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ARTICLE

Quality Characteristics of *Tteokgalbi* with Black Rice Bran and Organic Acid to Substitute Synthetic Caramel Colorant

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Abstract

This study aimed to evaluate the quality characteristics of *Tteokgalbi* with 1% (w/w) black rice bran only (T1), or with black rice bran and one of the following four types of organic acid: ascorbic acid (T2), citric acid (T3), tartaric acid (T4), or maleic acid (T5) as a substitute for caramel colorant. *Tteokgalbi* with only black rice bran showed the highest (p<0.05) values of moisture content and water holding capacity (WHC), while there were no significant differences in protein content, fat content, ash content, and thiobarbituric acid reactive substance (TBARS) values in treatments and controls (p>0.05). All the treated samples with any one of the four organic acids showed lower pH than controls (p<0.05). The lightness and redness of *Tteokgalbi* treated with any one of the four organic acids and black rice bran were higher than those of T1. The volatile basic nitrogen (VBN) values of T4 and T5 were higher than those of the other treatments (p<0.05). With regards to sensory characteristics, T1 and T2 showed overall acceptability similar to that of the controls (p>0.05). The results reported in this study show that *Tteokgalbi* with black rice bran and any one of the four organic acids listed above not only improved quality characteristics in cooking loss, WHC, lipid oxidation but also could successfully replace the synthetic caramel colorant. Overall, the most satisfactory results were obtained by adding black rice bran and ascorbic acid.

Keywords *Tteokgalbi*, black rice bran, organic acid, ascorbic acid, caramel colorant

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Introduction

Food color is a sensory element that is perceived first, because it is visible, and it is an important indicator of the quality of the food. In addition, cognitive information provided by the color of the food plays an important role in its acceptability, as color itself affects the taste and image of food (Park *et al.*, 2012). Since the original color of a food is often lost during processing, color additives are often used to restore the color. Synthetic colorant have been utilized widely as they are cheap and stable (Yoon *et al.*, 1997). Caramel colorant, a synthetic additive that has a black-brown color is used not only for processed sauces, beverages, and snacks but also for processed meat products and this pigment is added during the manufacturing of *Tteokgalbi* (Lee, 2016). However, consumers tend to avoid caramel colorant, since it has been reported to carry the risk of causing cancer (Kim, 2012; Kim *et al.*, 2013).

The bran of black rice, one of the pigmented rice cultivars, could be used as a natural substitute to synthetic caramel colorant (Oh *et al.*, 2015). Black rice bran is healthy and has antioxidant properties, as it contains phenolic compounds such as tocopherol (Kim *et al.*, 2015). It is also valuable, as it contains anthocyanins such as cyanidin-3-glucoside and peonidin-3-glucoside (Chung and Lee, 2003). However, anthocyanins are greatly affected by pH. In fact, their basic molecule chemical structure invariably contains a flavylium cation which turns red in acidic solutions. Conversely, in neutral or alkaline solutions the flavylium cation is deprotonated to give the quinoidal base, and, as a consequence, its color turns blue (Hwang and Ki, 2013; Markakis and Jurd, 1974). It is difficult to use black rice bran alone as a pigment, because it has a dark color and is unstable under processing and storage conditions. Therefore, it is postulated that by adding organic acids, which are routinely used as pH-adjusting agents, and organic acid will enhance the color and stability of black rice bran.

Organic acids are organic compounds with acidic properties. Ascorbic acid, citric acid, tartaric acid, and maleic acid are among the organic acids most widely utilized in food industry. When these acids are added to a food product, they lower the pH and as a result, they exert antimicrobial and antioxidant effects by suppressing the growth of microorganisms (Kim and Hahn, 2003). The pH change, resulting from the addition of organic acids to a processed meat product, enhances the water holding and water binding capacity, and it also plays an important role in cooking loss (Weiss and Reynolds, 1988). Therefore, organic acids added to processed meat products increase their shelf life by ensuring sterility and stability (Kang *et al.*, 2002), enabling to produce high-quality and cost-effective products. Furthermore, organic acids improve the taste and flavor of food products because of their unique sour taste (Park and Lee, 2005). However, adding excessive quantities of certain types of organic acids to processed meat products results in an acidic and bitter taste, which leads to a decline in consumer acceptability. Therefore, caution needs to be exercised while using organic acids in food processing.

The aim of this study was to evaluate the quality characteristics of *Tteokgalbi* in which synthetic caramel colorant has been replaced by black rice bran and any one of four organic acids, and to generate data that can be used to evaluate the possibility of replacing caramel colorant in other food products.

Materials and Methods

Ingredients and preparation of *Tteokgalbi*

Fresh beef round (*M. semimebranosus*) and back fat were purchased from a local processor. Excess fat and visible connective tissue were removed, then the meat was ground with grinder (PA-82, Mainca, Spain) in two sequential steps: initially it was ground to pieces 8-mm in size, successively these were further processed to smaller pieces of 3-mm size. The seven different *Tteokgalbi* were prepared according to the composition given in Table 1. Lean meat, fat and ice were mixed with supplementary ingredients that are traditionally added for seasoning purposes (1.5% salt, 0.2% phosphate, 3.0% soy sauce, 1.2% sugar, 0.1% ground black pepper, 1.0% onion powder, 0.5% garlic powder, 0.2% ginger powder, 0.5% sesame oil, 1.2% isolated soy protein), 1.0% caramel colorant, 1.0% black rice bran, and 0.1% one of four organic acids (either ascorbic acid, citric acid, tartaric acid, or maleic acid). The mixed batter was divided into equal portions (each weighing approximately 100 g, and measuring 90 mm in thickness), which were molded into *Tteokgalbi* traditional patty shaped. Each *Tteokgalbi* then was subjected to a 24 h holding time, after which they were heated for 30 min at 80°C in a heating chamber. The processed *Tteokgalbi* patties were stored at 4°C in a refrigerator, and all the experiments were performed within the same day.

Proximate composition

The compositional properties of the *Tteokgalbi* were analyzed using AOAC procedures (2000). In order to quantify the composition of *Tteokgalbi*, moisture content (950.46B) was measured by the drying method at 105°C in drying oven (HSC-150/300, MS I&C, Korea), protein content (981.10) was measured by the Kjeldahl method (2020, Foss, Denmark), fat content (960.69) was measured by Soxhlet method (E-816, BUCHI Labortechnik AG, Switzerland), and ash content (920.153) was measured by the ash incinerating method 550°C (550-126, Fisher scientific, USA).

pH

Five grams of each *Tteokgalbi* were homogenized with 20 mL of distilled water, and the pH was measured using a Model 340 pH meter (Mettler-Toledo GmbH, Switzerland).

Color

The color of *Tteokgabli* was determined using a chroma

Table 1. Formulations of *Tteokgalbi* with black rice bran and different types of organic acid (Unit: %)

Ingredients	Treatments[1)]						
	Control (-)	Control (+)	T1	T2	T3	T4	T5
Beef meat	80	80	80	80	80	80	80
Back fat	10	10	10	10	10	10	10
Ice water	10	10	10	10	10	10	10
Total	100	100	100	100	100	100	100
Salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Phosphate	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Soy sauce	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sugar	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Pepper	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Onion powder	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Garlic powder	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ginger powder	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sesame oil	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Isolated soy protein	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Caramel colorant	-	1.0	-	-	-	-	-
Black rice bran	-	-	1.0	1.0	1.0	1.0	1.0
Ascorbic acid	-	-	-	0.1	-	-	-
Citric acid	-	-	-	-	0.1	-	-
Tartaric acid	-	-	-	-	-	0.1	-
Maleic acid	-	-	-	-	-	-	0.1

[1)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

meter (CR-410, Minolta, Japan; illuminate C, calibrated with a white plate, CIE L*=97.83, CIE a*=-0.43, CIE b* =1.98). Lightness (CIE L*), redness (CIE a*), yellowness (CIE b*) values were recorded and six replicate measurements were taken for each parameters.

Cooking loss

Each *Tteokgalbi* was first weighed (weight of raw sample) and then cooked at 75°C for 30 min in a water bath (Model10-101, Dae Han Co., Korea). After cooling at room temperature (21°C) for 1 h, each *Tteokgalbi* sample was weighed again (weight of cooked sample) and the cooking loss (weight loss of each sample after cooking) was calculated according to the following formula (with weight expressed in grams).

Cooking loss (%) = (weight of raw sample – weight of cooked sample) / weight of raw sample × 100

Water holding capacity (WHC)

Water holding capacity was measured by filter paper compressing, using the method described by Grau and Hamm (1953). A filter paper (Whatman No. 2, Whatman TM, UK) was placed in the middle of a plexiglass plate, and a 300 mg of *Tteokgalbi* sample was put on top of the filter paper. After pressing the sample for 3 min by applying a constant pressure with another plexiglass plate, a planimeter (Planix 7, Tamaya Technics Inc., Japan) was used to measure the area of the meat and the area of the moisture left on the filter paper. The WHC (%) was calculated using the formula shown below:

WHC (%) = [sample meat area (mm^2) / total moisture area (mm^2)] × 100

Shear force

The shear force of each *Tteokgalbi* samples was measured with a texture analyzer (TA-XT2*i*, Stable Micro Systems, UK) which chopped vertically to a 2.5×1.5×2.0 cm sized meat sample. For texture analysis, a Warner-Bratzler blade was installed with the following settings: stroke, 20 g; test speed, 2.0 mm/s; and distance, 10.0 mm (Bourne *et al.*, 1979).

Thiobarbituric acid reactive substance (TBARS) value

Lipid oxidation was measured using a modified version of the TBARS extraction method described by Tarladgis *et al.* (1960). The TBARS values are expressed in mg of malondialdehyde (MA)/kg of sample. Ten grams of each *Tteokgalbi* sample were homogenized in 50 mL of distilled water with 0.2 mL of 0.3% (w/v) dibutyl hydroxyl toluene and the cup was washed with 47.5 mL of distilled water. The mixture of total homogenate, 2.5 mL of 4 N HCl and 1 mL of antifoaming agent (KMK-73, Shin-Etsu Silicone Co. Ltd., Korea) was distilled and 50 mL of distillate was collected. Five milliliter of distillate was reacted with 5 mL of 0.02 M TBARS in 90% acetic acid at 100°C for 30 min. After cooling at room temperature, the absorbance was measured at 538 nm using a UV/VIS spectrophotometer (Optizen 2120 UV plus, Mecasys Co. Ltd., Korea). A blank was prepared with 5 mL distilled water and 5 mL 0.02 M TBARS in 90% acetic acid.

TBARS value (mg of MA/ kg of sample) = Absorbance (O.D) × 7.8

Volatile basic nitrogen (VBN)

VBN was measured by the micro-diffusion method using a Conway unit (Pearson, 1968). Five grams of each *Tteokgalbi* were homogenized in 45 mL of distilled water and filtered through Whatman No.1 paper (Whatman International, UK). The filtrate was mixed with 1 mL of 50% (w/v) K_2CO_3 solution and placed into the outer chamber of the Conway micro-diffusion cell. One milliliter of 0.01 N H_3BO_3 and 0.05 mL of indicator were placed into the inner chamber of the Conway micro-diffusion cell. After incubating the sealed cell at 37°C for 90 min, the solution in the inner chamber was titrated with 0.02 N H_2SO_4 until a faint reddish color was produced. The value of VBN was expressed by converting to mg per 100 g of sample (mg %) using the following formula:

$$VBN (mg \%) = (a - b) \times (F \times 0.02 \times N \times 14.007 \times 100 \times 100) / S$$

Where S is sample weight (g), a is the amount of sulfuric acid (mL) injected to titrate, b is the amount of sulfuric acid injected in blank (mL), and F is the standardized index of 0.02 N H_2SO_4 (0.02 N H_2SO_4 = 0.28014)

Sensory evaluation

A trained 15-member panel consisting of researchers from the Food Processing Research Center of Korea Food Research Institute in the Republic of Korea evaluated *Tteokgalbi* following the guidelines described before (Choi *et al.*, 2008). Each *Tteokgalbi* was cooked at 80°C for 30 min in a water bath (Model10-101, Dae Han Co., Korea) and then cut into 15 mm in thickness. Panelists were instructed to cleanse their palates between samples with water. The color, flavor, tenderness, juiciness, and overall acceptability of the cooked samples were evaluated using a 9-point descriptive scale (1 = extremely undesirable, 9 = extremely desirable).

Statistical analysis

Statistical analysis was performed using SPSS Ver. 20.0 (SPSS Inc., USA) and the results are expressed as the mean plus or minus the standard deviation. Duncan's multiple range test ($p<0.05$) was used to determine the significance of differences observed among treatments.

Results and Discussion

Proximate composition of *Tteokgalbi*

Table 2 shows the results of the proximate composition analysis of *Tteokgalbi*, to which black rice bran and one of the four organic acids under study (either ascorbic acid, citric acid, tartaric acid, or maleic acid) to replace caramel pigment. There was no significant difference between the controls and the treatments ($p>0.05$) except for T1, which had the highest moisture content ($p<0.05$). Park and Kim (2016) and Joo and Choi (2012) demonstrated that the moisture content of meat products with added black rice and that of cookies with added black rice bran increased, which is similar to the trend exhibited by T1 in this research. The moisture content of the other treatments decreased depending on the organic acid added and was significantly lower than that of T1 ($p<0.05$); this finding agrees with the results of a previous study (Aktaş *et al.*, 2003). There was no significant difference in the protein and fat contents ($p>0.05$) among the treatments. In previous studies, the addition of black rice bran resulted in an increase in the vitamin and mineral contents (Bae and Chung, 2015; Joo and Choi, 2012), and meat products with added rice bran dietary fiber showed an increase in the ash content (Choi *et al.*, 2008). However, as regards the ash content, the difference observed in this study was not significant ($p>0.05$).

pH and color of *Tteokgalbi*

The effect of adding black rice bran and one of the four types of organic acids to *Tteokgalbi* on the pH and color is shown in Table 3. The pH of *Tteokgalbi* before heating was the highest in the controls and T1, whereas those of

Table 2. Proximate compositions of *Tteokgalbi* formulated with black rice bran and different types of organic acid

Parameters	Control (-)[1)]	Control (+)	T1	T2	T3	T4	T5
Moisture content (%)	59.67±1.18[bc]	58.84±0.87[bc]	61.71±0.81[a]	57.70±1.34[c]	58.38±0.35[bc]	59.80±1.37[b]	58.38±1.20[bc]
Protein content (%)	13.22±0.42	13.65±0.11	13.35±0.15	13.58±0.16	13.25±0.75	13.25±0.50	13.79±0.62
Fat content (%)	11.02±3.06	13.39±5.39	9.06±4.47	10.45±5.74	11.90±2.26	13.16±9.30	10.33±4.12
Ash content (%)	1.63±0.14	1.74±0.06	1.84±0.08	1.67± 0.01	1.63±0.13	1.51±0.07	1.65±0.11

All values are mean±standard deviation of three replicates.

[a-c]Means within a row with different letters are significantly different (p<0.05).

[1)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

Table 3. Comparison pH and color attributes on *Tteokgalbi* formulated with black rice bran and different types of organic acid

Parameters	Control (-)[1)]	Control (+)	T1	T2	T3	T4	T5
Raw							
pH	6.62±0.09[a]	6.65±0.01[a]	6.64±0.01[a]	6.54±0.01[b]	6.39±0.08[c]	6.38±0.01[c]	6.38±0.02[c]
CIE L*	22.84±5.01[ab]	24.39±1.80[a]	17.45±0.68[c]	19.88±1.67[bc]	20.85±1.91[b]	21.26±2.08[ab]	20.97±1.85[b]
CIE a*	17.47±1.43[bc]	20.08±1.88[a]	16.54±0.97[c]	19.07±1.98[ab]	17.68±1.56[bc]	17.70±1.63[bc]	17.66±1.61[bc]
CIE b*	14.73±3.98	14.85±1.38	13.73±0.55	14.12±1.09	16.22±1.92	15.16±1.36	16.40±1.26
Cooked							
pH	6.89±0.01[a]	6.90±0.01[a]	6.89±0.01[a]	6.76±0.01[b]	6.61±0.01[c]	6.60±0.01[c]	6.52±0.03[d]
CIE L*	19.71±1.80[c]	22.09±1.74[b]	16.46±0.81[d]	19.68±1.80[c]	24.35±1.82[a]	22.01±2.40[b]	25.09±0.59[a]
CIE a*	19.18±1.82[bc]	21.51±1.90[a]	18.34±1.16[c]	18.66±1.48[bc]	20.04±1.25[abc]	20.37±1.93[ab]	21.33±1.55[a]
CIE b*	14.98±0.98[c]	16.20±1.67[c]	14.93±0.58[c]	16.47±1.24[c]	20.40±1.61[ab]	19.18±2.27[b]	21.25±0.47[a]

All values are mean±standard deviation of three replicates.

[a-d]Means within a row with different letters are significantly different (p<0.05).

[1)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

T3, T4, and T5 were the lowest (p<0.05). The pH after heating was similar to that before heating, with T5 showing the lowest pH (p<0.05). According to the findings of previous research on organic acid-added pork and poultry products and organic acid-fermented milk, organic acids acted as weak acids and reduced the pH level (Garrote *et al.*, 2000; Mani-Lopez *et al.*, 2012). Similarly, in the current investigation, the pH of *Tteokgalbi* was decreased upon adding organic acids.

The lightness value of T1 with black rice bran alone was the lowest and shows differences compared to both before and after heating (p<0.05). Controls and T4 were the lightest (p<0.05) with no significant differences between them prior to heating (p>0.05). There was no significant difference between T1 and T2 (p>0.05), which had the lowest lightness (p<0.05). T3 and T5 had the highest lightness after heating (p<0.05). There was no significant difference between the lightness of the control (+) and that of T4, or the lightness of the control (-) and that of T2 (p>0.05). The redness of T1 was the lowest before heating (p<0.05). There was no significant difference between the redness of the control (-) and that of T3, T4 and T5 (p>0.05). T2 had the highest redness before heating (p< 0.05), which did not differ significantly from that of the control (+) (p>0.05). T3, T4, T5 and the control (+) had the highest redness after heating (p<0.05) and there were no significant differences among these treatments (p>0.05). The control (-) and T1 and T2 had the lowest redness (p<0.05) and showed no significant differences (p>0.05) among themselves. According to previously published reports, addition of black rice to bread and of black rice bran to cookies decreased the lightness and redness of these products (Im and Lee, 2010; Joo and Choi, 2012). The results of the current work are consistent with those observations. This was attributed to the unique color of black rice (CIE L*: 35.6, CIE a*: 8.4, CIE b*: -3.7) (Park and Kim, 2016). It is possible that anthocyanins, a pigment in black rice bran, lowered the lightness of *Tteokgalbi*. Anthocyanins are affected by pH and turn stable red in acidic conditions (Bassa and Francis, 1987). Anthocyanins show the broadest absorption spectrum and highest absorbance at acidic pH and their absorbance maximum shifts towards longer wavelength as pH increases (Hwang and Ki, 2013). Therefore, organic acids were used in this research to adjust the pH, and, as a result, the addition of any one of the four organic acids under investigation to *Tteokgalbi* with black rice bran improved its lightness and redness.

Cooking loss, water-holding capacity, and shear force of *Tteokgalbi*

Table 4 shows the effect of the addition of black rice bran and one of the organic acids under study on cooking loss, water-holding capacity, and shear force of *Tteokgalbi*. Controls showed the highest cooking loss (p<0.05), whereas the treatments with added black rice bran had lower cooking loss (p<0.05). Water-holding capacity refers to the capacity of the product to retain water during processing. There was no significant difference in the water-holding capacity among all the treatments, with the exception of T1 (p>0.05). T1 had a significantly higher level of water-holding capacity (p<0.05). Park *et al.* (2016) found that water-holding capacity tended to increase with the addition of black rice. In contrast, in the present research, the water-holding capacity of treatments with added organic acids decreased, probably because of the pH-lowering effect of these organic acids (Weiss and Reynolds, 1988). Shear force refers to the level of hardness measured by mechanically cutting meat products. T2 had the highest shear force, whereas the controls exhibited the lowest (p<0.05), and all the treatments, with the exception of T4, had higher levels of shear force than that of the controls (p<0.05). Water-holding capacity and shear force of processed meat products are affected by the ratio of raw meat to additives and by the pH (Miller *et al.*, 1980). Kim *et al.* (2002) demonstrated a positive correlation between water-holding capacity and shear force. However, in the present research, there were no significant differences in the water-holding capacity among the experimental treatments and controls, with the exception of T1, nor were there any significant differences in the shear force among the experimental treatments. In this experiments, the previously postulated positive correlation between water holding capacity and shear force was shown only by T1 that had a higher level of shear force than the controls perhaps owing to the increase in water-holding capacity resulting from the addition of black rice bran (p<0.05).

Thiobarbituric acid reactive substances (TBARS) value and volatile basic nitrogen (VBN) content of *Tteokgalbi*

The TBARS value and VBN content of *Tteokgalbi* added with, black rice bran and one of the organic acids under study are listed in Table 5. T5 showed the significantly (p<0.05) lower TBARS value while there were no significant differences among the TBARS values of the

Table 4. Cooking yield, water holding capacity and shear force of *Tteokgalbi* formulated with black rice bran and different types of organic acid

Parameters	Control (-)[1)]	Control (+)	T1	T2	T3	T4	T5
Cooking loss (%)	8.53±1.47[a]	7.50±1.86[ab]	6.04±0.59[bc]	5.09±0.69[c]	6.37±0.37[bc]	6.55±0.27[bc]	5.78±0.47[c]
Water holding capacity (%)	44.61±5.89[b]	49.75±8.38[b]	68.32±3.78[a]	55.98±7.88[b]	49.62±1.55[b]	50.31±4.94[b]	53.26±4.35[b]
Shear force (kg)	0.57±0.10[c]	0.59±0.05[c]	0.65±0.05[b]	0.81±0.15[a]	0.63 ±0.03[b]	0.56±0.13[c]	0.73±0.14[b]

All values are mean±standard deviation of three replicates.

[a-c]Means within a row with different letters are significantly different (p<0.05).

[1)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

Table 5. TBARS (thiobarbituric acid reactive substance) and VBN (volatile basic nitrogen) value of *Tteokgalbi* formulated with black rice bran and different types of organic acid

Parameters	Control (-)[1)]	Control (+)	T1	T2	T3	T4	T5
TBA (mg MA/kg)	0.50±0.01[a]	0.50±0.02[a]	0.48±0.01[a]	0.49±0.03[a]	0.48±0.01[a]	0.49±0.01[a]	0.45±0.01[b]
VBN (mg %)	19.27±1.40[a]	15.31±1.66[bc]	14.40±0.91[c]	13.94±1.09[c]	16.75±0.89[b]	15.55±1.19[bc]	20.99±1.08[a]

All values are mean±standard deviation of three replicates.

[a-c]Means within a row with different letters are significantly different (p<0.05).

[1)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

controls and all the other treatments (p>0.05). Control (-) and T5 had the highest VBN content (p<0.05), whereas T1 and T2 had the lowest (p<0.05). Previously, bread with added black rice was reported to contain low levels of TBARS and sausages with added black rice grain showed low levels of TBARS (Im and Lee, 2010; Jang *et al.*, 2004). The results of the present research are consistent with these findings. The TBARS value is important in determining sensory evaluation. Meats containing 0.50 mg MA/kg or less of thiobarbituric acid (TBA) are considered fit for diet consumption, whereas 1.2 mg MA/kg or more is regarded as indicative of rotting (Choi *et al.*, 2007; Turner *et al.*, 1954). In meat, the protein decomposes with time because of microorganism- and enzyme-mediated breakdown, while the level of volatile basic nitrogen increases, therefore both the protein content and the VBN content serve as important indicators in evaluating the freshness of meat or meat products. More notably, VBN has a huge impact on sensory properties, and a putrefied flavor is generated in general when the VBN content increases to more than 18-23 mg% (Seol *et al.*, 2012).

Sensory properties of *Tteokgalbi*

The effect of the addition of black rice bran along with one of the four types of organic acids under study on the sensory properties of *Tteokgalbi* is shown in Table 6. There were no significant differences in color and juiciness among controls and treatments (p>0.05). However, controls and T2 received the highest vote in respect of color. Treatments with organic acids, with the exception of T5, scored higher than T1, to which only black rice bran had been added. This is consistent with the measured color results; addition of organic acids increased lightness and redness by affecting the anthocyanins in black rice bran. The controls, (-) and (+), T1, and T2 were significantly higher in flavor, whereas experimental treatments, T3 to T5, turned out to be lower (p<0.05). Tenderness showed a similar tendency, with the control (+) and T2 showing the highest level of tenderness. T1 and T2 received the highest rating as regards overall acceptability (p<0.05), but did not differ significantly from the controls (-) and (+). T4 and T5 had a low level of overall acceptability. Overall acceptability is assumed to have been affected by all the factors. It is worth noting that the trend of overall acceptability is most similar to that of flavor. A drop in the pH of the organic acid treatments resulted in acidic flavor and adversely affected sensory evaluation (Kang *et al.*, 2002). Kemp *et al.* (1989) reported that a decrease in the pH of vacuum-packed ham resulted in an increase in acidic flavors and off-flavors. The findings of the research presented here are consistent with these previous observations.

Conclusion

The aim of this research was to investigate quality and sensory properties of *Tteokgalbi* to which black rice bran and any one of four organic acids under study to substitute synthetic caramel pigment. The lightness and redness of T1 were lower than those of the control. Addition of organic acids improved the level of redness relative to that of T1, to which only black rice bran had been added. T1 had the highest level of water-holding capacity. There was no significant difference in the TBA levels of control and that of treatments, with the exception of T5, which had a lower level of VBN compared to that of all the other treatments and control (-). There was no significant difference in the overall acceptability of the controls and that of the treatments T1 and T2. Therefore, it is believed that black rice bran and ascorbic acid could be used to substitute the synthetic caramel pigment used in *Tteokgalbi*, making it possible to produce, at no extra cost, good meat

Table 6. Sensory characteristics of *Tteokgalbi* formulated with black rice bran and different types of organic acid

Parameters[1)]	Control (-)[2)]	Control (+)	T1	T2	T3	T4	T5
Color	7.60±1.14	7.60±1.14	6.60±1.14	7.60±1.67	6.60±1.52	7.00±1.87	6.20±1.30
Flavor	7.40±0.89[a]	7.60±0.55[a]	6.80±1.10[a]	7.20±2.49[a]	3.80±1.10[b]	4.40±0.89[b]	4.75±0.50[b]
Tenderness	7.00±0.01[ab]	8.00±0.01[a]	7.20±0.84[ab]	8.00±0.01[a]	6.75±0.96[b]	6.10±1.14[b]	6.60±0.89[b]
Juiciness	7.00±0.01	8.00±0.01	7.20±1.10	7.20±0.84	6.20±2.17	6.40±1.82	6.20±1.64
Overall acceptability	6.80±1.10[a]	8.00±0.01[a]	7.50±0.58[a]	7.00±2.35[a]	4.75±0.96[b]	4.40±1.14[b]	5.00±0.82[b]

All values are mean±standard deviation of three replicates.

[a,b]Means within a row with different letters are significantly different (p<0.05).

[1)]Color, flavor, tenderness, juiciness and overall acceptability; preference (1=extremely bad or undesirable, 10=extremely good or desirable).

[2)]Control (-), patty with no additive; Control (+), patty with caramel colorant; T1, patty with 1% black rice bran; T2, patty with 1% black rice bran+ ascorbic acid; T3, patty with 1% black rice bran+citric acid; T4, patty with 1% black rice bran+tartaric acid; T5, patty with 1% black rice bran+ maleic acid.

products in terms of quality and sensory characteristics.

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