Black Rice Bran as an Ingredient in Noodles: Chemical and Functional Evaluation

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Abstract: This study examined the feasibility of using black rice bran (BRB) as an ingredient of noodles and evaluated the effect of BRB incorporation in noodles in terms of chemical and functional attributes. Noodles were prepared with BRB as an ingredient at different levels (2%, 5%, 10%, and 15%). Addition of BRB (5%, 10%, and 15%) significantly decreased the cohesiveness of noodles in texture evaluation. Noodles with different levels of BRB were functionally evaluated and content of polyphenolics, flavonoids, and anthocyanins were improved compared to the control. Additionally, antioxidant activity of BRB noodles was increased compared to the control. BRB can be an excellent ingredient to increase the nutritional value and antioxidant properties of noodles.

Keywords: antioxidant properties, black rice bran, noodle, texture profile analysis (TPA)

Introduction

Noodles are made from simple ingredients including wheat flour, water, and salt and are one of the most popular foods consumed throughout the world. Noodles are favored by consumers for ease of cooking, handling, transportation, and affordable cost. However, noodles often lack other essential nutritional components such as protein, dietary fiber, and vitamins, which are lost during wheat refinement. Consumers are now considering secondary features such as functional and nutritional aspects of the products. With growing concerns regarding national health and expanding markets of functional products worldwide, some specialty noodles, including green seaweed, banana flour, and rye flour are being investigated for their secondary benefits (Prabhasankar and others 2009; Choo and Aziz 2010; Kruger and others 1998).

Black rice, as a rice species with great potential for human health, has recently gained increased research focus (Ling and others 2002). Endogenous antioxidant activity has recently been attributed to a variety of specific polyphenolic compounds in black rice (Nam and others 2005). Black rice contains many beneficial components, including polyphenolics, flavonoids, phytic acid, and γ-oryzanol (Fardet and others 2008). These antioxidant compounds eliminate reactive oxygen species (ROS), such as lipid peroxide and superoxide anion radicals (Ichikawa and others 2001; Toyokuni and others 2002). In black rice, the antioxidant compounds are located primarily in the aleurone layer, named rice bran, which is characterized by a dark purple color (Kong and Lee 2010). Black rice derives its name from its rich natural anthocyanin compounds, such as cyanidin-3-glucoside and peonidin-3-glucoside, not found in white rice (Hu and others 2003). Black rice bran (BRB) is a good source of dietary fiber and phytochemicals and has been incorporated into breads (Abdul-Hamid and Luan 2000; Kong and Lee 2010). However, no scientific report has dealt with the application of BRB in noodles.

In this study, BRB was selected because of its high nutritional content and high distribution of antioxidant compounds. The objective was to determine the feasibility of using BRB flour as a noodle ingredient and to evaluate the effect of incorporation BRB in noodles in terms of its chemical and functional attributes.

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Materials and Methods

Materials

Black rice (*Oryza sativa* cv. *Heugjinjubyeo*) was obtained from the Rural Development Administration, Korea. Whole black rice was milled into rice bran and endosperm using a gradual milling system (85% milling degree). Milling yield was determined by dividing the mass of the resulting milled rice by 1000 g, the original whole rice sample mass (Siebenmorgan and others 2006). Milled samples were passed through 100-mesh sieves and heated at 100 °C for 30 min to inactivate the endogenous lipase (Juliano 1985). Wheat flour (10% protein, 1% fat content, and 77% carbohydrate) was purchased from a local market in Cheongju, Korea. Gallic acid, ascorbic acid, Folin-Ciocalteu reagent, 1,1-diphenyl-2-picrylhydrazyl (DPPH), diammonium salt of 2,2-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), potassium ferricyanide, ferric chloride, ferrous chloride and ferrozine (3-(2-pyridyl)-5,6-bis-(4-phenylsulphonic acid)-1,2,4-triazine) were purchased from Sigma Chemical Co. (St. Louis, Mo., U.S.A.). All other reagents and solvents used were of analytical and HPLC grade.

Preparation of BRB noodles

The flour mixture of wheat and BRB was prepared in ratios of 98:2; 95:5; 90:10, and 85:15 (wheat flour/BRB; w/w). An additional noodle with no BRB included was also prepared as a control. The noodle dough was prepared on basis of a 250 g wheat flour mixture. A salt solution (102.5 mL) composed of 2% salt was added to each noodle formulation to form dough. Noodle dough was prepared and mixed for 5 min at slow speed and then for 10 min at medium speed (Electronic mixer, KMC550, Kenwood, Havant, UK). The dough was then allowed to stand at

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room temperature (23 °C) for 60 min and then pressed into sheets (Kyungbuk Machine, Daegu, Korea). Noodle sheets were then passed through cutting blades to form 3 mm wide noodle strands. Noodles (25 g) were cooked for 5 min in 250 mL of cool water. Then, the cooked noodles were placed in 250 mL cool water for 1 min and drained for 5 min. After cooking and draining, noodle cooking characteristics and textural properties were determined.

Proximate analysis and cooking characteristics of BRB noodles

Moisture, ash, crude protein, and crude fat contents of noodles were determined according to the AOAC (2000) method. Cooking loss was determined by evaporation of cooking water collected from each sample in an air oven at 105 °C (Prabhasankar and others 2009). The residue was weighed and reported as percentage of the original noodle sample. Swelling index of cooked noodle (SI; grams of water per gram of dry noodle) was evaluated by drying noodle samples at 105 °C, expressed as [weight of cooked product ($W1$) – weight after drying ($W2$)]/weight after drying ($W2$). Water absorption of the noodle was determined as {[weight of cooked noodle ($W3$) – weight of raw noodle ($W4$)]/weight of raw noodle ($W4$)} ×100 (Tudorica and others 2009). All measurements were performed in at least triplicate.

Color measurement

The Hunter color parameters L, a, and b of control and BRB noodles were measured by a colorimeter (Minolta, CR-200, Tokyo, Japan) through round plastic optical cells (21 mm in diameter and 5 mm in depth), standardized with calibration plate sets and a white plate. Color results were expressed as tristimulus parameters (L, a, b, C, and H), with H (hue angle = arctan b/a) indicating sample color (0 or 360 = red; 90 = yellow; 180 = green; 270 = blue) and C [chroma = $(a^2 + b^2)^{1/2}$] indicating color purity or saturation (Zhu and others 2010). The raw noodle sheet was folded into three layers, placed over the spectrocolorimeter port and enclosed within a blackened container to remover ambient light. Measurements were made in triplicate at two locations on the noodle surface for each sample and averaged for each replicate.

Texture profile analysis

Texture characteristics of cooked noodles were determined using a texture analyzer (TA.XT2, Stable Micro Systems Ltd., Godalming, UK). For the texture profile analysis (TPA), noodles were cooked in separate batches and tested separately 15 and 20 min after cooking to avoid rapid textural changes of cooked noodles immediately after cooking (Corke and Bhattacharya 1999). The probe was a stainless steel cylinder probe with a diameter of 3.5 mm. The pre-test speed was 5 mm/s and the test and post-test speeds were 1 mm/s. The target distance was 3 mm. Each test sample was compressed twice, each compression being followed by decompression. The time interval between the end of the first compression and the second compression was 5 s. The first peak force was termed hardness, and the negative force area of the curve during retraction of the probe was termed adhesiveness. Cohesiveness was obtained by dividing the area of the second compression by the area of the first cycle. At least 10 individual strands were tested for each group. Results are reported as an average of the measurements.

Preparation of BRB noodle extract

Aqueous extracts of noodle samples were prepared by homogenizing noodles (5.0 g in case of raw; 10.0 g in case of cooked) in 50 mL of distilled water for 5 min at room temperature. After centrifugation, the supernatant was separated from the residue and made to 50 mL with distilled water. The noodle extracts were used for determining various antioxidant properties.

Determination of total polyphenolics

Polyphenolic contents of the noodle extracts were determined using the Folin-Ciocalteu method (Dewanto and others 2002) with some modifications and results were expressed as milligrams gallic acid equivalents per 25 g of noodles. Standard solution or noodle extract (200 μL) was mixed with 2 mL of 2% sodium carbonate solution and 100 μL 50% Folin-Ciocalteu reagent. After incubation for 30 min at room temperature, the absorbance was measured at 750 nm. All extracts were analyzed in triplicate.

Determination of flavonoids

Flavonoid contents of the noodle extracts were determined by a colorimetric method (Jia and others 1999) with some modifications and results were expressed as milligrams (+)-catechin equivalents per 25 g of noodles. Standard solution or noodle extract (250 μL) was mixed with 1.25 mL of distilled water and 75 μL 5% $NaNO_2$ solution. After 5 min, 150 μL 10% $AlCl_3 \cdot H_2O$ was added. After 6 min, 500 μL 1 M NaOH and 275 μL distilled water were added to the mixture. The solution was mixed well and the intensity of pink color was measured at 510 nm. All noodle extracts were analyzed in triplicate.

Determination of anthocyanins

Anthocyanin content was determined using a pH differential method (Turker and Erdoğdu 2006). Noodle extract (150 μL) was mixed with 0.025 M potassium chloride buffer (pH 1.0) and 0.4 M sodium acetate buffer (pH 4.5). The solution was measured at 510 nm and 700 nm. All noodle extracts were analyzed in triplicate. The total anthocyanin content was calculated as cyanidin-3-glucoside. Results were calculated as follows:

$$\text{Anthocyanin content (mg/L)} = \frac{A \times \text{MW} \times \text{DF} \times 100}{\varepsilon \times V},$$

where A (absorbance) = $(A_{510}–A_{700})_{\text{pH}1.0} - (A_{510}–A_{700})_{\text{pH}4.5,}$
MW (molecular weight of cyanidine-3-glucoside) = 449.2,
DF = dilution factor,
ε (cyanidin-3-glucoside molar absorbance) = 26900 $M^{-1}cm^{-1}$,
and V = volume of extract.

DPPH radical scavenging activity

The DPPH radical scavenging activity of noodle extracts was estimated according to the method of Cheung and others (2003) with some modifications. Aliquots of 1.0 mL of 0.2 mM DPPH in ethanol were mixed with 50 μL of the noodle extracts. The mixtures were vigorously shaken and left to stand for 10 min under subdued light. The absorbance at 520 nm was measured against water as a blank. The DPPH radical cation scavenging activity was expressed as ascorbic acid equivalent antioxidant activity (AEAC) and defined as the milligrams ascorbic acid equivalents per 25 g of noodles.

ABTS radical scavenging activity

The scavenging activity of noodle extracts on the ABTS radical cation was estimated according to the method of Re and others (1999) with some modifications. ABTS radical cation was generated by adding 7 mM ABTS to 2.45 mM potassium persulphate solution and the mixture was left to stand overnight in the dark at room temperature. The ABTS radical cation solution was diluted with distilled water to obtain an absorbance of 1.4 to 1.5 at 735 nm (molar extinction coefficient $\varepsilon = 3.6 \times 10^4$ mol^{-1} $1cm^{-1}$). Diluted ABTS radical cation solution (1 mL) was added to 50 μL of extracts or ascorbic acid standard solution. The absorbance was measured at 735 nm after 1 h. The ABTS radical cation scavenging activity was expressed as ascorbic AEAC and defined as the milligrams ascorbic acid equivalents per 25 g of noodles.

Metal chelating activity

The chelating activity of the noodle extracts was determined according to the method explained by Dinis and others (1994). The noodle extract (1 mL) was reacted with 100 μL of ferrous chloride (2 mM) and ferrozine (5 mM) for 10 min, and the absorbance of the mixture was measured at 562 nm.

Reducing power

The reducing power of noodle extracts was determined according to the method of Oyaizu (1986) with some modifications. Noodle extracts (250 μL), 200 mM sodium phosphate buffer (250 μL pH 6.6), and 1% potassium ferricyanide (250 μL) were mixed and incubated in a water bath at 50 °C. After 20 min, 250 μL 10% trichloroacetic acid (w/v) was added to the mixture and centrifuged at 1000 rpm (240 × *g*) for 10 min. The supernatant (500 μL) was then mixed with an equal volume of distilled water and ferric chloride solution (0.1%, w/v). The intensity of blue green color was measured at 700 nm using a spectrophotometer.

Statistical analysis

The results are reported as means ± standard deviation (SD). The significance of differences among treatment means was determined by one-way analysis of variance (ANOVA) using SAS version 8.1 (SAS Institute, Cary, N.C., U.S.A.) with a significance level of 0.05.

Results and Discussion

Proximate analysis

The mean values for the proximate parameters, moisture, ash, crude protein, and crude fat contents of noodles are shown in Table 1. According to Chung and Lim (1999), black rice contained higher contents of protein, lipids, ash, and total dietary fiber than brown rice. Moisture contents of noodles with BRB flour were affected by the level of BRB flour. The BRB noodles showed higher moisture content, and as the levels of BRB flour increased, moisture content increased. Replacing noodle ingredients with BRB flour considerably improved the protein and fat contents ($P < 0.05$). Likewise, increased levels of BRB flour considerably increased the ash contents of noodles ($P < 0.05$).

Cooking characteristics of BRB noodles

For consumers, cooking quality is the most important quality attribute, including cooking time, cooking loss, and swelling during cooking. Cooking characteristics of different noodle samples are presented in Table 1. The optimum cooking time was determined to be 7 min for all treatments. Optimum cooking time of the noodle was achieved when the core of the noodle strand was no longer visible. The swelling index decreased linearly with amylose content, but increased with the heat of gelatinization (Sasaki and Matsuki 1998). Both protein content and monoglycerides inhibited the extent of swelling (Wang and Seib 1996; Roach and Hoseney 1995). However, in the current study, the swelling index was shown to be irregular between 2% and 15% BRB flour in noodles. Among the cooking parameters of noodle, cooking loss is a commonly used predictor of overall noodle cooking performance by both consumers and industry. No significant difference was recorded for cooking loss in noodles. Cooking loss is mainly influenced by dissolving and releasing of gelatinized starches from the noodle surface during cooking (Chang and Wu 2008). The degree of cooking loss depends on the strength of the gel matrix structure and starch gelatinization rate (Chansri and others 2005).

Color measurement

The influence of BRB flour on the color of raw noodle is shown in Table 2. Addition of BRB flour at various levels (2% to 15%) significantly ($P < 0.05$) changed the color characteristics of raw noodles. Raw control noodles were light yellow with high color purity (*C*) compared with BRB noodles. Raw noodles with more BRB were darker. Addition of BRB flour significantly decreased lightness (*L*) in a dose-dependent manner. In addition, noodles incorporated with BRB flour considerably imparted redness as

Table 1–Composition and cooking characteristics of different noodle samples.[a]

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	DM of RN[b] (g/100g)	DM of CN (g/100g)	Swelling index (g of water/g of dry noodle)	Cooking loss (g/100g of raw noodle)	Water absorption (%)
Control	32.60 ± 0.1^{c}	1.21 ± 0.1^{e}	10.94 ± 0.1^{d}	0.36 ± 0.0^{e}	67.40 ± 0.0^{a}	36.31 ± 0.8^{a}	1.75 ± 0.1^{ab}	2.86 ± 0.2^{a}	67.28 ± 4.0^{a}
BRB-2%	32.96 ± 0.2^{bc}	1.33 ± 0.0^{d}	11.06 ± 0.1^{cd}	0.55 ± 0.1^{d}	67.04 ± 0.0^{b}	36.05 ± 0.1^{b}	1.77 ± 0.0^{a}	3.15 ± 0.1^{a}	67.85 ± 1.7^{a}
BRB-5%	33.02 ± 0.0^{bc}	1.50 ± 0.0^{c}	11.25 ± 0.1^{bc}	0.90 ± 0.0^{c}	66.98 ± 0.0^{b}	37.31 ± 0.3^{a}	1.68 ± 0.0^{b}	3.13 ± 0.6^{a}	64.70 ± 0.8^{a}
BRB-10%	33.32 ± 0.1^{ab}	1.81 ± 0.0^{b}	11.47 ± 0.3^{b}	1.59 ± 0.1^{b}	66.68 ± 0.0^{c}	36.98 ± 0.2^{ab}	1.70 ± 0.0^{ab}	3.48 ± 0.1^{a}	63.95 ± 1.6^{a}
BRB-15%	34.32 ± 0.1^{a}	2.18 ± 0.0^{a}	11.88 ± 0.0^{a}	2.46 ± 0.0^{a}	65.68 ± 0.0^{d}	36.78 ± 0.4^{ab}	1.72 ± 0.0^{ab}	3.47 ± 0.2^{a}	63.83 ± 1.4^{a}

[a]Expressed on a dry basis and mean ± standard deviation. Values followed by different superscript letters are significantly ($P < 0.05$) different (Duncan's multiple range test).
[b]DM = dry matter, RN = raw noodle, CN = cooked noodle.

Table 2–Influence of black rice bran flour on the color of different raw noodles.[a]

Sample[b]	*L*	*a*	*b*	*H*	*C*
Control	76.39 ± 0.9^{a}	1.34 ± 0.1^{d}	16.82 ± 0.2^{a}	85.43 ± 0.3^{a}	16.88 ± 0.2^{a}
BRB-2%	47.86 ± 1.2^{b}	4.57 ± 0.1^{c}	3.09 ± 0.2^{b}	34.15 ± 1.5^{b}	5.51 ± 0.2^{c}
BRB-5%	33.14 ± 1.0^{c}	6.49 ± 0.4^{a}	1.67 ± 0.2^{c}	14.51 ± 2.7^{c}	6.70 ± 0.4^{b}
BRB-10%	26.30 ± 1.2^{d}	6.62 ± 0.3^{a}	0.81 ± 0.0^{d}	6.97 ± 0.1^{d}	6.67 ± 0.3^{b}
BRB-15%	22.76 ± 1.3^{e}	5.89 ± 0.4^{b}	0.52 ± 0.0^{e}	5.04 ± 0.6^{d}	5.91 ± 0.4^{c}

[a]*H* (hue angle = arctan *b*/*a*) indicates sample color (0 or 360 = red; 90 = yellow; 180 = green; 270 = blue), and *C* [chroma = $(a^2 + b^2)^{1/2}$] indicates color purity or saturation (higher values are more vivid).
[b]Mean of triplicate determinations expressed. Values followed by the different superscript letters are significantly ($P < 0.05$) different (Duncan's multiple range test).

reflected in hue angle (*H*). Addition of BRB flour at 15% decreased *H* of raw noodle from 85.43 to 5.04, which is very "red." These results were due to anthocyanins in the BRB flour. Addition of BRB flour considerably decreased the chroma (*C*) of raw noodles, but not in a dose-dependent manner. In a previous study, protein and ash content significantly affected noodle color (Yun and others 1997). Color interferes with our flavor perception and may considerably affect the acceptability of foods. Natural pigments in foods can not only enhance the sensory properties of food products but also functionally improve their nutritional quality.

Texture profile analysis

Texture attributes of cooked noodle with BRB flour are presented Table 3. Hardness of noodles containing 2% BRB flour was reduced from the control. However, an increased hardness value was obtained for noodles with 10% BRB. The general trend observed is a progressive increase in noodle hardness with increasing BRB flour concentration. Both cohesiveness and chewiness results showed similar trends. There was a trend of decreasing cohesiveness and chewiness with increasing BRB flour. On the other hand, there were no significant differences in gumminess between 2% and 15% BRB flour in noodles. Textural properties of noodle are mainly affected by the matrix structural network of starches, glutens, proteins, fibers, and other additional ingredients. These may either weaken or strengthen formation of hydrogen bonds within the noodle structure network.

Antioxidant compounds in BRB noodles

Studies have shown that dietary polyphenolic constituents derived from plants possess effective antioxidant activities and significantly contribute to free-radical scavenging capacity *in vitro* and *in vivo* (Rice-Evans and others 1997). Table 4 shows antioxidant contents (polyphenolics, flavonoids, and anthocyanins) in noodles made with wheat flour (100%) and noodles made with BRB flour at different levels. Aqueous extracts of raw and cooked noodles containing BRB flour exhibited higher polyphenolic content (Table 4) compared to the control ($P < 0.05$). Our earlier research found that BRB had considerable polyphenolic contents (Kong and Lee 2010). Addition of BRB flour at various levels (2% to 15%) generally increased the antioxidant compounds of noodles except for cooked noodles incorporated with 15% BRB. In addition, the increase was significant between noodles with 2%, 5%, 10%, and 15% BRB flour. In the case of cooked noodles, control noodles had lower antioxidant contents (5.38, 0.02 mg/25 g noodles, polyphenolics and anthocyanins respectively, flavonoids were not detected) than raw noodle. Cooked BRB noodles also demonstrated lower antioxidant contents than raw noodles. This could be due to leaching of antioxidant compounds (polyphenolics, flavonoids, and anthocyanins) into the cooking medium indicating that its gruel has considerably higher antioxidant contents. Control noodles had negligible anthocyanin content (0.10, 0.02 mg/25g noodles, raw and cooked noodle, respectively. Gruel had no detectable anthocyanin content). With increased level of BRB incorporation, anthocyanin contents increased from 0.15 to 1.77 mg cyanidin-3-glucoside equivalents per 25 g of raw noodles

Antioxidant activities of BRB noodle

ROS are generated by some tumor promoters in the development of cancer (Jakobisiak and others 2003). Recent epidemiological studies have shown a strong association between whole grain consumption and reduced risk of several chronic diseases (Hu 2002). This association may be attributed to the antioxidant compounds from rice bran such as polyphenolic compounds, vitamin E, and γ-oryzanol (Chotimarkorn and others 2008). To contribute to this effort, we investigated the possibility that the BRB antioxidant compounds present in noodles might be effective scavengers of free radicals (Table 4). It was found that the addition of BRB flour to the noodle increased the antioxidant capacity compared with the control noodle. The raw noodles with 15% added BRB flour showed the highest antioxidant activity (ABTS, DPPH radical scavenging activities, chelating effect, and reducing power). Upon cooking, the retention of the chelating

Table 3–Texture attributes of cooked noodle with black rice bran flour.[a]

Sample	Hardness G	Adhesiveness g s	Springiness	Cohesiveness	Gumminess	Chewiness
Control	1975.12 ± 365.6^{ab}	-42.31 ± 23.5^{a}	0.86 ± 0.1^{b}	0.61 ± 0.0^{a}	1188.04 ± 168.3^{a}	1034.07 ± 216.5^{a}
BRB-2%	1806.06 ± 249.5^{b}	-37.47 ± 11.3^{a}	0.92 ± 0.0^{a}	0.58 ± 0.0^{ab}	1037.58 ± 113.7^{b}	953.47 ± 118.8^{ab}
BRB-5%	1920.11 ± 253.4^{ab}	-40.77 ± 14.1^{a}	0.90 ± 0.1^{ab}	0.57 ± 0.0^{b}	1082.06 ± 79.3^{ab}	980.00 ± 110.6^{ab}
BRB-10%	2036.62 ± 402.7^{ab}	-62.90 ± 30.2^{b}	0.89 ± 0.1^{ab}	0.51 ± 0.0^{c}	1035.55 ± 142.1^{b}	922.66 ± 146.5^{ab}
BRB-15%	2226.11 ± 469.8^{a}	-61.18 ± 12.7^{b}	0.81 ± 0.0^{c}	0.47 ± 0.0^{d}	1036.42 ± 139.5^{b}	843.94 ± 134.1^{b}

[a]Mean of triplicate determinations expressed. Values followed by different superscript letters are significantly ($P < 0.05$) different (Duncan's multiple range test).

Table 4–Antioxidant activities and antioxidant compounds of different noodle samples.

	Raw noodle					Cooked noodle					Gruel				
Sample	*C*	2%	5%	10%	15%	*C*	2%	5%	10%	15%	*C*	2%	5%	10%	15%
ABTS[a]	22.12^{e}	25.28^{d}	29.99^{c}	83.65^{b}	94.66^{a}	17.12^{e}	19.14^{d}	23.65^{c}	53.11^{b}	42.39^{a}	5.54^{e}	7.21^{d}	9.10^{c}	29.62^{b}	35.82^{a}
DPPH[b]	–[h]	1.75^{d}	4.70^{c}	11.69^{b}	18.92^{a}	–	–	4.35^{c}	18.01^{b}	11.53^{a}	0.34^{d}	1.33^{d}	3.74^{c}	6.69^{b}	11.80^{a}
Chelating effect[c]	30.44^{d}	49.88^{c}	76.44^{b}	89.34^{a}	91.23^{a}	37.28^{d}	36.06^{cd}	41.78^{c}	74.50^{b}	64.47^{a}	–	62.19^{a}	36.89^{b}	54.63^{a}	44.01^{b}
Reducing power[d]	0.11^{e}	0.21^{d}	0.40^{c}	0.58_{b}	0.66^{a}	0.07^{e}	0.15^{d}	0.27^{c}	0.57^{b}	0.44^{a}	0.08^{d}	0.15^{c}	0.29^{b}	0.43^{a}	0.45^{a}
Polyphenol[e]	15.40^{e}	19.43^{d}	29.74^{c}	36.55^{b}	47.09^{a}	5.38^{d}	7.57^{d}	12.18^{c}	32.19^{a}	20.64^{b}	0.99^{e}	1.94^{d}	4.61^{c}	8.19^{b}	12.71^{a}
Flavonoid[f]	–	0.40^{d}	1.98^{c}	4.78^{b}	7.54^{a}	–	–	1.30^{c}	7.86^{b}	4.57^{a}	–	–	0.60^{c}	1.54^{b}	3.02^{a}
Anthocyanin[g]	0.10^{d}	0.15^{d}	0.43^{c}	1.27^{b}	1.77^{a}	0.02^{e}	0.15^{d}	0.56^{c}	2.50^{b}	1.57^{a}	–	–	0.40^{c}	1.12^{b}	1.74^{a}

[a]Mean of triplicate determinations expressed as AEAC mg ascorbic acid equivalent per 25 g of noodles.
[b]Mean of triplicate determinations expressed as AEAC mg ascorbic acid equivalent per 25 g of noodles.
[c]Mean of triplicate determinations expressed as chelating effect (%).
[d]Mean of triplicate determinations expressed as reducing power 700 nm.
[e]Mean of triplicate determinations expressed as mg gallic acid equivalents per 25 g of noodles.
[f]Mean of triplicate determinations expressed as mg (+)-catechin equivalents per 25 g of noodles.
[g]Mean of triplicate determinations expressed as mg cyanidin-3-glucoside equivalents per 25 g of noodles.
[h]Not detected. Values followed by the different superscript letters are significantly ($P < 0.05$) different (Duncan's multiple range test).

effect of BRB needles was relatively higher compared to control noodles. However, in 2% cooked BRB noodles, a lower chelating effect was observed in the BRB noodles than cooked control noodles. This could be due to leaching of antioxidant compounds into the cooking medium, as indicated by its gruel (2% BRB noodles) having a considerably higher chelating effect (62.19%). No scavenging activity was noticed in gruels of control noodles. As mentioned above, BRB contains polyphenolic compounds such as flavonoids and anthocyanins. The higher antioxidant capacity of noodles with added BRB flour was due to the polyphenolics present in the BRB flour. Nam and others (2005) mentioned that BRB has remarkable antioxidant activity, since it is rich in polyphenolic compounds, especially anthocyanins, which play an important role in the scavenging of free radicals.

Conclusions

In conclusion, BRB contains many beneficial components, including polyphenolics, flavonoids, phytic acid, and anthocyanins. In this study, BRB was selected because of its nutritional content and high distribution of antioxidant compounds. Noodles with different levels of substitution were functionally evaluated and results showed that noodles containing BRB improved the antioxidant activities when compared to the control noodles. BRB can be an excellent ingredient to increase the nutritional value and antioxidant properties of noodles.

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