

Fermentation properties of beer produced from Korean two-row barley or malt (*Gwangmaek*) supplemented with Korean red ginseng extracts and *Bokbunja* (*Rubus coreanus* Miquel) juice

Ji-Won Park¹, Ji Hyeon Kim¹, Young-An Kwon², and Wang June Kim^{1,*}

¹Department of Food Science and Biotechnology, Dongguk University-Seoul

²Department of Food Science and Culinary Art, Woo-Suk University

Abstract This study involved the production of specialty lager beers supplemented with Korean red ginseng extracts or *Bokbunja* (Korean black raspberry, *Rubus coreanus* Miquel) juice. The effects of the Korean red ginseng extracts or *Bokbunja* juice on the specific gravity, pH, yeast viability, free amino nitrogen content, reducing sugar content, color, alcohol content, turbidity, and sensory evaluation were evaluated. The alcohol content of the beers containing the extracts or juice were within the standard alcohol amounts (3.63–4.0%, v/v). The pH values of the three samples containing *Bokbunja* juice were lower than that of the control values. The sensory evaluation showed that the addition of *Bokbunja* juice was superior to the ginseng extracts, and the optimal addition time was before or after the secondary fermentation. These data indicate that the flavor and odor of the *Bokbunja* juice are more persistent than that of the ginseng extracts.

Keywords: fermentation property, Korean two-row barley malt, Korean red ginseng extracts, *Bokbunja* juice, specialty beer

Introduction

Beer is a well-known alcoholic beverage that is classified based on the nature of the raw materials and microorganisms used in fermentation and flavoring (Boulton and Quain, 2008). Brewers add supplementary materials during the brewing process to provide additional fermentable ingredients, particularly carbohydrates for yeast growth. In the mashing process, materials such as maize, rice, corn, and wheat may be mixed with barley malt. The use of each material affects the character of the wort or beer (Briggs et al., 2004). In particular, fruits are used to produce a variety of beers, and their juices can be added during brewing. The introduction of whole fruit into beer was originally practiced in Belgium (De Keersmaecker, 1996). Young lambic beer is blended with various fruits including cherries (*Prunus cerasus* L.) and raspberries (*Rubus idaeus* L.) (Daenen et al., 2008; Prasad, 2014).

As discretionary income and an interest in personal health has risen, the consumption of healthy foods has been promoted. To meet increased consumer demand, the brewing industry has invested in the development of new technologies and innovations for specialty beers (Lee et al., 2013b; Yeo and Liu, 2014).

Ginseng has been used as a tonic for 2,000 years in Asian countries (Jang et al., 2011; Jeon, 2013). Ginseng and red ginseng products are representative health-functional foods and are well-known for their anti-carcinogenesis and immune system-boosting

properties (Lee et al., 2013b). Ginseng products consumed in Korea include ginseng tea, liquid extracts, capsules, soft drinks, and ginseng wine (Jang et al., 2011; Jee et al., 2006). However, beers with added ginseng or red ginseng have not been developed or commercialized, even in Korea where consumers prefer purchasing healthier products.

Bokbunja, Korean black raspberry (*Rubus coreanus* Miquel) fruit, is native to Korea, Japan, and China (Lee, 2015). *Bokbunja* fruits are mainly used to produce traditional wine in Korea, and they contain anthocyanins, which function as antioxidants and possess anti-inflammatory properties. The consumption of *Bokbunja* wine has increased because of its therapeutic effects on asthma, enuresis, and allergic diseases, etc. (Jin et al., 2008; Lee, 2013a). The development of *Bokbunja* beers has also been lacking. Thus, a beer with Korean red ginseng extract or *Bokbunja* juice is expected to be the premium specialty beer of Korea.

In this study, Korean red ginseng extract and Korean black raspberry (*Bokbunja*) juice were added at various fermentation stages. Several properties of each beer were analyzed during the fermentation process, and sensory analysis was performed after secondary fermentation.

Materials and Methods

Raw materials

Korean two-row barley malt (*Gwangmaek* malt) was supplied by the National Institute of Crop Science (Iksan, Jeollabuk-do, Korea). Czech Saaz pellet-type hops (Hopunion, Czech) and *Saccharomyces cerevisiae* Saflager W-34/70 (Fermentis, Marcq-en-Baroeul, France) were used for brewing. Alpha-amylase (from *Bacillus licheniformis*, Almylex BT2), glucoamylase (from *Aspergillus niger*, GA-L New), and β-glucanase (from *Trichoderma reesei*,

*Corresponding author: Wang June Kim, Department of Food Science and Biotechnology, College of Life Science and Biotechnology, Goyang 10326, Republic of Korea
Tel: +82-31-961-5144

E-mail: wjkim@dongguk.edu

Received September 23, 2019; revised October 30, 2019;

accepted November 13, 2019

Laminex BG2) were provided by Vision Biochem Co. Ltd. (Seongnam, Korea). Fermented red ginseng extract G21 (Myeongjang®, Basan Co., Anseong, Korea) or *Bokbunja* juice (Berrywell, Gochang, Korea) was added during each fermentation step. Beers supplemented with Korean red ginseng extract at the start of primary fermentation, at the end of primary fermentation, and at the end of secondary fermentation are indicated as S1, P1, and SF1, respectively. Beers supplemented with *Bokbunja* juice at the start of primary fermentation, at the end of primary fermentation, and at the end of secondary fermentation are indicated as S2, P2, and SF2, respectively.

Mashing and wort boiling

Mashing was performed according to the European Brewery Convention (EBC) mash method (Convention EB, 1998). Seventy-five (75) grams of malt were mixed with 600 mL of distilled water and preheated to 52°C in an amber bottle (Schott Duran, Mainz, Germany). Three enzymes (α -amylase, glucoamylase, and β -glucanase) were then added (0.1% of barley malt, v/w). The mashing-in process began with a 20 min incubation at 52°C. The temperature was then increased at a rate of 1°C/min. The bottle was cooled down to 20°C, and filtration was conducted using filter paper (No. 597 1/2, Whatman, Dassel, Germany). The clarified wort was boiled with the hops intermittently for 20 min and cooled to 15°C until the hops settled.

Fermentation

The upper layer of the hopped wort was collected for beer fermentation. Korean red ginseng extract and *Bokbunja* juice were added to the hopped wort (0.05% of wort, w/v and 3% of wort, v/v, respectively) at the start of primary fermentation (S). *S. cerevisiae* Saflager W-34/70 (Fermentis) was inoculated at a ratio of 1 g/L, and the initial concentration was 5.0×10^6 cells/mL. Red ginseng extract or *Bokbunja* juice was also added at the end of primary fermentation (P) and secondary fermentation (SF). Primary fermentation and secondary fermentation were conducted at 14°C for seven days and at 4°C for 21 days, respectively.

Yeast viability

Yeast viability was assessed according to methods established by the American Society of Brewing Chemists (ASBC) (Crumplen, 1997). Yeast cells were counted using yeast extract-peptone-dextrose (YPD) agar plates during primary and secondary fermentation.

Beer quality analysis

To determine the differences between samples, several beer quality properties were analyzed. All measurements were conducted in triplicate. The pH of the wort and beer was measured by a pH meter (ORION 3 STAR, Thermo, Singapore).

The specific gravity (SG) of the wort and beer was measured using a hydrometer (200-DK-6, Daekwang, Seoul, Korea). The SG of the hopped wort was measured before the yeast was pitched and at the end of each fermentation stage.

Reducing sugar (RS) was measured using the 3,5-dinitrosalicylic acid (DNS) method (Miller, 1959). The absorbance of each sample

was determined at 550 nm, and the RS content was calculated based on a standard curve.

The color of all samples was measured throughout the fermentation process with a portable spectrophotometer (CR-2500d, Minolta Co., Ltd., Osaka, Japan). One (1) mL of each sample was deposited into a specially produced vial. The data were recorded as L, a, and b values, which represent lightness, redness, and yellowness, respectively (Han et al., 2016).

The free amino nitrogen (FAN) content of the wort and beer were measured during fermentation in accordance with the official analysis method of the Association of Official Agricultural Chemists (AOAC) (Horwitz and Latimer, 2011). The absorbance of each sample was determined at 570 nm using a spectrophotometer (UVmini-1240, Shimadzu, Kyoto, Japan). FAN content was calculated as follows:

$$\text{Free amino nitrogen (mg/L)} = \frac{\text{net absorbance value of the test solution} \times 2}{\text{dilution/net absorbance value of the standard solution}}$$

Alcohol content and turbidity

After secondary fermentation, the alcohol content of each sample was determined using a vinometer (211-DK-12, Daekwang, Seoul, Korea). All values were calculated according to the method described in the Korean Food Standard Codex (Korea Food K. and Drug Administration, 2012). Turbidity was analyzed using a UV/Vis-spectrophotometer (UVmini-1240, Shimadzu, Kyoto, Japan). The absorbance of each sample was determined at 430 and 700 nm. If the absorbance at 700 nm was 0.039 times higher than at 430 nm, the beer was deemed “turbid.”

Sensory evaluation

A descriptive analysis was used to test sensory evaluation. The panels were comprised of graduate and undergraduate students from Dongguk University. Panel members were selected based on their accuracy and ability to reproducibly detect bitterness. Each candidate was tested four times with five reference materials (20, 40, 60, 80, and 100 mg/L of an aqueous iso-humulone solution). Candidates showing insignificant differences ($p > 0.05$) between the five means of four replicates per reference material (poor reproducibility) and who did not show an increasing order that correlated with the iso-humulone concentrations (low accuracy) were excluded (Kim et al., 1993). Twenty panels were composed of men and women at a ratio of ten to ten. They were trained through several orientation and discussion sessions so that they became familiar with the descriptors, which can be found in Table 1.

Descriptive words were adopted from the descriptive terminologies listed in the ASBC standard (Crumplen, 1997). They include odor, taste, mouthfeel, and aftertaste. The odor was sub-categorized as fruity (O1) or alcoholic (O2); the taste was sub-categorized as bitter (T1), sweet (T2) or sour (T3); and mouthfeel was sub-categorized as mouth coating (M1), carbonation (M2), or astringent (M3). The duration of aftertaste was denoted as A1, and the overall preference was denoted as P1. The intensity of each attribute was scored on a 1-9 linear interval scale (1: not present at all; 2: very weak; 3, 4: weak; 5, 6: moderate; 7, 8: strong; 9:

Table 1. Recommended descriptors in the sensory evaluation of beer and their reference materials

Class terms	First Tiers	Descriptors' abbreviations	Definitions	Reference materials ¹⁾
Aromatic	Fruity	Odor (O)1	Of specific fruits or mixtures of fruits	Ethanol (50 g/L-water)
	Alcoholic	O2	General effect of ethanol and higher alcohols	
Bitter	Bitter	Taste (T)1	Bitter	Isohumulone
Sweet	Sweet	T2	Sweet	Sucrose, 7.5 g/L-water
Sour Acidic	Sour	T3	Lactic, sour milk; use with Citrus for citrus-sour	
Mouthfeel	Mouth coating	Mouthfeel (M)1	Creamy	Quercitrin, 240 mg/L
	Carbonation	M2	CO ₂ content	
	Astringent	M3	Mouth puckering, tannin-like, tart	

1) Referenced from Crumplen (1997). Diluted reference materials were used to attain different intensities.

very strong) (Kim, 1998).

All samples were stored at 4°C for one week before use, and the tests were performed in tasting booths at 20°C. Ten (10) mL of each beer sample was given to the panels in glass cups labeled with random three-digit codes. The panels answered questions for each sample, and further questions were provided for another sample. Tasting panels were required to test each sample within 2 min on average and to take 30 s rests between each sample to cleanse their palates with water and crackers (King and Heymann, 2014).

Statistical analysis

Statistical analyses were performed using GraphPad PRISM software (GraphPad Software, Inc.). All experiments were performed in triplicate. The data were analyzed using analysis of variance (ANOVA) at a significance level of $\alpha=0.05$ followed by Tukey's post-test.

Results and Discussion

Yeast viability

Figure 1 shows the yeast viability during fermentation. Cell numbers for all samples steadily increased during primary fermentation from 6.8 to 7.6 log cells/mL, and yeast growth was maintained at 6.2 log cells/mL during secondary fermentation. The yeast viability of beers supplemented with Korean red ginseng extract or *Bokbunja* juice before primary fermentation (S1 and S2) was higher by 0.2 log cells/mL when compared to the control during primary fermentation (Fig. 1A). Fig. 1B shows the changes in yeast viability during secondary fermentation. The number of initial yeast cells was higher in beers with extract or juice added after primary fermentation (P1 and P2) when compared to other samples. The yeast viability of P1 and P2 changed similarly during secondary fermentation, and the differences were statistically significant compared to the control ($p<0.05$). There were also significant differences between S1 and P1 during secondary fermentation ($p<0.05$).

Specific gravity

Figure 2 shows the changes in SG throughout the fermentation process. The SGs of all samples were similar, and there were no significant differences ($p>0.05$). The SGs for all samples before

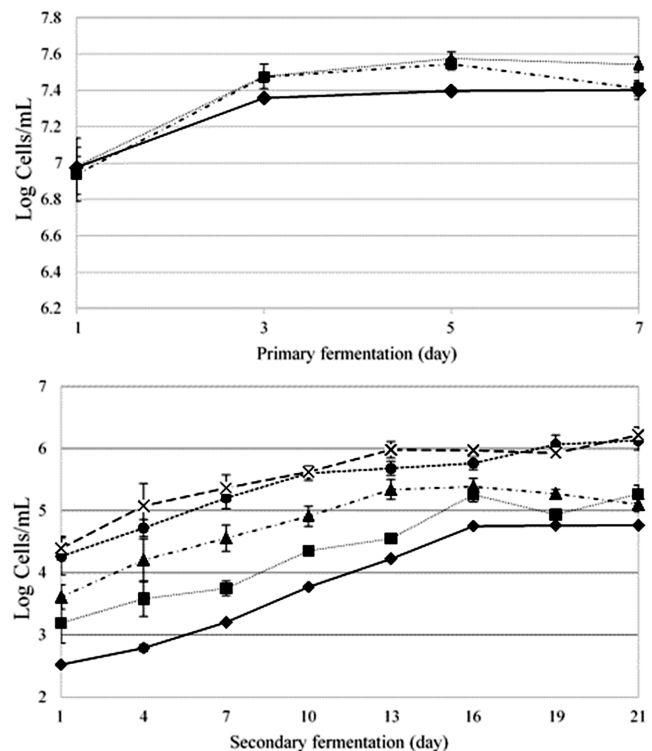


Fig. 1. Change in yeast viability of the control and extract- or juice-supplemented samples during primary and secondary fermentation. ◆: Control, ▲: S1, ■: S2, ●: P1, ×: P2. Error bars represent the standard deviation (n=3).

fermentation were close to 1.040, and it decreased in all samples to about 1.010 after primary fermentation (Fig. 2). The SG of S2 was slightly higher than other samples at the start of primary fermentation, and there was no significant difference ($p>0.05$). The SG of SF2 (1.011 ± 0.000) was higher than that of other samples, but it was not significantly different ($p>0.05$). This could indicate that the red ginseng extract and *Bokbunja* juice did not affect the SG of the wort or beers due to their small quantities.

pH

Figure 3 shows the changes in pH for all samples during the fermentation process. As fermentation progressed, the pH values of all samples decreased. In particular, the pH values of samples containing *Bokbunja* (S2, P2, and SF2) were lower than the

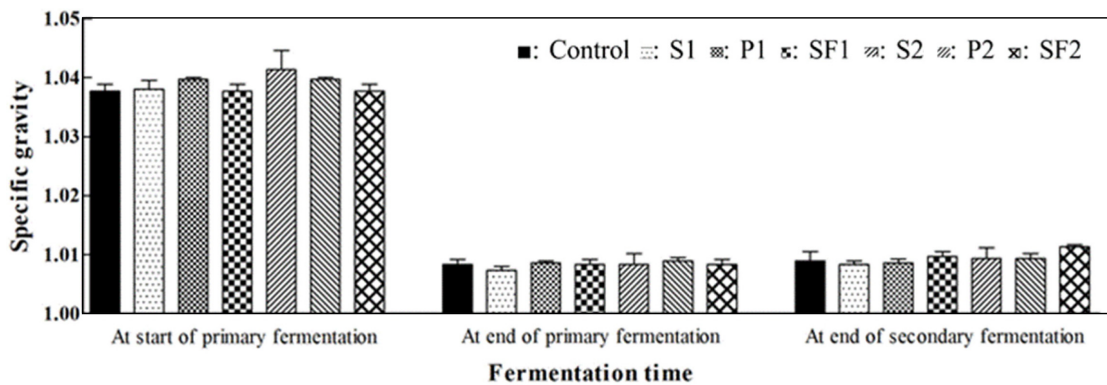


Fig. 2. Kinetic changes in the specific gravity of the control and extract- or juice-supplemented samples. Error bars represent the standard deviation (n=3).

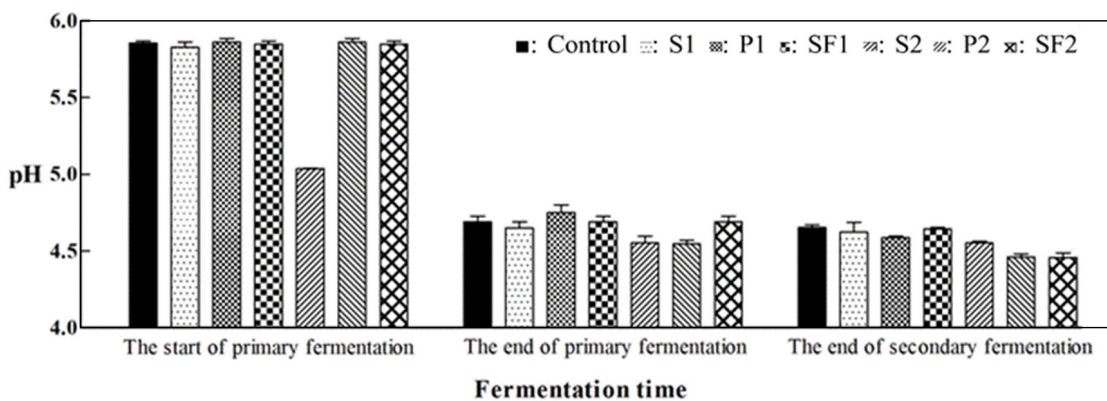


Fig. 3. Kinetic changes in the pH of the control and extract- or juice-supplemented samples. Error bars represent the standard deviation (n=3).

control and red ginseng samples. The initial pH values of the wort were between 5.3-5.6 depending on the materials used during mashing (Martínez et al., 2017). At the start of primary fermentation, all samples, except for S2, exhibited pH values of 5.83 ± 0.03 and 5.86 ± 0.03 . The pH of S2 was 5.04 ± 0.00 , and there was a statistically significant difference between S2 and the other samples ($p < 0.05$). This difference was likely caused by the low pH range of the *Bokbunja* juice (3.42-3.56) (Lee and Ahn, 2009; Ra and Kim, 2016). The pH values of the three samples supplemented with *Bokbunja* juice (S2, P2, and SF2) were 4.55 ± 0.01 , 4.46 ± 0.02 , and 4.33 ± 0.20 at the end of secondary fermentation ($p < 0.05$). While the pH value of S2 was constant before (4.55 ± 0.05) and after secondary fermentation (4.55 ± 0.01), the pH values of the control, P2, and SF2 decreased after secondary fermentation. The values changed according to the stage at which the juice was added. At the end of secondary fermentation, the pH values of P2 and SF2 decreased when compared to the control ($p < 0.05$). The addition of red ginseng extract to the wort or beer did not affect the pH value of any sample ($p > 0.05$).

Free amino nitrogen (FAN) content

Free amino nitrogen (FAN) content indicates the amount of small peptides, amino acids, ammonium ions, etc. in beer. If the FAN content is too high, it forms a haze that makes the beer

cloudy. In contrast, low FAN content leads to insufficient yeast growth and low alcohol production (Briggs et al., 2004). FAN is regarded as an index for predicting yeast viability and fermentation efficiency because it is used by yeast as a nutrient source and influences beer quality and stability (Han et al., 2016; Lekkas et al., 2009).

Figure 4 presents the changes in FAN values during primary and secondary fermentation. The FAN content of all samples gradually decreased during primary fermentation (Fig. 4A). Over that period, the initial FAN value of S2 was higher than that of the control and S1 ($p > 0.05$). There was no change between the initial and final FAN values for all samples during secondary fermentation (Fig. 4B). In addition, there was a statistically significant difference between the changes in the FAN values of P1, P2, and the control over the same period ($p < 0.05$).

Reducing sugar (RS) content

Changes in RS content during primary fermentation are presented in Fig. 5. The RS content decreased as the primary fermentation proceeded. The initial RS content was highest in S2. The results indicate that the *Bokbunja* juice had a higher saccharide content than the red ginseng extract. It is known that *Bokbunja* juice is high in sugar and can likely be used as a carbon source by yeast. The RS content of the control, S1, and S2 did not show any

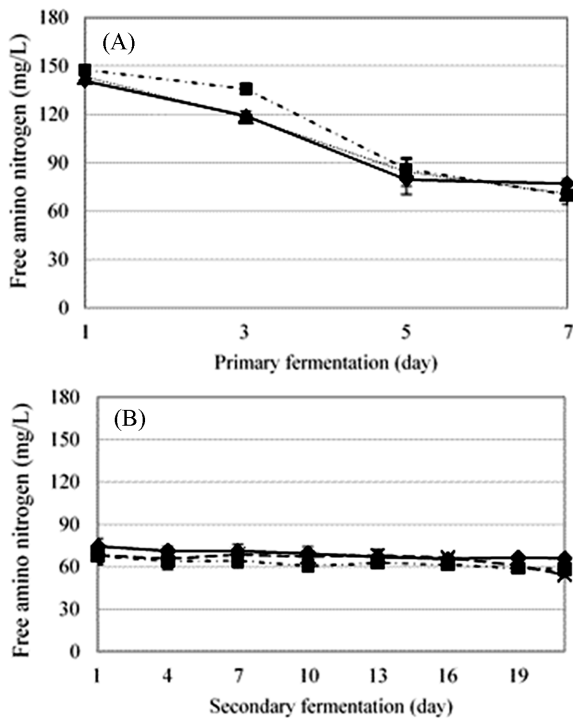


Fig. 4. Change in the free amino nitrogen content of the control and extract- or juice-supplemented samples during primary and secondary fermentation. A: primary fermentation, B: secondary fermentation, or maturation. ◆: Control, ▲: S1, ■: S2, ●: P1, ×: P2. Error bars represent the standard deviation (n=3).

significant differences at the start of primary fermentation ($p > 0.05$). The initial RS content of P1 showed no difference when compared with the control or S1. The RS reduction was similar in all samples during primary fermentation. The initial RS content of P2 was slightly higher than that of the control and S2. The change in RS content during secondary fermentation was not significantly different for any sample (data not shown).

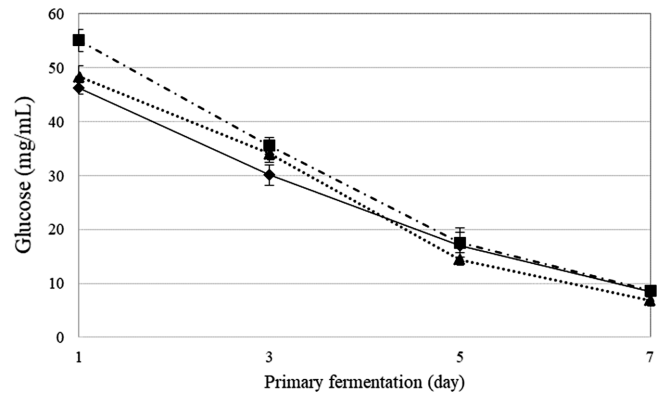


Fig. 5. Change in the reducing sugar content of the control and extract- or juice-supplemented samples during primary fermentation. ◆: Control, ▲: S1, ■: S2. Error bars represent the standard deviation (n=3).

Color

Changes in the color of the control and extract- or juice-supplemented samples during fermentation are presented in Table 2 and 3, respectively. The L values of the control and red ginseng samples tend to increase as fermentation progress (Table 2). This is due to decreasing amounts of nitrogen compounds such as FAN caused by the Maillard reaction (Poreda et al., 2014). Compared to the control, S1 had a lower lightness ($L=33.00 \pm 0.38$), redness ($a=1.18 \pm 0.21$), and yellowness ($b=12.89 \pm 0.27$) at the start of primary fermentation ($p < 0.05$). The b value of S1 was higher after primary fermentation (13.24 ± 0.26) and then decreased after secondary fermentation (12.54 ± 0.94). In addition, the b value of P1 (14.62 ± 0.31) was highest among red ginseng-supplemented samples. For the *Bokbunja* juice-supplemented samples, the L and b values tended to decrease, and the a value increased after adding the *Bokbunja* juice.

The L value was highest for S2 and lowest for SF2. Visually, S2 also seemed to be more transparent than P2 or SF2 at the end

Table 2. Change in color of the control and three samples with red ginseng extract

		The start of primary fermentation	The end of primary fermentation	The end of secondary fermentation
Control	L value	35.32±0.18	37.43±1.16	39.07±0.98
	a value	0.34±0.04	0.32±0.08	0.64±0.24
	b value	11.26±0.24	11.23±0.03	10.47±0.47
S1	L value	33.00±0.38**	36.82±0.39	37.38±0.07
	a value	1.18±0.21*	0.67±0.10	0.79±0.17
	b value	12.89±0.27*	13.24±0.26**	12.54±0.94
P1	L value	35.32±0.18*	37.75±0.44	37.16±0.10
	a value	0.34±0.04	0.79±0.17	1.05±0.39
	b value	11.26±0.24	14.62±0.31***	13.08±1.04
SF1	L value	35.32±0.18	37.75±0.44	38.24±0.20
	a value	0.34±0.04	0.79±0.17	0.51±0.26
	b value	11.26±0.24	14.62±0.31	12.76±0.77

1) Mean±standard deviation (n=3)

2) Significance level in the unpaired t-test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Change in color of the control and three samples with *Bokbunja* juice

		The start of primary fermentation	The end of primary fermentation	The end of secondary fermentation
Control	L value	35.32±0.18	37.43±1.16	39.07±0.98
	a value	0.34±0.04	0.32±0.08	0.64±0.24
	b value	11.26±0.24	11.23±0.03	10.47±0.47
S2	L value	26.72±0.83***	29.50±0.67**	30.40±1.45**
	a value	8.10±0.92**	8.47±1.15**	7.90±1.10**
	b value	7.04±0.07***	8.58±0.35**	9.06±0.57
P2	L value	35.32±0.18	24.01±0.37***	26.68±0.64***
	a value	0.34±0.04	11.00±0.07***	9.47±0.60***
	b value	11.26±0.24	6.74±0.40***	7.92±0.29*
SF2	L value	35.32±0.18	37.75±0.44	25.45±1.01***
	a value	0.34±0.04	0.79±0.17	10.15±0.66***
	b value	11.26±0.24	14.62±0.31	6.32±0.42**

1) Mean±standard deviation (n=3)

2) Significance level in the unpaired t-test: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 4. Alcohol content and turbidity of the control and extract- or juice-supplemented samples

	Alcohol content (%)	Turbidity
Control	3.8±0.16	Existed
S1	3.7±0.25	Existed
P1	3.7±0.25	Existed
SF1	3.8±0.22	Existed
S2	4.2±0.09	Existed
P2	3.6±0.19	Existed
SF2	3.8±0.15	Existed

1) Mean±standard deviation (n=3)

of secondary fermentation. Regarding the a value, S2 showed the lowest value (7.90±1.10) while SF2 showed the highest value (10.15±0.66). This indicates that the red color of the sample darkened due to the later addition of the *Bokbunja* juice during fermentation. Furthermore, there was a statistically significant difference between the control and the *Bokbunja* juice-supplemented samples according to L, a, and b values ($p<0.05$).

Alcohol content and turbidity

The alcohol content and turbidity of the samples after secondary fermentation are presented in Table 4. The alcohol content in commercial lager beers is 2.8-8.5% (Zhao et al., 2010). The alcohol content of S2 was 4.2% ($p>0.05$), which was similar to all other samples. There was no significant difference between the control and beer samples supplemented with extract or juice ($p>0.05$). Martínez et al. (2017) reported that the initial RS concentration of persimmon-added wort affected the final ethanol content of the beers, and the beer with a higher ratio of added persimmon juice contained more alcohol. All samples showed turbidity, likely because clarification and filtration were not carried out after secondary fermentation.

Sensory evaluation

Tables 5 and 6 present the results of the sensory evaluation. The

intensity of the bitter taste (T1) was stronger in S1 and P1 when compared to the control ($p<0.05$). This could be explained by the bitter taste of the red ginseng, itself. In addition, the intensity of the astringent mouthfeel (M3) was stronger in S1 (4.50±0.33), P1 (4.55±0.38), and SF1 (4.58±0.38) than in the control (3.82±0.11), and there was no significant difference ($p>0.05$). In terms of overall preference (P1), SF1 had the highest score ($p<0.05$). Regarding *Bokbunja* juice-supplemented beers, SF2 had the highest score in terms of fruity odor intensity (O1), sweetness (T2), sourness (T3), aftertaste (A1), and overall preference (P1). The odor and flavor of S2 and P2 were lower than SF2, which may be because the odor and flavor were altered during fermentation. The odor and flavor of the sample supplemented with juice at the end of secondary fermentation almost remained unchanged before the sensory test was conducted. Regarding the fruity odor (O1), all samples supplemented with *Bokbunja* juice showed a stronger intensity than the control ($p<0.05$). Consequently, the values of the three samples containing *Bokbunja* juice were higher than the red ginseng-supplemented samples. The beers with extract or juice added later during fermentation received higher scores in terms of overall preference (P1).

Conclusion

Beer with Korean red ginseng extract or *Bokbunja* juice was maintained with original beer's own fermentation properties. Yeast viability, specific gravity, free amino nitrogen, reducing sugar, and alcohol content were not significantly different between any samples due to the small amount of extract or juice added. The lower pH of *Bokbunja* juice affected the pH of the wort or beer, and the beers supplemented with juice received a higher score when compared to others in terms of overall sensory evaluation preference. In addition, beers supplemented with Korean red ginseng extract or *Bokbunja* juice after secondary fermentation had higher scores than beer with these added before primary fermentation. Therefore, the time at which extract or juice is added must be considered to produce specialty beers such as fruit beer.

Table 5. Sensory properties of the control and red ginseng extract-supplemented beer

	Control	Red ginseng-supplemented beer		
		S1	P1	SF1
O1	4.42±0.20	4.43±0.10	4.48±0.04	4.68±0.41
O2	4.77±0.12	5.03±0.27	4.61±0.04	5.00±0.43
T1	4.40±0.06	5.32±0.12**	5.30±0.13**	5.13±0.26
T2	3.38±0.20	3.06±0.06	3.19±0.51	3.22±0.12
T3	3.47±0.26	3.35±0.28	3.40±0.18	3.77±0.02
M1	4.20±0.13	3.73±0.03*	3.57±0.22	3.42±0.17*
M2	2.73±0.25	3.17±0.35	3.93±0.18*	3.13±0.21
M3	3.82±0.11	4.50±0.33	4.55±0.38	4.58±0.38
A1	4.25±0.10	4.83±0.31	4.92±0.27	4.83±0.19
P1	4.07±0.12	4.05±0.36	4.45±0.28	4.48±0.09*

1) Mean±standard deviation (n=3)

2) Significance level in the unpaired t-test: * $p<0.05$, ** $p<0.01$ **Table 6. Sensory properties of the control and *Bokbunja*-supplemented beer**

	Control	<i>Bokbunja</i> juice-supplemented beer		
		S2	P2	SF2
O1	4.42±0.20	5.78±0.39*	6.08±0.04**	6.28±0.03***
O2	4.77±0.12	4.52±0.09	4.73±0.13	4.85±0.18
T1	4.40±0.06	4.52±0.20	4.50±0.22	4.30±0.15
T2	3.38±0.20	3.85±0.19	4.25±0.16*	5.23±0.13**
T3	3.47±0.26	4.63±0.22*	4.48±0.51	4.60±0.12*
M1	4.20±0.13	3.37±0.35	3.05±0.13*	3.42±0.36
M2	2.73±0.25	3.13±0.17	3.70±0.10*	3.73±0.23*
M3	3.82±0.11	4.37±0.15*	4.53±0.24	4.30±0.21
A1	4.25±0.10	4.57±0.19	4.95±0.23*	5.02±0.09**
P1	4.07±0.12	5.00±0.38	5.38±0.10**	5.68±0.12***

1) Mean±standard deviation (n=3)

2) Significance level in the unpaired t-test: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Adding them after primary fermentation is better than before primary fermentation in maintaining each beer's flavor and taste until consumption.

Recently, craft breweries have been producing beers with various flavors. Developing Korean red ginseng and *Bokbunja* beers requires focusing on specific factors such as age, gender, preference between beer and other alcoholic beverages, etc. The optimal amount of extract or juice has to be taken into account, and investigating the consumer's perception of each beer is necessary.

Acknowledgments

This work was a research project (IPET, 114088-3 and 319049-3) of the IPET (Korea Institute of Planning and Evaluation for Technology of Food, Agriculture, Forestry, and Fisheries), supported by the Ministry of Agriculture, Food, and Rural Affairs.

References

- Boulton CA. Yeast management and the control of brewery fermentations. *Brew. Guard.* 120: 25-29 (1991)
- Boulton C, Quain D. *Brewing yeast and fermentation.* John Wiley and Sons, USA. p. 406 (2008)
- Briggs DE, Boulton CA, Brookes PA, Stevens R. *Brewing science and practice.* CRC Press, USA. pp. 34, 38, 98-102, 270, 510-512, 539-540 (2004)
- Crumplen RM. *Laboratory methods for craft brewers.* American Society of Brewing Chemists, Minnesota, USA. pp. 9, 35-83 (1997)
- Daenen L, Sterckx F, Delvaux FR, Verachtert H, Derdelinckx G. Evaluation of the glycoside hydrolase activity of a *Brettanomyces* strain on glycosides from sour cherry (*Prunus cerasus* L.) used in the production of special fruit beers. *FEMS Yeast Res.* 8: 1103-1114 (2008)
- De Keersmaecker J. The mystery of lambic beer. *Scientific American.* 275: 74-80 (1996)
- Convention EB. *Analytica-EBC.* 5th ed. Method 4.5.1. Fachverlag Hans Carl, Nürnberg, Germany (1998)
- Han H, Kim J, Choi E, Ahn H, Kim WJ. Characteristics of beer produced from Korean sixrow barley with the addition of adjuncts. *J. Inst. Brew.* 122: 500-507 (2016)
- Horwitz W, Latimer GW. *Official methods of analysis of AOAC International.* J. AOAC Int., Maryland (2011)
- Jang M, Min JW, Yang DU, Jung SK, Kim SY, Yang DC. Ethanolic fermentation from red ginseng extract using *Saccharomyces cerevisiae* and *Saccharomyces carlsbergensis*. *Food Sci. Biotechnol.* 20: 131-135 (2011)
- Jee HK, Cho YJ, Kim CT, Jang YS, Kim CJ. Increase of solubility of ginseng radix by extrusion cooking. *Korean J. Food Sci. Technol.* 38: 361-368 (2006)
- Jeon CG. Strategic development of ginseng industry for higher value-added industrialization. Korea Rural Economic Institute, Seoul,

- Korea. pp. 10-105 (2013)
- Jin TY, Heo SI, Lee WG, Lee IS, Wang MH. Manufacturing characteristics and physicochemical component analysis of *Bokbunja* (*Rubus coreanus* Miquel) jam. J. Korean Soc. Food Sci. Nutr. 37: 48-52 (2008)
- Kim GO, Kim SS, Sung NG, Lee YC. Sensory science theory and applications. Shin Gwang, Korea. pp. 79-130 (1993)
- Kim KO., Lee YC. Sensory evaluation of food. Hakyonsa, Seoul, Korea. pp. 116-124 (1998)
- King ES, Heymann H. The effect of reduced alcohol on the sensory profiles and consumer preferences of white wine. J. Sens. Stud. 29: 33-42 (2014)
- Korea Food and Drug Administration. Korean Food Standards Codex. 5-27-1. Korea Food and Drug Administration, Cheonju, Korea (2012)
- Lee SJ, Ahn BM. Changes in physicochemical characteristics of black raspberry wines from different regions during fermentation. Korean J. Food Sci. Technol. 41: 662-667 (2009)
- Lee JH, Choi KH, Sohn EH, Jang KH. Quality characteristics and ginsenosides composition of ginseng-*Yakju* according to the particle size of ginseng powder. Prev. Nutr. Food Sci. 18: 234 (2013)
- Lee DY, Heo SJ, Kim SG, Choi HK, Lee HJ, Cho SM, Auh JH. Metabolomic characterization of the region- and maturity-specificity of *Rubus coreanus* Miquel (*Bokbunja*). Food Res. Int. 54: 508-515 (2013)
- Lee JM. Analysis of *Bokbunja* products show they contain *Rubus occidentalis* L. fruit. J. Funct. Foods. 12: 144-149 (2015)
- Lekkas C, Hill AE, Taidi B, Hodgson J, Stewart GG. The role of small wort peptides in brewing fermentations. J. Inst. Brew. 115: 134-139 (2009)
- Martínez A, Vegara S, Martí N, Valero M, Saura D. Physicochemical characterization of special persimmon fruit beers using bohemian pilsner malt as a base. J. Inst. Brew. 123: 319-327 (2017)
- Miller GL. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal. Chem. 31: 426-428 (1959)
- Prasad MP. In-vitro evaluation of antioxidant properties of fermented fruit beer samples. Int. J. Sci. Res. 3: 1545-1550 (2014)
- Poreda A, Czarnik A, Zdaniewicz M, Jakubowski M, Antkiewicz P. Corn grist adjunct-application and influence on the brewing process and beer quality. J. Inst. Brew. 120: 77-81 (2014)
- Ra HN, Kim NG. Antioxidant activities and quality characteristics of gravy sauce added with *Bokbunja* (*Rub coreanus* Miquel), mulberry and blueberry. Korean J. Food Cook. Sci. 32: 458-465 (2016)
- Yeo HQ, Liu SQ. An overview of selected specialty beers: Developments, challenges and prospects. Int. J. Food Sci. Technol. 49: 1607-1618 (2014)
- Zhao H, Chen W, Lu J, Zhao M. Phenolic profiles and antioxidant activities of commercial beers. Food Chem. 119: 1150-1158 (2010)