 30 μL of apricot wine sample, the absorbance was read at exactly 6 min after initial mixing. The results were corrected for dilution and expressed in μM Trolox/1 mL of apricot wine. Absorbance was measured using a spectrophotometer (UV-1601, Shimadzu Co.).

2.10. FRAP assay

Ferric ion reducing antioxidant power was measured according to the method previously described by OSZMIAŃSKI *et al*. (2011). The assay was based on the reducing power of a compound (antioxidant). A potential antioxidant will reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), with the latter forming a blue complex (Fe^{2+}/TPTZ) that increases absorbance at 593 nm. Moreover, FRAP reagent was prepared by mixing with an acetate buffer (300 μM, pH 3.6), a solution of 10 μM of TPTZ in 40 μM of HCl and 20 μM of $FeCl_3$ at a ratio of 10:1:1 (v/v/v). The reagent (300 μL) and apricot wine sample solutions (10 μL) were added to each well and thoroughly mixed. The absorbance was measured at 593 nm after 10 min. A standard curve was plotted using different Trolox concentrations. All solutions were prepared on the same day of experimentation. The results were corrected for dilution and expressed in μM of Trolox/1 mL of apricot wine. Absorbance was measured using a spectrophotometer (UV-1601, Shimadzu Co.).

2.11. Free sugar and organic acid analyses

The free sugar and organic acid contents in the wine samples were identified and quantified using a Prominence HPLC instrument (Shimadzu Co.) with a refractive index detector (RID-10A, Shimadzu Co.), as described by KIM *et al*. (2018). The wine samples were centrifuged at 3,578 × g for 10 min, and the resultant supernatants were filtered

through a Millex-HV 0.45-μm membrane filter (Millipore Co., Bedford, MA, USA) to obtain analytical samples. Free sugar content was determined using a Sugar-Pak I column (6.5 mm × 300 mm, 10 μm; Waters, Milford, MA, USA). The mobile phase was Ca–EDTA buffer (50 mg/L) at a flow rate of 0.5 mL/min at 90°C. Organic acids were quantified using a Shodex RSpak KC-811 column (8.0 mm × 300 mm, 6 μm; Showa Denko KK, Kawasaki, Japan), and a mobile phase of 0.1% H_3PO_4 at a flow rate of 1 mL/min at 65°C. Standard curves were plotted using different concentrations of each compound. The results were expressed as each compound's equivalents in g/L of apricot wine.

2.12. Analysis of volatile compounds

Volatile compounds were analyzed as described by LEE *et al*. (2016) with minor modifications, using a 7890A GC–MS system (Agilent, Santa Clara, CA, USA). Volatile compounds were separated using a DB-WAX column (60 m × 0.25 mm i.d., 0.25 μm film thickness, Agilent, Santa Clara, CA, USA) and detected using an Agilent 5975C TAD inert XL MSD. Helium was used as the carrier gas at a constant flow rate of 1 mL/min. The temperature of the GC oven was initially held at 40°C for 2 min, increased at a rate of 2°C/min until 220°C, and then increased at 20°C/min to 240°C, and maintained at 240°C for 5 min. Volatile compounds were collected using a headspace (HS) solid-phase microextraction (SPME) fiber (10 mm length, 50/30 μm DVB/CAR/PDMS; Supelco, Bellefonte, PA, USA) with magnetic stirring. Five milliliters of each sample was placed in a HS vial (20 mL, 23 × 75 mm, PTFE/silicone septum, magnetic cap, Agilent, Santa Clara, CA, USA) and then 1.25 g NaCl was added to increase the efficiency of salting-out of volatile aromatic compounds in the HS. Prior to extraction, the sample was shaken in a water bath at 35°C for 20 min to achieve equilibrium. Afterward, the SPME fiber was inserted into the vial and incubated at 35°C for 40 min. The chemical standards for volatile ester compounds were customized by Chem Service Inc. (West Chester, PA, USA). Other volatile compound standards were purchased from Sigma-Aldrich (St Louis, MO, USA). Volatile compounds were identified by comparing their retention times and mass spectra against the Wiley 9 spectral library (John Wiley and Sons, Hoboken, NJ, USA) using NIST 0.8 (version 5.0; NIST, Gaithersburg, MD, USA). For the quantitative analysis of each compound in the wine, a calibration curve was established by plotting the peak area against the concentration of the chemical standards. Some chemicals that were commercially unavailable were quantified using standard curves of volatile compounds that had similar molecular properties. The results were expressed as each volatile alcohol compound's equivalents in mg/L of apricot wine and each volatile ester and terpene compound's equivalents in μg/L of apricot wine, respectively.

2.13. Sensory evaluation

A seven-point hedonic scale was used for sensory evaluation. Each apricot wine was placed in a sample bottle and left undisturbed at room temperature for 1 h, with the bottle lid still closed before being subjected to sensory evaluation. After opening the lid, each wine was poured into wine glasses to evaluate color, sweetness, sourness, and overall preference. Clarity and turbidity levels were considered as part of the parameters for color evaluation. The well-trained panel was composed of 20 students (13 males and 7 females aged 20–29 years old) from the School of Food Science and Biotechnology, Kyungpook National University, Korea. Each panelist evaluated the apricot wines with at least a 3-min

interval between samples, and water was provided to cleanse their palate. Sensory scores ranged from 1 (very poor) to 7 (excellent).

2.14. Statistical analysis

All experiments were conducted at least three times or more. Statistical significance was determined by the Student's *t*-test for independent means using Microsoft Excel (Microsoft, Redmond, WA, USA). One-way analysis of variance and Duncan's multiple range test were used to determine significant differences between means. Statistical significance was set at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Effect of different pretreatment conditions on the physicochemical parameters of apricot juice

The effects of different pretreatments on the physicochemical parameters of apricot juice are listed in Table 2. The yield of apricot juices subjected to pectinase treatment were higher by 5.66%, 10.02%, and 10.38% in apricot pulp containing 0.05%, 0.1%, and 0.2% pectinase, respectively, compared with the control juice, but the yields of juices treated with 0.1% and 0.2% pectinase enzyme were not considerably different. In addition, juices treated with pectinase enzyme had a statistically lower pH and higher total acid contents relative to the control juice. The reducing sugar contents of apricot juices also increased with increasing pectinase enzyme concentrations, but no significant differences were found between pectinase-treated juices. Apricot juices treated with 0.05%, 0.1%, and 0.2% pectinase had reducing sugar contents of 15.65%, 15.83%, and 15.90%, respectively. The pH and total acid contents of apricot juices by deacidification significantly increased and decreased, respectively, with increasing $CaCO_3$ concentration compared with those of non-treated apricot juice.

Table 2. Effects of pectinase enzyme and $CaCO_3$ concentrations on the physicochemical properties of apricot juices.

Treatment	Pectinase enzyme			
	Non-treated	0.05%	0.1%	0.2%
Juice yield (%)	67.20±0.12^{d}	72.86±0.03^{c}	77.22±0.05^{b}	77.58±0.05^{a}
pH	3.16±0.02^{a}	3.11±0.01^{b}	3.10±0.04^{b}	3.10±0.07^{b}
Total acidity (%)	2.56±0.02^{b}	2.62±0.03^{a}	2.63±0.04^{a}	2.64±0.3^{a}
Soluble solids (°Bx)	16.2±0.05^{b}	16.4±0.08^{a}	16.4±0.05^{a}	16.4±0.09^{a}
Reducing sugars (%)	14.5±0.04^{b}	15.65±0.10^{a}	15.83±0.08^{a}	15.90±0.12^{a}
Treatment	**Deacidification ($CaCO_3$)**			
	Non-treated	**0.1%**	**0.2%**	**0.3%**
pH	3.14±0.06^{d}	3.22±0.01^{c}	3.33±0.02^{b}	3.42±0.01^{a}
Total acidity (%)	2.56±0.10^{a}	2.48±0.03^{a}	2.30±0.05^{b}	2.17±0.04^{c}

All data are expressed as mean±standard deviation (n = 3).
Different letters in the same row indicate significant differences at $p<0.05$.

Fruits other than grape, such as apricot, have high acidity, which needs to be controlled before, during, or after fermentation, for producing a suitable final wine (VELIĆ *et al.*, 2018). In this study, each 0.1% pectinase treatment and 0.3% $CaCO_3$ treatment improved the juice yield and appropriate physicochemical changes in apricot juice, so we further investigated the appropriate combination of these pretreatment conditions for apricot wine.

3.2. Effects of different chaptalization types and the combination of pretreatments on the fermentation and physicochemical properties of apricot wine

The influences of the various chaptalization techniques and the combination of pretreatments on the changes in fermentation characteristics during alcohol fermentation and physicochemical properties of fully fermented apricot wine are provided in Fig. 1 and Table 3. The soluble solid and alcohol contents of all the apricot wines similarly decreased and increased, respectively, for the first 3 days of fermentation. After then, all the pectinase-treated apricot wines showed higher soluble solid and alcohol contents, compared with the control wine because of increased juice yield and reducing sugar caused by 0.1% pectinase treatment. The pH and total acidity of all the apricot wines decreased and increased, respectively, for first or second days of fermentation, then steadily increased and slightly decreased, respectively, until complete fermentation. The pH and total acidity of apricot wines treated with $CaCO_3$ (SCP and PCP wines) were significantly lower and higher, respectively, than those of other apricot wines from beginning to end of the fermentation process. The total phenolic and total flavonoid contents of all the apricot wines were significantly superior to those of the control wine because pectinase released phenols and polyphenols from the plant cell wall (CHANG *et al.*, 1995). In addition, PCP and PCPC wines that were chaptalized with puree concentrate presented higher total acidity, as well as total phenolic and flavonoid contents, compared with those of SCP and SCPC wines that were chaptalized with sugar, because all of these compounds were concentrated in the added apricot puree concentrate. Although the total phenolic and total flavonoid contents of pectinase-treated apricot wines were relatively higher than those of other groups, the lower pH and higher total acid content of PCP wine may be negatively associated with the sensory properties. On the contrary, PCPC wine contained similar contents of functional compounds but better palatability compared to PCP wine because of deacidification.

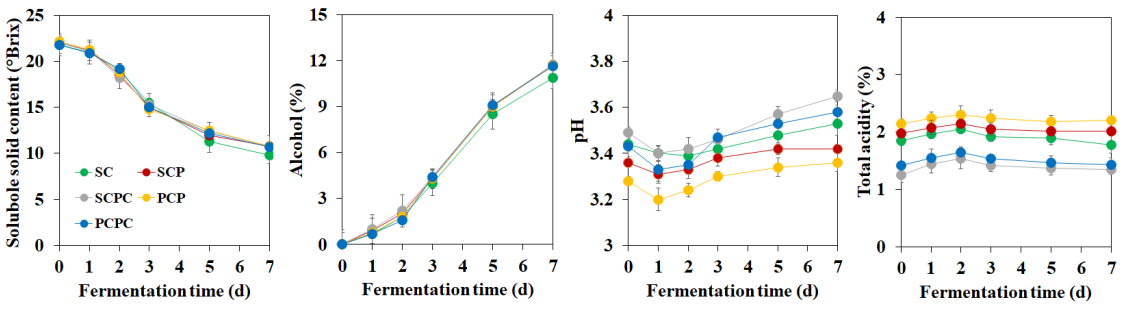

Figure 1. Changes in the soluble solid, alcohol, pH, and total acidity of apricot wines during fermentation. *SC* sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$

Table 3. Effects of different chaptalization types and pretreatment conditions on the physicochemical parameters of apricot wines.

Parameter	Wine				
	SC	SCP	SCPC	PCP	PCPC
Soluble solids (°Bx)	9.80±0.20^{b}	10.75±0.10^{a}	10.75±0.10^{a}	10.80±0.20^{a}	10.70±0.10^{a}
Alcohol (%)	10.9±0.10^{b}	11.74±0.20^{a}	11.72±0.10^{a}	11.70±0.10^{a}	11.64±0.10^{a}
pH	3.53±0.10^{ab}	3.42±0.09^{b}	3.65±0.05^{a}	3.36±0.03^{c}	3.58±0.05^{a}
Total acidity (%)	1.78±0.04^{c}	2.02±0.01^{b}	1.35±0.01^{e}	2.20±0.03^{a}	1.43±0.04^{d}
Total phenolic compounds (mg/mL)	11.41±0.37^{c}	16.95±3.11^{b}	17.15±2.03^{b}	21.87±0.96^{a}	21.43±1.21^{a}
Total flavonoids (mg/mL)	0.39±0.00^{b}	0.41±0.01^{a}	0.42±0.01^{a}	0.43±0.01^{a}	0.43±0.01^{a}

All data are expressed as mean±standard deviation (n = 3).
Different letters in the same row indicate significant differences at $p<0.05$.
SC sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$

3.3. Free sugar and organic acid contents of apricot wines

The impacts of different chaptalization types and the combination of pretreatments on the free sugar and organic acid contents in apricot wines are evident in Table 4. After alcoholic fermentation, sucrose, glucose, galactose, and fructose were identified in the apricot wines. Fructose was the most abundant reducing sugar (0.599±0.014–4.662±0.019 g/L) in all the apricot wines. Marked differences in the organic acids were observed between each apricot wine. Citric acid and quinic acid of SCP and SCPC wines were significantly decreased and increased compared with SC wine, respectively, whereas tartaric acid and malic acid of SCPC wine were the lowest among all the apricot wines. Citric acid and quinic acid contents of PCP and PCPC wines were significantly higher than other wines because various components of apricot were concentrated during puree concentrate preparation, whereas tartaric acid of PCPC wine was significantly lower than PCP wine due to deacidification. Succinic acid levels were comparable among all the apricot wines, and acetic acid of pectinase-treated apricot wines was slightly increased compared with control apricot wine. According to AMERINE *et al*. (1965), the decreasing order of sourness intensity of organic acids is malic acid, tartaric acid, citric acid, and lactic acid. $CaCO_3$ treatment was reported to reduce wine acidity by inducing the precipitation of tartrate and malate (MATTICK *et al*., 1980). Thus, the combination of pectinase and $CaCO_3$ treatments increased the yield of apricot juice and reduced the acidity in apricot wine.

3.4. Antioxidant activity of apricot wines

The various antioxidant activities, such as DPPH radical scavenging activity, ABTS radical scavenging activity, and FRAP of apricot wines are shown in Fig. 2. All of the antioxidant activities were highest in PCP and PCPC wines, followed by SCP and SCPC wines, and then SC wine, which might be attributed to the release of pigment compounds, such as flavonoids, by pectinase (all the pectinase-treated apricot wines) and the concentration of those compounds in the added puree concentrate (PCP and PCPC wines).

Table 4. Composition of free sugar and organic acid contents (g/L) of apricot wines depending on different chaptalization types and pretreatment conditions.

Parameter	Wine				
	SC	SCP	SCPC	PCP	PCPC
Free sugars					
Sucrose	0.08±0.01^{a}	ND	ND	ND	ND
Glucose	0.16±0.06^{c}	0.28±0.03^{b}	0.25±0.01^{b}	0.70±0.02^{a}	0.67±0.03^{a}
Galactose	0.23±0.04^{c}	0.86±0.01^{b}	0.82±0.04^{b}	1.58±0.02^{a}	1.50±0.06^{a}
Fructose	0.60±0.01^{c}	2.66±0.01^{b}	2.64±0.01^{b}	4.56±0.02^{a}	4.66±0.02^{a}
Organic acid					
Citric acid	11.58±0.35^{b}	9.89±0.25^{c}	9.61±0.34^{c}	14.40±0.51^{a}	14.25±0.48^{a}
Tartaric acid	2.83±0.08^{b}	2.84±0.11^{b}	0.42±0.04^{d}	3.11±0.12^{a}	0.73±0.06^{c}
Malic acid	5.61±0.12^{a}	4.39±0.12^{b}	3.20±0.09^{c}	4.29±0.09^{b}	2.96±0.10^{d}
Quinic acid	7.37±0.16^{c}	11.48±0.34^{b}	11.34±0.33^{b}	34.17±1.03^{a}	32.87±1.17^{a}
Succinic acid	0.50±0.02^{a}	0.54±0.04^{a}	0.52±0.04^{a}	0.45±0.02^{b}	0.44±0.02^{b}
Acetic acid	0.18±0.01^{c}	0.31±0.04^{b}	0.29±0.01^{b}	0.42±0.02^{a}	0.40±0.02^{a}

All data are expressed as mean±standard deviation (n = 3).
Different letters in the same row indicate significant differences at $p<0.05$.
SC sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *ND* not detected

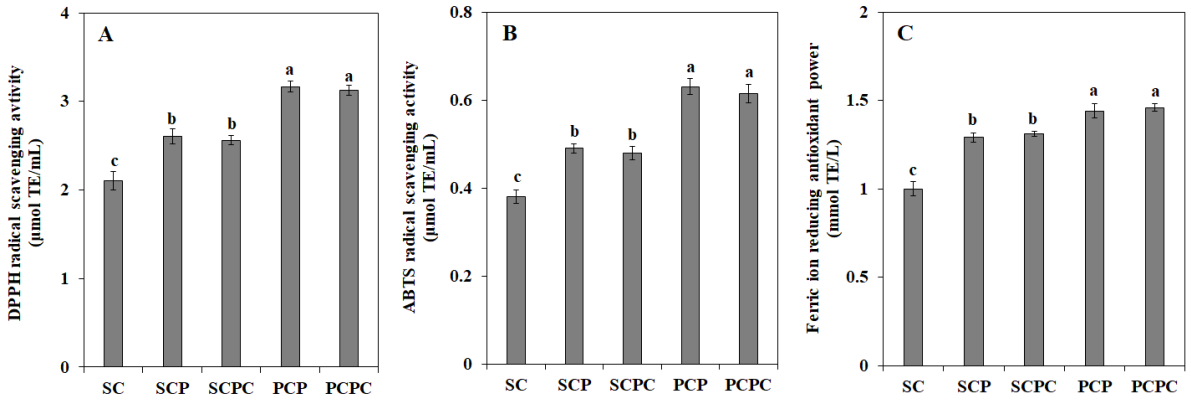

Figure 2. Effects of different chaptalization types and pretreatment conditions on the DPPH radical scavenging activity (A), ABTS radical scavenging activity (B), and ferric ion reducing power (C) antioxidant activities of apricot wines.
Different letters indicate significant differences at $p<0.05$.
L-AA L-ascorbic acid, *TE* Trolox equivalents, *SC* sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$

Apricot contains numerous phenolic compounds, including catechin, epicatechin, *p*-coumaric acid, caffeic acid, and ferulic acid, that contribute to the antioxidant activity and nutritional benefits (CAMPBELL and PADILLA-ZAKOUR, 2013; SOCHOR *et al*., 2010). ARNOUS *et al*., (2002) mentioned that total polyphenol and total flavonol compounds could significantly contribute to the overall antioxidant activity of wine. As such, in the present study, the high antioxidant activities displayed by the apricot wines depended on the increased total phenolic and flavonoid compounds released by pectinase pretreatment and concentrated by puree concentrate chaptalization.

3.5. Volatile aromatic compounds of apricot wines

The volatile aromatic compounds of apricot wines are given in Table 5. The volatile higher alcohol compounds were more abundant in pectinase-treated apricot wines than control apricot wine. In PCP and PCPC wines, most of the volatile higher alcohols, except for 1-propanol, were detected at levels lower than in SCP and SCPC wines, respectively. Moreover, SCPC wine showed the highest amount of 1-propanol, isobutanol, isoamyl alcohol, 1-hexanol, 3-ethoxypropanol, 1-decanol, and benzyl alcohol, among all the apricot wines. A higher amount of 2,3-butanediol, which is an unattractive compound in wine because of its buttery aroma (BARTOWSKY and HENSCHKE, 2004), was detected in greater quantities in SC and SCP wines than in the other apricot wines examined. Total volatile ester compounds were the highest in SC wine, as those of pectinase-treated apricot wines were evaporated during pectinase treatment at 30°C for 2 h. Furthermore, PCP and PCPC wines presented significantly lower total volatile ester compounds than those of the other wines, which is considered to be due to the loss of their corresponding precursors during heat treatment of the puree concentrate production process. SC wine contained the highest amounts of isoamyl acetate, ethyl hexanoate, ethyl octanoate, and ethyl-9-decanoate, as well as ethyl decanoate. These compounds primarily influenced the changes in the amount of total volatile ester compounds. Volatile terpenes were higher in all the pectinase-treated apricot wines than control apricot wine. In particular, linalool and α-terpineol of PCP and PCPC wines were significantly higher than those of the other wines. The group of higher alcohols is well known as one of the dominant chemical constituents in wine, in which they play a major role as ester precursors (LAMBRECHTS and PRETORIUS, 2000). Esters are well recognized as the most abundant aromatic compounds in wine (ROJAS *et al*., 2001) and are produced by yeasts during alcoholic fermentation, whereas terpenes are only present in small amounts in some fruits, such as grape (especially in aromatic cultivars), apricot, and peach. However, terpenes can mostly affect the floral properties of wines with low odor thresholds (100-400 ppb) (MAICAS and MATEO, 2005). In the present study, significantly decreased contents of volatile ester compounds were detected in the pretreated apricot wines compared with non-treated apricot wine, but the levels of volatile higher alcohols and terpenes were greater, which might have assisted in improving the sensory properties of apricot wine.

Table 5. The concentration of volatile aromatic compounds in apricot wines depending on different chaptalization types and pretreatment conditions.

Compound	Odor description	Threshold (mg/L)	Amount of volatile aromatic compound				
			SC	SCP	SCPC	PCP	PCPC
1-Propanol	Alcohol, ripe fruity[1]	306[1]	85.48±6.55^{b}	97.17±9.45^{b}	169.76±14.11^{a}	103.27±10.11^{b}	178.63±13.28^{a}
Isobutanol	Alcohol, solvent, green, bitter[1]	75[1]	159.27±12.09^{b}	176.03±16.23^{ab}	199.71±20.56^{a}	141.00±12.24^{b}	162.13±15.06^{b}
Isoamyl alcohol	Solvent, sweet, nail polish[2]	60[2]	2605.68±233.17^{a}	2863.76±256.18^{a}	3024.25±306.50^{a}	2729.15±250.06^{a}	2896.57±269.77^{a}
1-Hexanol	Herbaceous, grass, woody[1]	1.1[1]	20.10±1.94^{c}	30.68±3.31^{b}	37.41±3.42^{a}	23.85±2.65^{c}	32.64±3.04^{ab}
3-Ethoxypropanol	Fruity[1]	0.1[1]	10.04±1.11^{a}	10.27±0.98^{a}	10.73±0.94^{a}	6.82±0.61^{b}	6.77±0.64^{b}
1-Octanol	Jasmine, lemon[1]	0.8[1]	13.62±1.26^{b}	89.27±7.24^{a}	10.10±0.88^{b}	8.83±0.77^{b}	5.04±0.62^{c}
2,3-Butanediol	Floral, fruity, herbal, buttery[2,3]	150[2]	14.70±1.32^{a}	14.24±1.52^{a}	11.21±1.05^{b}	9.52±0.89^{b}	8.16±0.72^{b}
1-Decanol	Floral, fruity, bitter, winey[2]	0.4[2]	5.13±0.44^{b}	6.21±0.56^{a}	6.51±0.52^{a}	4.44±0.41^{b}	4.50±0.39^{b}
Benzyl alcohol	Roasted, sweet, fruity[1]	200[1]	20.07±2.12^{c}	52.63±5.10^{a}	60.63±6.12^{a}	35.17±3.41^{b}	41.17±4.41^{b}
Phenylethyl alcohol	Rose, honey[1]	14[1]	201.16±19.43^{a}	242.63±22.73^{a}	245.14±26.18^{a}	249.67±24.07^{a}	243.81±23.58^{a}
∑Alcohols			3135.25±279.43^{a}	3582.89±323.30^{a}	3775.46±380.28^{a}	3311.73±305.22^{a}	3579.42±331.51^{a}
Methyl acetate			ND	13.93±1.30^{b}	15.67±1.51^{b}	23.25±2.16^{a}	25.17±2.32^{a}
Ethyl acetate	Pineapple, fruity, balsamic[2]	12[2]	729.35±74.28^{a}	668.56±64.86^{a}	760.26±71.34^{a}	726.78±70.86^{a}	810.59±78.50^{a}
Ethyl propionate	Fruity[4]	1.8[4]	18.65±1.56^{a}	17.24±1.55^{a}	19.18±1.68^{a}	15.43±1.62^{a}	16.22±1.55^{a}
Ethyl isobutyrate	Sweet, rubber[4]	0.015[4]	11.51±1.05^{a}	9.51±0.92^{ab}	11.11±1.06^{a}	7.77±0.74^{b}	8.95±0.78^{b}
Propyl acetate	Sweet, fruity[4]	4.7[4]	24.83±2.62^{a}	18.04±1.77^{b}	21.16±2.04^{ab}	19.21±1.78^{b}	22.04±2.04^{ab}
Isobutyl acetate	Fruity, apple, banana[4]	1.6[4]	42.19±3.84^{a}	30.40±3.13^{b}	34.23±2.99^{b}	23.79±2.24^{c}	25.64±2.82^{bc}
Ethyl butanoate	Banana, pineapple, strawberry[1]	0.4[1]	43.24±4.13^{a}	28.37±2.47^{b}	29.59±3.41^{b}	22.59±2.01^{b}	23.10±1.98^{b}
Butyl acetate	Fruity[5]		4.88±0.43^{a}	3.96±0.35^{ab}	4.37±0.56^{a}	3.35±0.36^{b}	3.84±0.33^{ab}
Isoamyl acetate	Banana[1]	0.16[1]	2472.35±242.56^{a}	1403.56±142.53^{b}	1541.19±136.04^{b}	871.05±82.60^{c}	972.42±88.09^{c}
Ethyl pentanoate	Yeast, fruity[4]	0.094[4]	4.24±0.36^{a}	2.89±0.27^{b}	3.62±0.35^{a}	4.19±0.40^{a}	4.63±0.51^{a}
Ethyl hexanoate	Banana, green apple[1]	0.08[1]	749.92±72.65^{a}	515.85±49.06^{b}	535.92±55.50^{b}	388.25±36.12^{c}	442.16±43.69^{bc}
Hexyl acetate	Apple, cherry, pear, floral[1]	1.5[1]	60.09±7.32^{a}	47.19±4.53^{b}	58.32±5.36^{a}	18.63±1.92^{c}	22.85±2.12^{c}
Ethyl heptanoate	Fruit[4]	0.22[4]	9.26±0.87^{a}	6.41±0.67^{b}	5.27±0.61^{bc}	4.04±0.38^{c}	4.36±0.41^{c}

Methyl octanoate	Orange[4]		34.89±3.57^{a}	40.63±3.88^{a}	43.31±4.10^{a}	35.28±3.11^{a}	41.49±3.89^{a}
Ethyl octanoate	Fruity, sweet, banana, pear[1,2]	0.24-0.58[1,2]	2552.69±226.39^{a}	1521.94±126.93^{b}	1668.65±171.03^{b}	890.86±82.62^{d}	1114.51±103.43^{c}
Geranyl acetate	Floral, rose[6]		96.95±9.32^{b}	120.62±11.05^{a}	102.99±10.23^{ab}	67.65±6.59^{c}	62.78±6.32^{c}
Ethyl nonanoate			44.32±4.34^{a}	32.19±3.36^{b}	33.67±3.42^{b}	36.19±3.54^{b}	35.20±3.17^{b}
Methyl decanoate	Wine[4]	1.2[4]	14.46±1.28^{a}	12.63±1.01^{a}	13.90±1.21^{a}	9.91±0.79^{b}	10.33±0.92^{b}
Ethyl decanoate	Fatty acids, fruity, soap[1,2]	0.2[1,2]	1840.95±156.98^{a}	878.86±90.09^{b}	957.66±92.06^{b}	464.04±42.22^{c}	504.38±48.56^{c}
Ethyl benzoate	Heavy, floral, fruity[4]	5.75[4]	315.49±33.65^{b}	577.75±46.60^{a}	589.05±54.98^{a}	606.73±61.17^{a}	631.40±56.77^{a}
Ethyl 9-decenoate	Fruity[4]	0.1[4]	231.95±24.25^{a}	32.81±3.14^{b}	27.38±2.67^{b}	7.50±0.73^{c}	5.53±0.50^{c}
Methyl salicylate	Pepper, mint[4]		11.38±1.14^{b}	15.12±1.87^{a}	16.64±1.52^{a}	12.13±1.10^{b}	12.44±1.39^{b}
Ethyl phenylacetate	Fruity, sweet[4]		2.03±0.15^{b}	1.88±0.23^{b}	2.08±0.19^{b}	3.26±0.33^{a}	3.41±0.31^{a}
2-Phenylethyl acetate	Fruity, rose[1]	1.8[1]	41.38±3.36^{a}	34.34±3.18^{a}	35.77±3.48^{a}	24.39±2.31^{b}	26.72±2.43^{b}
Ethyl dodecanoate	Oily, fatty, fruity[1]	1.5[1]	175.20±18.21^{b}	178.56±15.56^{b}	223.61±21.13^{a}	120.02±10.65^{d}	154.12±12.98^{c}
∑Esters			9532.22±894.31^{a}	6213.25±580.31^{b}	6754.61±648.47^{b}	4406.30±418.35^{c}	4984.28±465.81^{c}
Linalool	Flowery, muscat[1]	0.025[1]	731.91±71.03^{c}	1007.80±96.32^{b}	897.27±90.43^{bc}	1424.51±153.07^{a}	1369.53±128.25^{a}
α-Terpineol	Lilac, floral, sweet[1]	0.25[1]	135.46±12.63^{c}	184.23±16.70^{b}	159.49±14.17^{bc}	302.61±28.65^{a}	288.09±26.72^{a}
Citronellol	Rose[1]	0.1[1]	18.48±1.72^{c}	28.88±2.64^{b}	27.68±2.60^{b}	58.05±5.57^{a}	60.98±5.78^{a}
Geraniol	Citric, geranium[1]	0.02[1]	40.89±4.65^{b}	53.12±5.35^{a}	49.27±4.55^{ab}	56.91±5.43^{a}	51.64±5.33^{a}
∑Terpenes			926.75±90.03^{c}	1274.03±121.01^{b}	1133.72±111.75^{bc}	1842.09±192.72^{a}	1770.24±166.08^{a}

All data are expressed as mean±SD (n = 3).
Different letters in the same row indicate statistically significant differences at $p<0.05$.
SC sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *ND* not detected
[1] CAI *et al.*, 2014; [2] BUTKHUP *et al.*, 2011; [3] BARTOWSKY and HENSCHKE, 2004; [4] ZHANG *et al.*, 2015; [5] NATTAPORN and PRANEE, 2011; [6] NISHIMURA, 1995

3.6. Sensory evaluation of apricot wines

The sensory evaluation results of apricot wines are shown in Fig. 3. All the pectinase-treated apricot wines obtained higher color scores compared with control apricot wine, due to clarification by pectinase enzyme. The flavor scores of SCPC wine, containing the highest amount of total volatile higher alcohols, and PCP and PCPC wines, which recorded the greatest abundance of total volatile terpenes, were significantly higher relative to the other apricot wines. The sweetness scores of pectinase-treated apricot wines were slightly higher than control apricot wine because of some remaining free sugars. The sourness of PCP wine was the strongest, whereas that of SCPC wine was the weakest because these wines contained, respectively, the highest and lowest presence of tartaric acid and malic acid, which are the two strongest organic acids. PCPC wine also obtained low sourness score because of its low tartaric acid and malic acid levels. In the overall preference, SCPC and PCPC wines, having the most reduced sourness, obtained the highest scores among all the apricot wines. SCP and PCP wines also obtained higher scores when compared with SC wine.

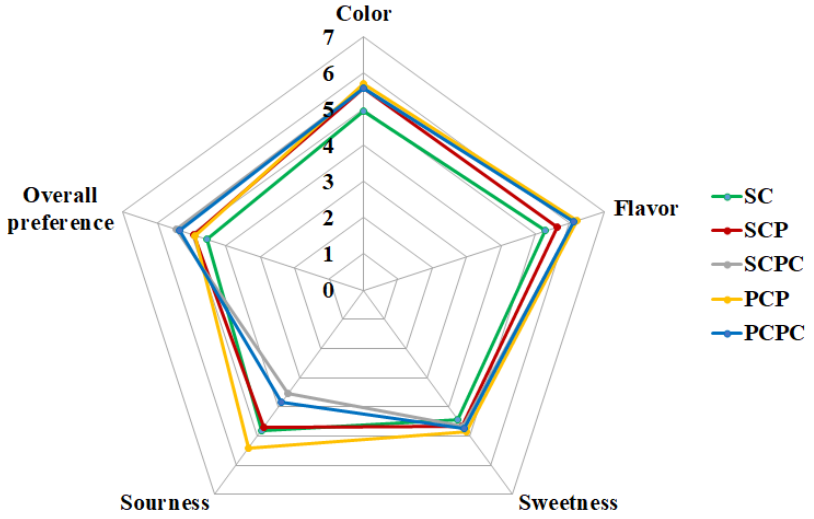

Figure 3. Sensory evaluation of apricot wines depending on different chaptalization types and pretreatment conditions.
SC sugar chaptalization, *SCP* sugar chaptalization treated with 0.1% pectinase, *SCPC* sugar chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$, *PCP* puree concentrate chaptalization treated with 0.1% pectinase, *PCPC* puree concentrate chaptalization treated with 0.1% pectinase and 0.3% $CaCO_3$

In this study, we investigated the effects of puree concentrate chaptalization and various pretreatments on the quality of apricot wine. The results demonstrated that apricot wines chaptalized with puree concentrate have shown not only higher antioxidant activity and total volatile terpene compounds than sugar-chaptalized apricot wines but also higher acidity that negatively affects the sensory properties of wine. Pectinase and $CaCO_3$ pretreatments can clarify the appearance apricot wines and reduce the acidity of apricot wines, indicating that combining puree concentrate chaptalization and various pretreatments may result to improved apricot wine quality.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea, Republic of Korea (Grant No. NRF-2017R1D1A3B03033451).

REFERENCES

Amerine M.A., Roessler E.B. and Ough C.S. 1965. Acids and the acid taste. I. The effect of pH and titratable acidity. Am. J. Enol. Viticult. 16:29-37.

Arnous A., Makris D.P. and Kefalas P. 2002. Correlation of pigment and flavanol content with antioxidant properties in selected aged regional wines from Greece. J. Food Compos. Anal. 15:655-665.

Banvolgyi S., Kiss I., Bekassy-Molnar E. and Vatai G. 2006. Concentration of red wine by nanofiltration. Desalination 198:8-15.

Bartowsky E.J. and Henschke P.A. 2004. The 'buttery' attribute of wine-diacetyl-desirability, spoilage and beyond. Int. J. Food Microbiol. 96:235-252.

Butkhup L., Jeenphakdee M., Jorjong S., Samappito S., Samappito W. and Chowtivannakul S. 2011. HS-SPE-GC-MS analysis of volatile aromatic compounds in alcohol related beverages made with mulberry fruits. Food Sci. Biotechnol. 20:1021-1032.

Cai J., Zhu B.Q., Wang Y.H., Lu L., Lan Y.B., Reeves M.J. and Duan C.Q. 2014. Influence of pre-fermentation cold maceration treatment on aroma compounds of Cabernet Sauvignon wines fermented in different industrial scale fermenters. Food Chem. 154:217-229.

Campbell O.E. and Padilla-Zakour O.I. 2013. Phenolic and carotenoid composition of canned peaches (*Prunus persica*) and apricots (*Prunus armeniaca*) as affected by variety and peeling. Food Res. Int. 54:448-455.

Chang T.S., Siddiq M., Sinha N.K. and Cash J.N. 1995. Commercial pectinases and the yield and quality of Stanley plum juice. J. Food Process. Pres. 19:89-101.

Clary C., Gamache A., Cliff M., Fellman J. and Edwards C. 2006. Flavor and aroma attributes of Riesling wines produced by freeze concentration and microwave vacuum dehydration. J. Food Process. Pres. 30:393-406.

Cosme F, Vilela A., Filipe-Ribeiro L., Inês A., Nunes F.M. 2018. Wine microbial spoilage: Advances in defects remediation. In Microbial Contamination and Food Degradation, Academic Press, New York, NY, USA. P 271-314.

Dragovic-Uzelac V., Levaj B., Mrkic V., Bursac D. and Boras M. 2007. The content of polyphenols and carotenoids in three apricot cultivars depending on stage of maturity and geographical region. Food Chem. 102:966-975.

Hegedűs A., Engel R., Abrankó L., Balogh E., Blázovics A., Hermán R., Halász J., Ercisli S., Pedryc A. and Stefanovits-Bányai É. 2010. Antioxidant and antiradical capacities in apricot (*Prunus armeniaca* L.) fruits: Variations from genotypes, years, and analytical methods. J. Food Sci. 75:C722-C730.

Jarvis B. 1996. Cider, perry, fruit wines and other alcoholic fruit beverages. In Fruit Processing. Arthey D., Ashust P.R., eds. Springer US, New York, NY, USA. p 97-134.

Kim D.H., Lee S.B. and Park H.D. 2018. Fermentation characteristics of Campbell Early grape wine inoculated with indigenous Korean wine yeasts encapsulated in Ca-alginate beads after air-blast drying. Ital. J. Food Sci. 30:535-552.

Lambrechts M.G. and Pretorius I.S. 2000. Yeast and its importance to wine aroma - a review. S. Afr. J. Enol. Vitic. 21:97-129.

Lee S.B., Kim D.H. and Park H.D. 2016. Effects of protectant and rehydration conditions on the survival rate and malolactic fermentation efficiency of freeze-dried *Lactobacillus plantarum* JH287. Appl. Microbiol. Biotechnol. 100:7853-7863.

Loira I., Morata A., Palomero F., González C., Suárez-Lepe J.A. 2018. *Schizosaccharomyces pombe*: A promising biotechnology for modulating wine composition. Fermentation 4:70.

Madrau M.A., Piscopo A., Sanguinetti A.M., Del Caro A., Poiana M., Romeo F.V. and Piga A. 2009. Effect of drying temperature on polyphenolic content and antioxidant activity of apricots. Eur. Food Res. Technol. 228:441-448.

Maicas S. and Mateo J.J. 2005. Hydrolysis of terpenyl glycosides in grape juice and other fruit juices: a review. Appl. Microbiol. Biotechnol. 67:322-335.

Mattick L.R., Plane R.A. and Weirs L.D. 1980. Lowering wine acidity with carbonates. Am. J. Enol. Viticult. 31:350-355.

Miyawaki O., Gunathilake M., Omote C., Koyanagi T., Sasaki T., Take H., Matsuda A., Ishisaki K., Miwa S. and Kitano S. 2016. Progressive freeze-concentration of apple juice and its application to produce a new type apple wine. J. Food Eng. 171:153-158.

Nattaporn W. and Pranee A. 2011. Effect of pectinase on volatile and functional bioactive compounds in the flesh and placenta of 'Sunlady' cantaloupe. Int. Food Res. J. 18:819-827.

Nishimura O. 1995. Identification of the characteristic odorants in fresh rhizomes of ginger (Zingiber officinale Roscoe) using aroma extract dilution analysis and modified multidimensional gas chromatography-mass spectroscopy. J. Agric. Food Chem. 43:2941-2945.

Oszmiański J., Wojdyło A. and Kolniak J. 2011. Effect of pectinase treatment on extraction of antioxidant phenols from pomace, for the production of puree-enriched cloudy apple juices. Food Chem. 127:623-631.

Ough C.S. and Amerine M.A. 1988. Methods for Analysis of Musts and Wines. 2nd ed. Wiley & Sons, New York, NY, USA. pp. 176-180.

Pardo F., Salinas M.R., Alonso G.L., Navaroo G. and Huerta M.D. 1999. Effect of diverse enzyme preparations on the extraction and evolution of phenolic compounds in red wines. Food Chem. 67:135-142.

Pinelo M., Arnous A. and Meyer A.S. 2006. Upgrading of grape skins: Significance of plant cell-wall structural components and extraction techniques for phenol release. Trends Food Sci. Tech. 17:579-590.

Rojas V., Gil J.V., Piñaga F. and Manzanares P. 2001. Studies on acetate ester production by non-*Saccharomyces* wine yeasts. Int. J. Food Microbiol. 70:283-289.

Sharma H.P., Patel H. and Sugandha. 2017. Enzymatic added extraction and clarification of fruit juices-A review. Crit. Rev. Food Sci. 57:1215-1227.

Sochor J., Zitka O., Skutkova H., Pavlik D., Babula P., Krska B., Horna A., Adam V., Provaznik I. and Kizek R. 2010. Content of phenolic compounds and antioxidant capacity in fruits of apricot genotypes. Molecules 15:6285-6305.

Soliman H.I.A. 2013. Cryopreservation of *in vitro*-grown shoot tips of apricot (*Prunus armeniaca* L.) using encapsulation-dehydration. Afr. J. Biotechnol. 12:1419-1430.

Velić D., Klarić D.A., Velić N., Klarić I., Tominac V.P. and Mornar A. 2018. Chemical constituents of fruit wines as descriptors of their nutritional, sensorial and health-related properties. In Descriptive food science, Díaz V., García-Gimeno A., María R., eds, IntechOpen, London, UK. P 1-33.

Volschenk H., Van Vuuren H.J.J. and Viljoen-Bloom M. 2006. Malic acid in wine: origin, function and metabolism during vinification. S. Afr. J. Enol. Vitic. 27:123-136.

Watson B., Goldberg N., Chen H.P. and McDaniel M. 1999. Fermentation processing effects on colour, phenolic profiles and sensory character of Oregon Pinot noir wines. pp. 454-478. In: Proceedings of the 12th International Oenological Symposium. 31 May-2 June, Hotel Omni Mont-Royal, Montréal, Canada. Lemperle E (ed.). International Association for Winery Technology and Management, Breisach, Germany

Zhang S., Petersen M.A., Liu J. and Toldam-Andersen T.B. 2015. Influence of pre-fermentation treatments on wine volatile and sensory profile of the new disease tolerant cultivar Solaris. Molecules 20:21609-21625.

Zhishen J., Mengcheng T. and Jianming W. 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem. 64:555-559.

Paper Received April 20, 2020 Accepted September 9, 2020