Korean Journal for Food Science of Animal Resources

Korean J. Food Sci. An. 2018 August 38(4):737~748
DOI https://doi.org/10.5851/kosfa.2018.e12

pISSN : 1225-8563 eISSN : 2234-246X
www.kosfa.or.kr

ARTICLE

Physicochemical and Storage Characteristics of Hanwoo Tteokgalbi Treated with Onion Skin Powder and Blackcurrant Powder

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OPEN ACCESS

Received June 5, 2018
Revised July 6, 2018
Accepted July 6, 2018

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Abstract We evaluated the physicochemical and storage characteristics of Hanwoo Tteokgalbi treated with onion skin powder (OSP) and blackcurrant fruit powder (BFP). The experimental design included seven treatments: a control (ascorbic acid 0.1%), T1: OSP 0.3%, T2: OSP 0.6%, T3: BFP 0.3%, T4: BFP 0.6%, T5: OSP 0.15%+BFP 0.15%, and T6: OSP 0.3%+BFP 0.3%. The OSP was higher in both polyphenol and flavonoid contents compared to BFP ($p<0.05$). The moisture and ash contents of all Tteokgalbi samples with a large amount of added natural antioxidant powder (0.6%) were higher than those with small amounts of added antioxidant (0.3%). The cooking loss and water holding capacity were outstanding in the T2 treatment compared to the others ($p<0.05$). The lightness, redness, and yellowness values were reduced on the addition of 0.6% antioxidant powder ($p<0.05$). The springiness and cohesiveness values of the Tteokgalbi samples were higher for the 0.3% addition than the control and 0.6% addition ($p<0.05$). The Tteokgalbi samples with natural antioxidants showed similar sensory attribute scores compared to the control. The pH values reduced as the BFP increased ($p<0.05$), and the total microbial count increased after OSP addition. The 2-thiobarbituric acid reactive substance values of the samples treated with OSP were significantly lower than the control after day 10 ($p<0.05$). As a result, the addition of OSP or BFP did not have a significant negative influence on the quality characteristics of Hanwoo Tteokgalbi. In particular, the addition of 0.6% OSP was effective in increasing water retentivity and inhibiting lipid oxidation.

Keywords natural antioxidant, onion skin powder, black currant powder, Tteokgalbi, Hanwoo beef

Introduction

Since the 2000s, the purpose of food intake has shifted from relieving hunger to increasing health and giving pleasure. This change has been caused by changes in lifestyle arising from industrial development, urbanization, and economic growth. In the food industry, antioxidants are used to prevent oxidative degradation, rancidity, and the discoloration of food during processing and storage (Schillaci et al., 2014). From an industrial point of view, synthetic antioxidants are superior to natural antioxidants in their efficiency and price competitiveness, so they are extensively used in the mass production of food. However, recently, consumers have become increasingly concerned about the possible side effects of artificial preservatives on their health and have tried to exclude them from their diets.

Nowadays, instead of using chemical antioxidants, the development of foodstuffs using natural plant ingredients containing phenolic and flavonoid substances has been actively carried out (Burri et al., 2017; Cheng et al., 2018). Phytochemicals such as phenolic and flavonoid substances have a strong antioxidant capacity, and the ingestion of these substances has the effect of reducing the oxidative damage of cells, as well as the risk of chronic diseases (Alvarez-Suarez et al., 2018; Chen et al., 2018). Phytochemicals with antioxidant power are produced mainly from plant materials including fruits, vegetables, grains, and their by-products (Kaur and Kapoor, 2001; Leong et al., 2018; Smuda et al., 2018).

Globally, onions are one of the most common cooking ingredients and are used in a variety of foods. Onions are rich in quercetin and quercetin derivatives, which have a strong antioxidant capacity (Corzo-Martínez et al., 2007). However, when making food, the onion skin and outer layer are generally removed, despite their high antioxidant potential (Gawlik-Dziki et al., 2013).

The blackcurrant is a shrub native to Northern Asia and Europe, and its fruits and leaves are abundant in functional compounds such as ascorbic acid, flavone, anthocyanin, polyphenol, and polysaccharide, and it has been found to have antioxidant, antitumor, and anti-inflammatory properties (Xu et al., 2016). Recently, blackcurrant fruits have been reported to have a high antioxidant effect (Xu et al., 2018).

Therefore, in this study, onion skin, which is usually discarded despite its high antioxidant potential, and blackcurrant fruits were applied to Hanwoo Tteokgalbi as natural antioxidants, and effects on the physicochemical and storage characteristics during cold storage were investigated.

Materials and Methods

Preparation of natural antioxidant powders

Onion (*Allium cepa* L.) skin powder was purchased from a local market in Cheongju, Korea, and black currant fruit (*Ribes nigrum* L.) powder was purchased from internet market (More and up Co. Ltd., Seoul, Korea). The thinly spread powders on weight dishes were further air dried at room temperature (20°C) in darkness for 1 days and then completely vacuum freeze-dried below –50°C. The final onion skin powder (OSP) and black currant fruit powder (BFP) were stored at –20°C for later use.

Preparation of Hanwoo Tteokgalbi product

Hanwoo Tteokgalbi product with OSP and BFP formulation and experimental design are shown in the Table 1. Hanwoo beef (top round) were purchased in vacuum packaged containers from a butcher's shop (Chungju, Korea). Subcutaneous and excessive connective tissues were removed from beef and ground twice through a 9-mm plate. Seven batches were prepared by each 5 kg for 3 replications and the Hanwoo Tteokgalbi products were produced according to the following procedure. First, minced beef was mixed with curing ingredients (7% ice, 0.5% kiwi juice, 4% soy sauce, 2% sugar, 0.1% calcium lactate, and 1% refined salt) by hand for 15 min. uniformly, and then it was aged in the refrigerator (4°C) for 24 h. Second, the batter was

Table 1. Experimental design and formula for Hanwoo Tteokgalbi (Unit: %)

Treatments	Control	T1	T2	T3	T4	T5	T6
Onion skin powder	-	0.3	0.6	-	-	0.15	0.3
Black currant powder	-	-	-	0.3	0.6	0.15	0.3
Ascorbic acid	0.1	-	-	-	-	-	
							(Unit: g)
Hanwoo beef	76.38			Scallion	2		
Ice	7			Calcium lactate	0.1		
Onion	5			Galic	0.5		
Kiwi juice	0.5			Sesame oil	0.5		
Soy sauce	4			Salt	1		
Shiitake	1			Pepper	0.02		
Sugar	2						
Total				100			

mixed with the other grinded ingredients (5% onion, 1% shiitake, 2% scalion, 0.5% galic, 0.5% sesame oil, and 0.02% pepper) for 5 min and as experimental design, respective OSP and/or BFP were added and mixed for 5 min Third, the final batter was molded into 150 g (10 cm diameter, 1 cm thickness) units by burger press. The Hanwoo Tteokgalbi products were then stored in a cold chamber (FSR0120, JEIO TECH, Korea) at 4℃ for 10 days and used for analysis sample. The analyses of each sample was repeated three times. The un-heated Hanwoo Tteokgalbi products were presented as the photo (Fig. 1).

Analysis items

Total polyphenol and flavonoid contents

The powdered samples (3 g) were extracted with 80% (v/v) methanol-water solution (40 mL). Extraction was sonicated at

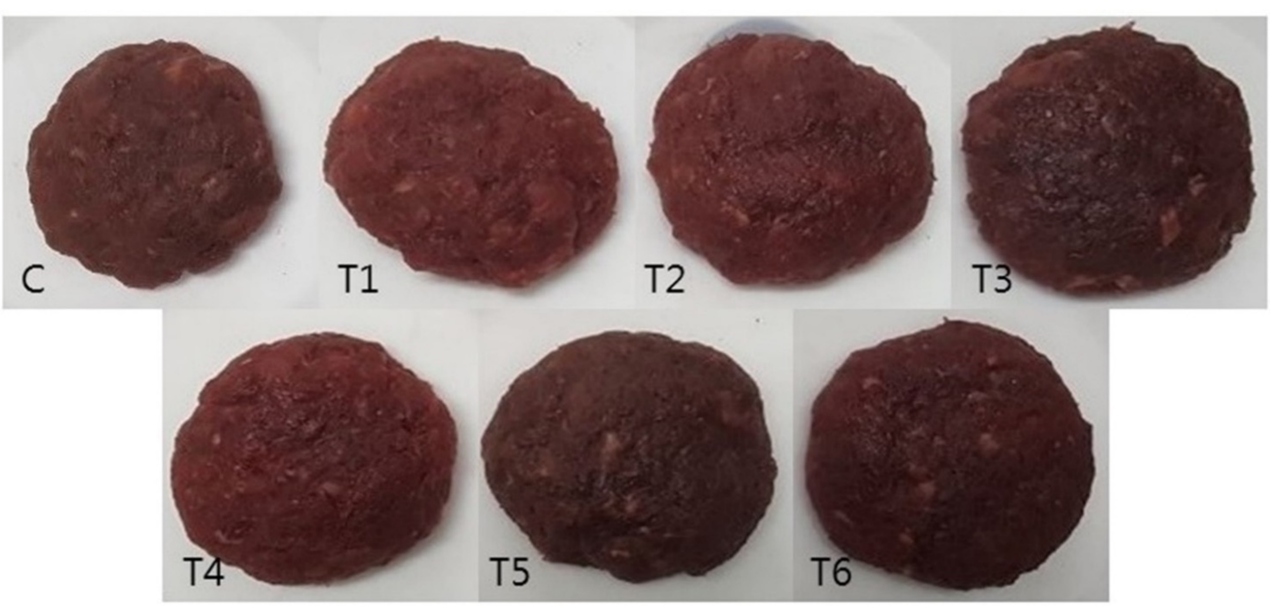

Fig. 1. A photo of the Hanwoo Tteokgalbi products with onion skin powder (OSP) and blackcurrant fruit powder (BFP).

room temperature for 30 min for 3 times in an ultrasonic bath (frequency 40 Hz, power 300 W; SD-350H, Seong Dong, Seoul, Korea). Three extracts were combined and filtered (Whatman No. 4). Then the solvent was evaporated using a rotary evaporator (EYELAN-1000, Eyela, Tokyo, Japan) under vacuum at 40℃. Total polyphenol contents of natural antioxidant powders were measured according to the Folin-Ciocalteu assay (Dewanto et al., 2002). A 1 mL of 2% Na_2CO_3 adding 50 μL of extract appropriately diluted, and 50% Folin-Ciocalteu phenol reagent (Sigma-Aldrich, St. Louis, MO, USA) 50 μL were added and mixed. After 30 min, the absorbance measured at 750 nm using a spectrophotometer (DU-650, Beckman, US). And the total polyphenol contents were expressed as mg of gallic acid equivalents (GAE) per g of dry weigh. All extracts were analyzed in triplicate. Total flavonoid contents of 80% ethanol extracts of natural antioxidant powders were measured according to a modification of the method of (Marinova et al., 2005). An aliquot (125 μL/mL) of extracts or standard solution of catechin was added to 1.5 mL micro tube containing 500 μL of distilled water. To the tube, 37.5 μL of 5% $NaNO_2$ was added. After 5 minutes, 75 μL of 10% $AlCl_3$ was added. After 6 minutes, 250 μL 1 M NaOH was added and mixed. After exactly 11 minutes, the absorbance was determined at 510 nm with UV-Vis Spectrophotometer (UV-1650PC, Shimadzu, Kyoto, Japan). Total flavonoid content was expressed as mg catechin equivalents (CE)/g dry weight. All extracts were analyzed in triplicate.

Moisture, fat, and ash contents

Moisture, fat and ash were assayed according to the AOAC (2000) methods.

Water holding capacity (WHC)

The centrifugation method described by Laakkonen et al. (1970) was used to measure WHC. The samples (0.5±0.05 g) from each product were placed in centrifugation tube with filter units, heated for 20 min at 80℃, and then cooled for 10 min. Samples were centrifuged at 2,000×g for 10 min 4℃ and WHC calculated as the change of sample weight.

Purge loss and cooking loss

The purge loss was measured using the modified method of Carballo et al. (1995). After the product was weighed, it was stored in a refrigerator for 24 h at 4℃. The sample was then removed from the refrigerator, removed from its package, and blotted with Kimwipes (Yuhan-Kimberly, Seoul, Korea) to eliminate any liquid from the surface of the sample. The weight of the sample was then recorded one more, and the purge loss calculated as a weight percentage. A Hanwoo Tteokgalbi product was placed into a polypropylene bag, cooked for 40 min at 70℃ in a water-bath, and cooled down to room temperature for 30 min. Cooking loss was calculated by the weight difference of samples before and after cooking.

Meat color

The surface color of sample was measured using a model JX-777 spectrocolorimeter (Color Techno System Co., Yamato, Japan) that was standardized to the white plate [lightness (L*), 94.04; redness (a*), 0.13; and yelllowness (b*), –0.51]. At this time, a white fluorescent lamp (D65) was used as the light source, and the meat color was indicated with L*, a*, and b* value represented lightness of the Hunter lab color coordinates, redness, and yellowness, respectively.

Texture analysis

The textural properties of the Tteokgalbi were analyzed using the EZ Test-500N texture analyzer (TA-XTZ-5, Shimadzu

Co., Japan) attached to a cylindrical plunger (5 mm diameter, depression speed=60 mm/min) and a 500 N load cell. Texture profile parameters that were measured included springiness, cohesiveness, and chewiness.

Sensory analysis

A sensory evaluation was performed by a panel of 15 trained tasters. The panel evaluated each treatment for each replication in triplicate, and the evaluation was performed with the samples at room temperature. Triplicate responses were taken to monitor the inherent texture variability associated with the samples. One slice, 1 cm in thickness and 8 cm in diameter, was cut into 6 pie-shaped wedges and presented to each panelist. The panelists chose 3 of the most characteristic wedges to avoid samples containing large pieces of connective tissue. The meat color, saltiness, bitterness, flavor, tenderness, juiciness, and total acceptability were evaluated using a 5-point scale.

Storage characteristics

Ten grams of samples were homogenized in 100 mL of distilled water for 30 sec using a model 400 blender (Seward, London, UK), and pH was measured using a pH meter (WTW, Weilheim, Germany). A 10 g sample was aseptically retrieved from the products, transferred into a sterile plastic bag, and homogenized with 0.1% peptone (90 mL) solution in a 400 Lab Blender (Seward) for 1.5 min. Serial 10-fold dilutions were prepared from each sample using 1 mL in 0.1% peptone (9 mL), inoculated on TMC medium, and incubated at 37°C for 48 h. The results were expressed as Log CFU/g. The 2-thiobarbituric acid reactive substance (TBARS) value of products was measured by the modified extraction method of Witte et al. (1970). Ten grams of each sample received cold 10% perchloric acid (15 mL) and triple distilled water (25 mL). After the sample was homogenized at 10,000 rpm for 10–15 sec in a homogenizer (AM-Series), the homogenate was filtered using qualitative filter paper No. 2 (Advantec, Denmark). The 5 mL of filtrate solution was mixed with TBA solution (5 mL 0.02 M), and its absorbance was measured at 529 nm using a spectrophotometer (DU-650, Beckman, US). Triple distilled water was used in the blank sample. TBA values were explained as mg of malonaldehyde per 1 kg sample (mg malonaldehyde kg). The TBA level was calculated using a standard curve with 1,1,3,3-tetramethoxypropane at a concentration ranging from 0 to 10 ppm, where $y=0.1975x–0.0011$ ($r=0.999$), and expressed by calculating y=absorbance and x=the TBA value.

Statistical analysis

The entire experiment data was analyzed using analysis of variance in the SAS program (2003) and statistical significance was verified among the means at a 95% level using Duncan's multiple range test.

Results and Discussion

Phytochemical contents

The total polyphenol and flavonoid contents of OSP and blackcurrant fruit powder (BFP) are shown in Table 2. The OSP had higher polyphenol and flavonoid contents compared to those of BFP ($p<0.05$). Onion peel and blackcurrants have been reported to be rich in antioxidants such as polyphenols and flavonoids (Tabart et al., 2007). According to Lee et al. (2011), the polyphenol content of onion skin is 120.07 mg/g, which is higher than the polyphenol content of 69.23 mg/g determined in this study. Bakowska-Barczak and Kolodziejczyk (2011) found a combined polyphenol and flavonoid value in blackcurrants of 22.97 mg/g, which is higher than the combined value (7.47 mg/g) of polyphenols and flavonoids found in this study. In this study, OSP and BFP showed low phytochemical contents because the solvent extraction process was not

Table 2. Total polyphenol and flavonoid contents of onion skin powder and black currant fruit powder (Unit: mg/g)

Treatments[1)]	Onion skin powder	Black currant fruit powder
Polyphenol	69.23±0.44[a]	4.50±0.09[b]
Flavonoid	4.26±0.43[a]	2.97±0.04[b]

[1)] Treatments are same as Table 1.
[a,b] Means±SD with different superscription within the same row differ ($p<0.05$).

performed as in the previous studies.

Physicochemical properties

Proximate analysis

The results of the proximate analysis of the Hanwoo Tteokgalbi samples treated with OSP and BFP are shown in Table 3. The moisture contents of all Tteokgalbi samples ranged from 73.96% to 75.59%, which is not different from control sample. The treatments containing 0.6% natural antioxidant powder tended to have higher moisture content than those of treatments containing 0.3% natural antioxidant powder (T1, T3, and T5 versus T2, T4, and T6). An increase of whey powder has been reported to reduce the water content in beef meatball (Serdaroğlu, 2006). However, in the treatments of this study, as the addition of onion skin and BFP increased, the moisture content of the meat products increased slightly. The slight increment in moisture was probably related to the presence of fibers in the products. Similar result was found by Selani et al. (2014).

The fat content of the Tteokgalbi samples ranged from 1.84 to 2.41 in the control and all treatments, but that of T6 was significantly lower than other treatments. The ash contents of the control and all treatments were 2.17 to 2.40, and the treatments using large amounts of added natural antioxidant (0.6%) had higher ash contents than those with small amounts of added antioxidant (0.3%). In addition, the addition of powder, such as fruit skins, has been reported to increases the ash content of meat products (Serdaroğlu, 2006), which we also observed in our samples.

Quality characteristics

The quality characteristics of the Hanwoo Tteokgalbi with natural antioxidants are presented in Table 4. The water holding capacity (WHC) values of the Tteokgalbi samples showed no significant difference in all treatments, except T2, which had the highest WHC value among the Tteokgalbi samples. There were no statistically significant differences between the control and treated samples in the purge loss of the Tteokgalbi samples, and the cooking loss was significantly lower in the control and T2 than the other treatments ($p<0.05$). The addition of dietary fiber, such as vegetable peel, has been reported to result in the excellent water absorption of meat products (Figuerola et al., 2005; O'Shea et al., 2012). Onion skin contains 63.7%–68.3% dietary fiber, and the total sugar content is 408.7–625.4 g/kg (dry basis) (Jaime et al., 2002). In this study, we found

Table 3. Proximate contents of Hanwoo Tteokgalbi with natural antioxidants

Treatments[1)]	CON	T1	T2	T3	T4	T5	T6
Moisture (%)	74.85±0.15[abc]	73.96±0.14[c]	74.40±1.04[bc]	74.20±0.43[c]	75.22±0.30[ab]	74.14±0.58[c]	75.59±0.13[a]
Fat (%)	2.00±0.06[cd]	2.19±0.12[abc]	2.27±0.17[ab]	2.41±0.09[a]	2.11±0.09[bc]	2.12±0.24[bc]	1.84±0.04[d]
Ash (%)	2.36±0.01[ab]	2.28±0.01[bcd]	2.39±0.05[ab]	2.17±0.12[d]	2.35±0.01[abc]	2.24±0.06[cd]	2.40±0.05[a]

[1)] Treatments are same as Table 1.
[a–d] Means±SD with different superscription within the same row differ ($p<0.05$).

Table 4. Quality characteristics of Hanwoo Tteokgalbi with natural antioxidants

Treatments[1)]	CON	T1	T2	T3	T4	T5	T6
WHC (%)	53.52±3.16^{b}	55.47±1.60^{b}	62.51±3.32^{a}	54.71±2.41^{b}	50.70±4.45^{b}	50.65±3.02^{b}	50.97±2.09^{b}
Purge loss (%)	1.38±0.54	1.45±0.73	0.56±0.15	1.94±0.84	0.73±0.16	1.26±0.17	1.27±0.63
Cooking loss (%)	15.25±0.43^{b}	18.07±0.09^{a}	15.23±1.29^{b}	18.27±0.51^{a}	17.64±0.25^{a}	17.51±2.59^{a}	15.91±0.63^{a}
L*	41.01±1.49^{d}	45.52±0.88^{b}	40.63±0.30^{d}	43.61±0.84^{c}	41.19±0.51^{d}	47.76±1.49^{a}	41.63±0.80^{d}
a*	5.36±0.29^{b}	5.95±0.22^{a}	4.98±0.32^{c}	5.73±0.23^{a}	4.42±0.18^{d}	5.68±0.36^{ab}	4.50±0.30^{d}
b*	13.71±0.48^{a}	13.09±0.44^{abc}	12.54±0.51^{cd}	12.83±0.49^{bc}	12.01±0.39^{d}	13.29±0.86^{ab}	12.65±0.30^{bcd}
Springiness (%)	22.02±4.48^{c}	54.45±7.46^{b}	20.85±3.23^{c}	60.28±4.90^{a}	22.58±1.66^{c}	53.52±4.53^{b}	22.53±3.39^{c}
Cohesiveness (%)	30.92±5.80^{b}	57.12±9.27^{a}	32.01±4.73^{b}	59.55±5.60^{a}	32.52±3.98^{b}	53.13±4.98^{a}	35.36±5.55^{b}
Chewiness (g)	77.90±20.12^{c}	83.23±23.99^{c}	97.19±20.28^{bc}	117.49±48.70^{b}	75.34±14.65^{c}	175.16±30.49^{a}	67.35±14.4^{c}

[1)] Treatments are same as Table 1.
[a–d] Means±SD with different superscription within the same row differ ($p<0.05$).
WHC, water holding capacity.

that the 0.6% OSP improved the WHC and cooking loss by increasing the absorption of moisture in the Tteokgalbi samples. In addition, the 0.6% OSP treatment had the highest pH value, and this is the reason for the high water holding capacity in this sample. However, the 0.3% OSP showed no positive effects on WHC and cooking loss.

These results suggest that OSP should be added at least 0.6% to improve water holding capacity and cooking loss. This high retention of moisture has been reported to have a positive effect on the quality characteristics of meat products such as texture characteristics and juiciness (Chevance et al., 2000; Rodriguez et al., 2006). Meanwhile, blackcurrant fruit was found to be rich in vitamin C (342.9 mg/100 g), and the total organic acids including citric acid, malic acid, and tartaric acid have been reported to be 32.7 g/kg (Mikulic-Petkovsek et al., 2013). Therefore, there was no positive effect on the water holding capacity because of the effects of the organic acids in BFP. Concerning the color of the Hanwoo Tteokgalbi meat with added natural antioxidant powders, the lightness (L*), redness (a*), and yellowness (b*) values were determined. The L* values of the Tteokgalbi samples ranged from 40.63 to 47.76, and the treatments with 0.6% added natural antioxidant powder had significantly lower L* values than those of treatments with 0.3% added powder ($p<0.05$). T5 showed the highest lightness value among the treatments. Concerning the redness values, the 0.3% added treatment had significantly higher values than those of 0.6% added treatment ($p<0.05$), and the redness values of the treatment (T2) with 0.6% OSP was significantly higher than those of 0.6% BFP (T4) and 0.3% OSP and 0.3% BFP combined treatment (T6). The yellowness values tended to decrease as the amount of added natural antioxidant powder increased. The control showed higher yellowness than those of BFP treatments (T3 and T4) and 0.6% treatments (T2 and T6), and the control was similar to the 0.3% OSP treatment (T1) and 0.15% OSP and 0.15% BFP combined treatment (T5). The primary pigment in onion skin is quercetin, and the quercetin content of the onion skin is 34,430 mg/kg (Nuutila et al., 2003). The primary source of blackcurrant fruit color is anthocyanin, whose contents in blackcurrant fruits range from 116.17 to 287.78 mg/100 g (Nour et al., 2011). According to previous studies, the yellowness of Tteokgalbi product was increased by the phytochemicals. But in this study, the lightness (L*), redness (a*), and yellowness (b*) values decreased with added OSP and BFP. These results are considered to be due to the dense, dark brown and purple colors of onion skin and black currant powders used in this study. In another study, when the color of goat meat treated with a 0.2% salt, kinnow, and pomegranate by-product powder was compared to that of an untreated sample, no significant differences in the lightness were found, although the degrees of redness and yellowness tended to decrease and increase, respectively (Devatkal et al., 2010). The results of this study suggest that the meat color is influenced by the constituents of the natural antioxidant powder.

Texture properties

The textural properties of the Tteokgalbi samples containing OSP and BFP were investigated, including springiness, cohesiveness, and chewiness. The springiness value of T3 was significantly higher than those of the other treatments, and all treatments showed higher or similar result to that of the control. The cohesiveness was higher for the 0.3% added samples than those of the control and 0.6% added samples ($p<0.05$). Concerning chewiness, that of T5 was significantly higher than control and the other treatments, and that of the control was similar or lower than those of the treated samples. Garcia et al. (2001) reported that the addition of 1.5% peach, 1.5% apple, and 1.5% orange dietary fiber to fermented pork sausage increased the springiness values. The addition of 3%, 6%, and 9% of wheat bran and carrot dietary fiber to chicken sausage increases the springiness values because of the greater water-binding capacity with increasing addition (Yadav et al., 2018). An increase of springiness was also observed in the addition of 0.3% blackcurrant and 0.3% OSPs to the Tteokgalbi. According to the Sánchez-Zapata et al. (2010), fiber source affects their technological properties due to the differences on the structure and constitution of plant cells. Grigelmo-Miguel et al. (1999) reported that, when 0.9%, 1.9%, 2.9%, and 3.9% peach dietary fiber were added to the fermented pork sausage, the chewiness values decreased with increasing addition. In this study, similar results were observed; that is, on increasing the addition of black currant and OSPs, which contain dietary fiber, from 0.3% to 0.6%, a reduction in the chewiness was observed.

Sensory tests

The results of the sensory evaluation of the Hanwoo Tteokgalbi samples treated with OSP and BFP are shown in Table 5. The color of the Tteokgalbi samples had positively higher scores in the control, T1, T2, and T3 samples compared to T4, T5, and T6. The saltiness of the sample treated with 0.3% natural antioxidant was significantly higher in than those of the control and 0.6% treatments ($p<0.05$), and the bitterness was significantly lower in the sample treated with 0.3% antioxidant compared to that with 0.6% treatment. T6 had the highest bitterness among all the treatments. The flavor scores for T1, T2, T4, and T5 were similar to that of the control, and T3 and T6 showed higher scores than the control ($p<0.05$). Concerning the tenderness and juiciness, there were no significant differences between control and treatments. The total acceptability score of T3 was the highest among the treatments, and none of the treatments showed significant differences compared to the control

Table 5. Sensory evaluation of Hanwoo Tteokgalbi with natural antioxidants

Treatments[1)]	CON	T1	T2	T3	T4	T5	T6
Color	$3.20±0.44^{a}$	$3.20±0.44^{a}$	$3.20±0.44^{a}$	$3.20±0.44^{a}$	$2.40±0.54^{b}$	$2.60±0.54^{ab}$	$2.20±0.44^{b}$
Saltiness	$2.00±0.00^{b}$	$4.00±0.70^{a}$	$2.20±0.44^{b}$	$3.20±0.83^{a}$	$2.00±0.70^{b}$	$3.40±0.54^{a}$	$2.40±0.54^{b}$
Bitterness	$3.60±1.14^{ab}$	$2.60±0.54^{bc}$	$3.40±0.54^{ab}$	$2.40±0.89^{c}$	$3.60±0.89^{ab}$	$2.20±0.44^{c}$	$4.00±0.00^{a}$
Flavor	$3.20±0.83^{c}$	$3.40±0.54^{bc}$	$3.60±0.54^{abc}$	$4.20±0.44^{a}$	$3.60±0.54^{abc}$	$3.60±0.54^{abc}$	$4.00±0.00^{ab}$
Tenderness	3.40±0.54	2.60±0.54	3.60±0.89	3.60±0.54	3.20±1.09	3.40±0.89	3.40±0.54
Juiciness	3.40±0.54	3.20±0.83	2.60±0.54	3.60±0.54	3.00±0.70	3.60±0.89	3.00±0.70
Total acceptability	$3.20±0.44^{ab}$	$3.00±0.00^{b}$	$3.40±0.54^{ab}$	$3.80±0.44^{a}$	$3.20±0.44^{ab}$	$3.60±0.54^{ab}$	$3.60±0.54^{ab}$

[1)] Treatments are same as Table 1.
[a–c] Means±SD with different superscription within the same row differ ($p<0.05$).

(p>0.05). As the amount of added natural antioxidant powder increased, the saltiness decreased and the bitter taste increased because of the quercetin in OSP and the anthocyanin and organic acids in BFP. The citric acid, which results in the sour taste, content of blackcurrant fruits has been reported to be 2,548.17–3,553.31 mg/100 g (Nour et al., 2011). Therefore, the reason for the high total acceptability of the Tteokgalbi samples with added BFP compared to untreated and OSP-treated samples is the high content of sour-tasting citric acid in the BFP.

Storage characteristics

The storage characteristics of Hanwoo Tteokgalbi with added OSP and BFP during refrigerated storage are shown in Table 6. The pH values of the T1 and T2 samples were maintained significantly higher than those of the control. In contrast, the pH values of the BFP-treated samples (T3, T4, T5, and T6) were lower than the control after 10 days at 4°C (p<0.05). The total microbial count (TMC) values did not show a significant difference between control and treatment from the day of manufacture to 3–10 days of storage, and the treatments with BFP had similar TMC values to those of the control. The combined OSP and BFP treatment showed significantly higher TMC values than the control after storage day 7. In addition, all treatments showed TMC levels within 5.26 Log CFU/g after 10 days. The TBARS values of the control and T3 were significantly lower than those of other treatments at storage day 0, and T4 showed the highest TBARS value. After storage for 3 and 7 days, T1 and T2 had similar TBARS values to those of the control. However, T1 and T2 had lower TBARS values than that of the control after 10 days. On the other hand, the samples with added BFP showed higher TBARS values than the control during after 10 days, and the mixed treatments showed higher TBARS values than that of the control between 0 and 7 days of storage, whereas the combined treatments had lower TBARS values than the control after 10 days. As mentioned earlier, the difference of pH values among the Hanwoo Tteokgalbi products during refrigerated storage seemed to be caused by the organic acids contained in onion skin and blackcurrant. Kim (1997) reported that the sulfur compounds from whole onion extract are the principal antibacterial agents. In addition, the flavonoids and polyphenols abundant in onion skin

Table 6. Storage characteristics of Hanwoo Tteokgalbi with natural antioxidants

Treatments[1)]	Day	CON	T1	T2	T3	T4	T5	T6
pH	0	5.40±0.01[c]	5.43±0.01[b]	5.46±0.01[a]	5.31±0.01[e]	5.24±0.02[f]	5.36±0.00[d]	5.34±0.00[d]
	3	5.40±0.00[d]	5.48±0.00[b]	5.50±0.00[a]	5.37±0.01[e]	5.31±0.01[f]	5.44±0.00[c]	5.37±0.00[e]
	7	5.47±0.00[c]	5.52±0.00[b]	5.54±0.01[a]	5.40±0.00[e]	5.32±0.00[f]	5.45±0.01[d]	5.40±0.00[e]
	10	5.44±0.02[b]	5.54±0.00[a]	5.55±0.01[a]	5.37±0.00[c]	5.37±0.01[c]	5.46±0.01[b]	5.45±0.00[b]
TMC (Log CFU/g)	0	3.69±0.12[ab]	4.25±0.20[a]	3.84±0.21[ab]	3.34±0.49[b]	3.38±0.12[b]	3.53±0.08[b]	3.58±0.15[b]
	3	4.15±0.21[cd]	4.69±0.30[ab]	4.84±0.21[a]	4.00±0.00[d]	4.15±0.21[cd]	4.30±0.00[bcd]	4.58±0.15[abc]
	7	4.00±0.00[d]	4.92±0.21[ab]	5.09±0.02[a]	4.00±0.00[d]	4.15±0.21[cd]	4.38±0.12[c]	4.73±0.05[b]
	10	4.00±0.00[c]	5.26±0.13[a]	5.09±0.02[a]	4.15±0.21[c]	4.15±0.21[c]	4.65±0.06[b]	4.97±0.03[a]
TBARS (mg malonaldehyde/ 1,000 g)	0	0.27±0.00[e]	0.42±0.06[d]	0.27±0.00[e]	0.82±0.08[b]	1.25±0.02[a]	0.72±0.07[c]	0.85±0.00[b]
	3	0.36±0.05[d]	0.28±0.03[d]	0.36±0.05[d]	0.79±0.08[b]	1.33±0.05[a]	0.48±0.02[c]	0.80±0.05[b]
	7	0.32±0.02[d]	0.34±0.03[d]	0.30±0.03[d]	0.69±0.03[b]	1.30±0.02[a]	0.53±0.01[c]	0.70±0.04[b]
	10	0.84±0.02[b]	0.38±0.00[g]	0.68±0.02[d]	0.78±0.04[c]	0.91±0.01[a]	0.51±0.02[f]	0.59±0.02[e]

[1)] Treatments are same as Table 1.
[a–g] Means±SD with different superscription within the same row differ (p<0.05).
TMC, total microbial count; TBARS, 2-thiobarbituric acid reactive substance.

have been reported to have antibacterial activity against pathogenic microorganisms (Daglia, 2012). However, in this study, it was presumed that the OSP showed no specific antibacterial activity because of contamination during the production of the OSP. Previous studies (Mikulic-Petkovsek et al., 2013; Nour et al., 2011) have shown that blackcurrants are high in organic acids including ascorbic acid, tartaric acid, malic acid, and citric acid, and these organic acids have been shown to have potent antibacterial activity against some microorganisms, including *Salmonella* (Mani-Lopez et al., 2012). In this study, the BFP did not show higher antibacterial activity than the control. Quercetin is present in the onion skin at 34,430±2,211 mg/kg, and onion skin has higher antioxidative capacity than the leaf, stem, and edible parts (Nuutila et al., 2003). In this study, the treatments with OSP showed higher lipid oxidation inhibition than the control and BFP treatments. Singh et al. (2009) reported that methanol extracts of onion peel showed excellent antioxidant ability, indicating its promise as a nutraceutical. In addition, Kim et al. (2014) reported that pork jerky with 0.5% onion skin extract and 0.5% barbecue flavor had a lower peroxide value (POV) value than the non-added jerky. In a previous study, Jia et al. (2012) added 0.5%–2.0% blackcurrant extract to pork patties and analyzed the TBARS over 9 days. The TBARS levels of the 1% and 2% added treatments were lower than those of 0.02% BHA added treatment. They concluded that these results were due to the high anthocyanin content of the blackcurrant extract. On the other hand, the antioxidant activity of BFP was not remarkable in this study because the total polyphenol and flavonoid contents were significantly lower than those of the OSP.

Conclusion

This study was conducted to investigate the applicability of OSP and BFP as natural antioxidants for Hanwoo Tteokgalbi. The OSP and BFP did not significantly reduce the quality characteristics of the Tteokgalbi. The addition of OSP resulted in excellent water retention and inhibition of fat oxidation, and the addition of BFP was superior concerning antibacterial activity. Therefore, these products can be applied as natural preservatives to meat products and are expected to be used industrially.

Acknowledgments

This work was supported by the intramural research grant of Chungbuk National University in 2015. Also, this research was supported by the Priority Research Centers Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2009-0093813).

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