



Effect of Black Rice Powder on the Quality Properties of Pork Patties

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Abstract

Physicochemical properties of pork patties formulated with black rice powder were investigated. Moisture contents of samples containing black rice powder were significantly higher than that of the control ($p < 0.05$). Protein, fat, and ash contents increased with increasing black rice powder content. Uncooked and cooked pH values of samples increased with increasing concentration of black rice powder. Lightness and yellowness of samples decreased with increasing concentration of black rice powder. Redness of cooked samples containing black rice powder was significantly lower than that of the control ($p < 0.05$). Water holding capacity and cooking yield of samples increased with increasing black rice powder concentration. Diameter and thickness reduction ratio of samples decreased with increasing black rice powder content. Sensory evaluation of samples showed no significant difference between samples. Thus, black rice powder improved the quality of pork patties.

Keywords black rice, pork patties, meat product

Introduction

Ground pork products such as pork patties have gained wide popularity for their soft texture and excellent sensory characteristics (Lee and Oh, 2008; Lee *et al.*, 2011). They are produced and sold as frozen processed meat products for easy accessibility at home and they represent some of the most popular processed meat products in Korea.

In recent times, a westernization of dietary habits has set in among Korean consumers and the consumption of processed meat products has progressively increase (MAFRA, 2015); as a result, various additives are added to alter the sensory characteristics of processed meat products to broaden the consumers' range of choice. However, the indiscriminate use of these additives has led to consumers being concerned about additives such as synthetic sweeteners and preservatives when consuming processed meat products (Han and Ahn, 1998). Based on consumer demands, the meat processing industry and researchers have actively conducted studies on functional processed meat products that can produce beneficial effects when people consume processed meat products with specific additives added in them. These functional additives must positively influence the nutritional value of the product while also satisfying sensory characteristics (Jimenez-Colmenero *et al.*, 2001).

With respect to case studies that used functional materials to provide functionality to foods, Park *et al.* (2016) reported that when pork skin gelatin with a high

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antioxidant activity and neuro-protective effect was added to emulsion-type sausages, the sausages showed increased pH, water holding capacity, and cooking yield. When red pepper seed powder, which promotes energy metabolism and anti-cancer and antioxidant effects, was added to ground pork, cooking loss and decrease in diameter and thickness was lower, while hardness increased and the sensory characteristics showed improvement (Kim *et al.*, 2016). Moreover, Kim *et al.* (2002) examined functional sausages using pine needles and green tea extracts and reported that adding pine needles and green tea to sausages resulted in lower fatty acid composition and volatile basic nitrogen content, total bacterial count measurement showing antibacterial activity, and improved sensory characteristics.

Rice, one of the traditional food ingredients that has been a staple food in Korea throughout its history, has been given functionality through the development of specialty varieties such as pigmented rice, and the consumption of such specialty rice has witnessed a rising trend (Jang *et al.*, 2004). Black rice, a type of pigmented rice, contains an anthocyanin-based black pigment in its skin, which imparts antioxidative, immunity boosting, and DNA damage suppressing qualities to the rice. (Choi and Oh, 1996; Kang *et al.*, 1998; Park *et al.*, 2008). Moreover, it is known to have a higher nutrient content than white rice, since it is milled in the uncleaned state (Ha *et al.*, 1999), which makes it a natural ingredient that is highly useful as a functional additive.

Therefore, the present study added black rice powder that exhibits distinct value as a functional additive to pork patties, one of the best known processed meat products, for the investigation of product quality characteristics.

Materials and Methods

Preparation of pork patties with added black rice powder

The pork patty products used in the present study were prepared according to the method of Kim *et al.* (2016) The patties were made from pork hind leg (Hongjumeat, Korea) that was frozen and used 24 h after slaughtering. Pork meat and fat were ground using a grinder (PA-82, Mainca, Spain) fitted with a 3 mm plate, and a mixer (RM-20, Mainca, Spain) was used to mix the meat material (70%), back fat (15%), and ice (15%) for 10 min, while adding nitrite-pickling-salt (NPS) (1.2%), sugar (1%), garlic powder (0.5%), onion powder (0.5%), and

black rice powder (*Oryza Sativa L*, suwon 415, carbohydrate and moisture: 86.51%, protein: 10.42%, fat: 3.13%, ash: 1.86%, pH: 6.8, CIE L*: 35.6, a*: 5.1, b*: -3.7, Garunara, Korea) in their respective amounts relative to the total weight. After the emulsified product had been thoroughly mixed, it was formed into identically-sized patties (length 90 mm × width 90 mm × height 12.5 mm); the patties were cooked for 30 min at 80°C in a heat chamber (10.10ESI/SK, Alto Shaam Co., Menomonee Falls, USA), and then frozen for 30 min at 10°C. The control did not have any black rice powder added (Control: 0%), while the formulated samples were prepared by adding 1%, 3%, and 5% black rice powder (Table 1). The prepared pork patties were stored at 4°C while the experiments were being conducted.

Proximate analysis

In compliance with the AOAC method (1990), crude protein content was measured by the Kjeldahl method, crude fat content was measured by the Soxhlet method, moisture content was measured by the drying oven method at 105°C, and crude ash content was measured the dry ashing method at 550°C.

pH

The pH was determined, following grinding and homogenization of 5 g of sample with 20 mL of distilled water for 60 s (HMZ-20DN, Pooglim Tech, Korea) and the pH was then measured using a pH meter (Model S220, Mettler-Toledo, Switzerland). All determinations were performed in triplicate.

Color

The inner surface of the specimen before and after heating was tested using a colorimeter (CR-10, Minolta, Japan) for measuring CIE L* (lightness), CIE a* (redness), and CIE b* (yellowness). A white standard plate with a CIE L* of +97.83, CIE a* of -0.43, and CIE b* of +1.98 was used as reference.

Water-holding capacity (WHC)

The water-holding capacity (WHC) was measured by modification of the procedure of Grau and Hamm (1953). Briefly, a 300 mg meat batter of each treatment was placed in a filter-press device and compressed for 3 min. The WHC was calculated from duplicate samples as a ratio of the sample film area to the total area; hence, a larger value suggests a higher WHC.

Table 1. Formulation of pork patties formulated with various black rice powder levels

Ingredient (%)		Black rice powder (%)			
		0 (control)	1	3	5
Main	Meat	70	70	70	70
	Fat	15	15	15	15
	Ice	15	15	15	15
Additive	NPS ¹⁾	1.2	1.2	1.2	1.2
	Sugar	1	1	1	1
	Garlic powder	0.5	0.5	0.5	0.5
	Onion powder	0.5	0.5	0.5	0.5
	Black rice powder	-	1	3	5

¹⁾NPS: Nitrite pickling salt.

WHC (%) = [Meat area (mm²) / Total area (mm²)] × 100

Cooking yield

The uncooked patties (initial weight) heat processed at 80±1°C for 30 min and then core temperature of samples was reached respectively at 80±1°C. After cooling for 1 h, cooked patties were weighed (cooking weight) and a percentage cooking yield was calculated from the weights.

Cooking yield (%) = [cooking weight (g) / initial weight (g)] × 100

Reduction in diameter and thickness

To measure the diameter and thickness of the same locations before and after a cooking, two points per patty were marked. The diameter and thickness of uncooked and cooked patties were recorded using Vernier calipers (CD-15APX, Mitutoyo Co., Japan).

Reduction in diameter (%) = {[uncooked diameter (mm) – cooked diameter (mm)] / uncooked diameter (mm)} × 100

Reduction in thickness (%) = {[uncooked thickness (mm) – cooked thickness (mm)] / uncooked thickness (mm)} × 100

Texture profile analysis (TPA)

The texture profile analysis of each sample was performed in duplicate. Samples were cut into 2.5 × 2.5 × 2.0 cm (length × width × height). The textural properties for each sample were measured using a cylinder probe (φ 100 mm diameter), set attached to a Texture Analyzer (TA 1, Ametek, USA). The test conditions were as follow: test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g. The texture profile

analysis (TPA) parameters, namely hardness [peak force on first compression (kg)], springiness [ratio of the sample recovered after the first compression], cohesiveness [ratio of active work done under the second force-displacement curve to that done under the first compression curve], gumminess [hardness × cohesiveness (kg)], and chewiness [hardness × cohesiveness × springiness (kg)] were computed.

Sensory evaluation

The sensory evaluations of each sample were performed in duplicate by sensory panelists. 12 panelists were screened from 15 potential panelists using basic taste identification test and trained with commercial pork patties product for 2 wk (three 30 min sessions per week) to familiarize them with the product characteristics planned to be evaluated. The color, flavor, tenderness, juiciness, and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the samples were evaluated based on a 10-point descriptive scale (1 = extremely undesirable, 10 = extremely desirable). All panelists were required to cleanse their palate between samples with water.

Statistical analysis

All analyses were conducted at least three times under each experimental condition and the mean values were reported. Analysis of variance were performed on all variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS version 9.3 for window, SAS Institute Inc., USA). The Duncan's multiple range test with α = 0.05%.

Result and Discussion

Proximate composition

The results of proximate composition measurements of

pork patties after heating according to the amount of black rice powder added are shown in Table 2. Moisture content was significantly higher in all black rice powder formulated samples than the control ($p < 0.05$). Protein and fat content tended to decrease as black rice powder content increased and the samples formulated with 3% and 5% black rice powder showed significantly higher values than the control ($p < 0.05$). In contrast, ash content tended to increase with the amount of black rice powder added. Serdaroglu *et al.* (2005) reported that adding legume powder to meatballs decreased the moisture content and increased protein content, while adding corn powder to meatballs resulted in increased protein content (Serdaroglu and Pegirmencioglu, 2004). These observations were inconsistent with the findings in the present study. However, Minerich *et al.* (1991) reported that when wild rice was added to beef patties, moisture content was higher, and protein and fat contents were lower than in the control, which was consistent with the present study. It is believed that these changes in proximate composition occurred because the addition of black rice powder caused an increase in the ash content, which then absorbed moisture, causing an increase in moisture content, and resulting in a relative decrease in protein and fat content.

pH and color

Table 3 shows the results of pre- and post-heating pH

and color measurements of pork patties according to the amount of black rice powder added. pH is a major factor affecting the quality of edible meats and processed meat products. Changes in pH can affect properties such as freshness, water holding capacity, softness, and texture. Moreover, a lower pH can facilitate the oxidation of myoglobin (a meat pigment) and lower water holding capacity, whereas a higher pH can have a positive impact on meat color and water holding capacity (Jee *et al.*, 1999; Zhu and Brewer, 1998). Before heating, pH increased significantly as the amount of black rice powder added increased ($p < 0.05$); this trend was maintained even after heating. Jang *et al.* (2004) observed that when sausages were made with grain powder added, the samples formulated with black rice powder showed a higher pH than the control, which was believed to be the result of the high pH (6.68) of the black rice powder. Pre- and post-heating lightness tended to decrease as the amount of black rice powder added increased, with post-heating lightness showing a significant decrease ($p < 0.05$). All black rice powder formulated samples showed significantly higher pre-heating redness values than the control ($p < 0.05$), whereas they showed significantly lower post-heating redness values ($p < 0.05$). It is believed that these results are due to the black rice powder having a redness value of 5.10, which was higher than the redness value of the control before heating (2.80), but lower than the redness value of the control

Table 2. Proximate composition of pork patties formulated with various black rice powder levels

Trait	Black rice powder (%)			
	0 (control)	1	3	5
Moisture (%)	55.30 ± 0.84 ^b	57.89 ± 1.74 ^a	59.30 ± 0.36 ^a	58.94 ± 0.08 ^a
Protein (%)	22.42 ± 1.00 ^a	20.51 ± 1.80 ^{ab}	18.43 ± 0.61 ^b	18.28 ± 0.47 ^b
Fat (%)	28.74 ± 3.26 ^a	25.92 ± 2.11 ^{ab}	20.40 ± 0.3 ^{bc}	17.23 ± 1.39 ^c
Ash (%)	1.85 ± 0.06 ^c	1.93 ± 0.01 ^{bc}	2.06 ± 0.04 ^{ab}	2.07 ± 0.01 ^a

All values are mean±SD.

^{a-c}Means in the same row with different letters are significantly different ($p < 0.05$).

Table 3. pH and color of pork patties formulated with various black rice powder levels

Trait		Black rice powder (%)				
		0 (control)	1	3	5	
pH	Uncooked	5.83 ± 0.01 ^d	5.93 ± 0.01 ^c	5.99 ± 0.01 ^b	6.09 ± 0.01 ^a	
	Cooked	6.08 ± 0.01 ^c	6.13 ± 0.01 ^b	6.19 ± 0.02 ^a	6.20 ± 0.01 ^a	
Color	Raw	CIE L*	67.80 ± 1.63 ^a	56.03 ± 1.67 ^b	51.98 ± 0.16 ^c	50.88 ± 1.01 ^c
		CIE a*	2.80 ± 0.39 ^b	4.55 ± 0.05 ^a	4.83 ± 0.58 ^a	4.95 ± 0.05 ^a
		CIE b*	9.05 ± 0.69 ^a	6.28 ± 0.68 ^b	1.05 ± 0.34 ^c	0.07 ± 0.17 ^c
	Cooked	CIE L*	70.33 ± 0.08 ^a	62.53 ± 0.30 ^b	52.95 ± 0.59 ^c	49.55 ± 0.18 ^c
		CIE a*	5.55 ± 0.11 ^a	4.95 ± 0.21 ^b	4.65 ± 0.05 ^b	5.00 ± 0.10 ^b
		CIE b*	10.00 ± 0.14 ^a	5.73 ± 0.28 ^b	1.70 ± 0.27 ^c	0.63 ± 0.15 ^d

All values are mean±SD.

^{a-d}Mean in the same row with different letters are significantly different ($p < 0.05$).

after heating (5.55). Pre- and post-heating yellowness showed a tendency to decrease as the amount of black rice powder added increased, with post-heating samples showing a significant decrease ($p < 0.05$). Serdaroglu *et al.* (2005) reported that meatballs with legume powder added had higher lightness, but did not show significant differences in redness or yellowness. Moreover, Lee *et al.* (2008) indicated that adding hot-air dried kimchi powder to pork patties resulted in increased redness and yellowness. It was determined that these color changes based on additives were due to the unique coloration of black rice powder (CIE L*: 35.6, a*: 5.1, b*: -3.7) having an effect on the pork patties.

Water holding capacity and cooking yield

The variation of water holding capacity and cooking yield of pork patties according to the amount of black rice powder added are shown in Fig. 1. For processed meat products, the water holding capacity is closely associated with pH, and is lowest near the isoelectric point at pH 5.0-5.2. As pH increases or decreases relative to the isoelectric point, water holding capacity shows an increasing curve (Deymer and Vandekerekhove, 1979). Experimental results showed water holding capacity ranging between 73.26 and 85.47%, from the control to the samples formulated with 5% black rice powder. Water holding capacity tended to increase with increasing black rice powder content, which was the same trend found in pH. Moreover, the samples formulated with 3% and 5% black rice powder showed significantly higher values than the con-

trol ($p < 0.05$). Cooking yield according to the amount of black rice powder added was 61.91-78.22%, showing a significant increase with increase in black rice powder content ($p < 0.05$). Gnanasambandam and Zayas (1992) reported that when meat products were produced with grain proteins added, as water holding capacity increased, cooking yield decreased. It was also reported that cooking yield increased in meatballs with legume proteins added and patties with wild rice added, which were consistent with the findings in the present study (Minerich *et al.*, 1991; Serdaroglu *et al.*, 2005). It was determined that as water holding capacity increased, moisture loss while heating decreased, resulting in enhanced cooking yield.

Reduction in diameter and thickness

The rates of reduction in the diameter and thickness of the pork patties after heating are shown in Fig. 2. Cooking yield and diameter change share an inverse relationship, with an increased yield resulting in a reduced diameter (Serdaroglu *et al.*, 2005). The rates of reduction in the diameter and thickness according to the amount of black rice powder added were 8.72-21.71% and 7.57-35.55%, respectively, which showed a decreasing trend as the amount of black rice powder added increased. The control and the sample formulated with 1% black rice powder showed significantly higher rates of reduction in diameter than the samples formulated with 3% and 5% black rice powder ($p < 0.05$), while showing a significant decrease in the rate of thickness reduction as the amount of black rice powder added increased ($p < 0.05$). In a similar study, when meat-

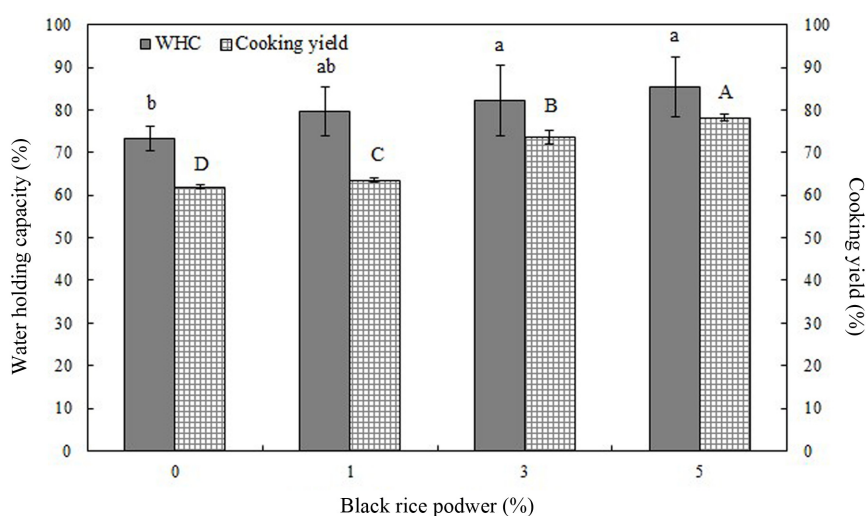


Fig. 1. Water holding capacity and cooking yield of pork patties formulated with various black rice powder levels. ^{a,b,A-D}Means on bars with different letters are significantly different ($p < 0.05$).

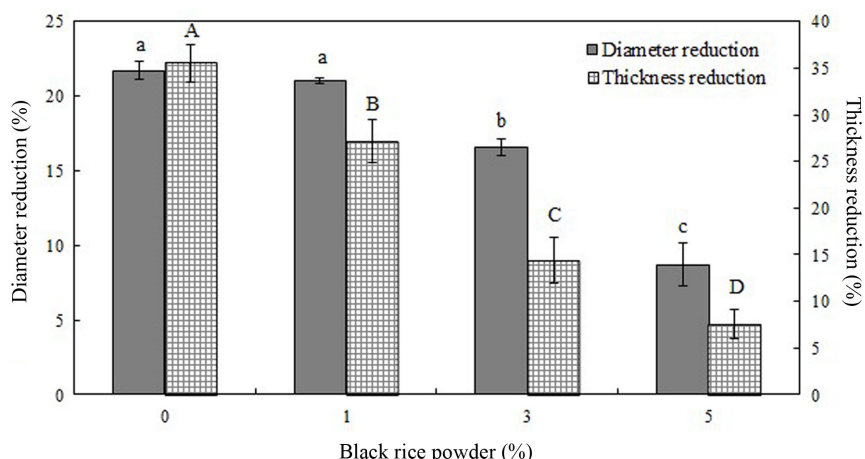


Fig. 2. Diameter and thickness reduction ratio of pork patties formulated with various black rice powder levels. ^{a-d,A-D}Means on bars with different letters are significantly different ($p < 0.05$).

balls were produced, adding legume proteins resulted in decreased rate of diameter reduction, with the samples to which black-eyed peas were added showing the lowest rate of diameter reduction (Serdaroglu *et al.*, 2005). It was also reported that corn powder did not affect the rate of diameter reduction of meatballs, but did cause a decrease in the rate of thickness reduction (Serdaroglu and Pegirmencioglu, 2004). Rice powder had characteristics to increase the water holding capacity. It was decreased water and fat exudative rate were decreased during cooking. Accordingly, the reduction rate of thickness and diameter were decreased.

Texture profile analysis

The physical properties of pork patties after heating as a function of the amount of black rice powder added are shown in Table 4. A study reported that when grain powder was added to meat products, it became involved with various textural elements to cause changes in the texture of the final product (Gnanasambandam and Zayas, 1992). The measurement results on the physical properties sho-

wed that as the amount of black rice powder added increased, the hardness, gumminess, and chewiness tended to decrease, with gumminess showing a significant decrease with increase in the amount of black rice powder added ($p < 0.05$). There were no significant differences in springiness between the control and formulated groups ($p > 0.05$), while the sample formulated with 1% black rice powder showed a significantly higher value for cohesiveness than the sample formulated with 5% black rice powder ($p < 0.05$). Meanwhile, Jang *et al.* (2004) reported that the addition of black rice powder resulted in increased hardness in sausages, which do not match the result of the present study. An increase in the moisture content of the proximate composition resulted in a relative decrease in the protein content, which in turn reduced the hardness and cohesiveness. Moreover, in the TPA test, gumminess is derived from hardness and cohesiveness, and since chewiness is determined by gumminess and springiness, gumminess and chewiness tended to decrease as hardness decreased.

Table 4. Texture properties of pork patties formulated with various black rice powder levels

Trait	Black rice powder (%)			
	0 (control)	1	3	5
Hardness (kg)	7.69 ± 0.73 ^a	4.95 ± 1.16 ^b	3.29 ± 0.53 ^c	2.71 ± 0.32 ^c
Springiness	0.91 ± 0.02	0.87 ± 0.07	0.86 ± 0.08	0.88 ± 0.08
Cohesiveness	0.26 ± 0.02 ^{ab}	0.30 ± 0.07 ^a	0.28 ± 0.06 ^{ab}	0.22 ± 0.04 ^b
Gumminess (kg)	2.03 ± 0.28 ^a	1.47 ± 0.40 ^b	0.90 ± 0.11 ^c	0.58 ± 0.13 ^d
Chewiness (kg)	1.84 ± 0.25 ^a	1.28 ± 0.34 ^b	0.78 ± 0.13 ^c	0.51 ± 0.14 ^c

All values are mean ± SD.

^{a-d}Means in the same row with different letters are significantly different ($p < 0.05$).

Table 5. Sensory evaluation of pork patties formulated with various black rice powder levels

Trait	Black rice powder (%)			
	0 (control)	1	3	5
Color	9.05 ± 0.54 ^a	8.36 ± 0.82 ^b	8.63 ± 0.52 ^{ab}	± 0.52 ^{ab}
Flavor	8.40 ± 0.61	8.38 ± 0.46	8.77 ± 0.33	± 0.41
Tenderness	8.50 ± 0.69	8.62 ± 0.42	8.58 ± 0.34	8.16 ± 0.65
Juiciness	8.38 ± 0.82	8.49 ± 0.65	8.76 ± 0.48	8.53 ± 0.57
Overall acceptability	8.46 ± 0.70	8.40 ± 0.67	8.75 ± 0.41	8.78 ± 0.50

All values are mean±SD.

^{a,b}Means in the same row with different letters are significantly different ($p<0.05$).

Sensory evaluation

The results of a sensory evaluation on pork patties with black rice powder added are shown in Table 5. In sensory evaluations, one of the most important factors in evaluating the value of edible meats or processed meat products is their surface color (Gnanasambandam and Zayas, 1992). Among the sensory evaluation items, with the exception of color, there were no significant differences in flavor, tenderness, juiciness, and overall acceptability. However, the sample formulated with 1% black rice powder, but not 3% and 5% black rice powder, showed significantly lower scores than the control ($p<0.05$). These findings were inconsistent with studies that reported that sausages with black rice added showed higher sensory characteristics than those of the control of sausages formulated with other grains (Jee *et al.*, 1999), and that sensory evaluation of meatballs with black-eyed peas added received high marks in most of the evaluation categories (Serdaroglu *et al.*, 2005). However, because the samples formulated with 3% and 5% black rice powder did not show significant differences in color against the control, it was determined that adding $\geq 3\%$ black rice powder can yield sensory evaluation results similar to those of the control.

Conclusion

The present study analyzed the product quality characteristics of pork patties according to the amount of black rice powder added with the objective of obtaining the basic data needed for the development of pork patties formulated with black rice powder as the functional additive. Moisture and ash content in pork patties showed significantly higher values in the samples formulated with black rice powder than the control ($p<0.05$), while protein and fat content showed a decreasing trend as the amount of black rice powder added increased. Pre- and post-heating yellowness tended to decrease as the amount of

black rice powder added increased. Water holding capacity and cooking yield tended to increase with black rice powder content, while the rate of reduction in diameter and thickness tended to decrease with increasing black rice powder content. Measurements of the physical properties showed that hardness, gumminess, and chewiness decreased as black rice powder content increased. In the sensory evaluation, there were no significant differences between the control and formulated groups for all categories, except color. In summarizing the findings mentioned above, to give the functionality of black rice powder to pork patties and to enhance the product physical properties, it would be advisable to add 3-5% of black rice powder.

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