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Quality Characteristics and Antioxidant Potential of Rice-Germ Rice Processed with Different Heat Treatments

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Abstract: Rice germ is a part of the rice kernel, and has been a matter of wide interest for food scientists and nutritionists because of its nutraceutical properties. The objective of this study was to investigate the physical and sensory characteristics and antioxidant properties of rice containing rice germs that were exposed to different heat treatments for 20 or 30 min. The thermal treatments significantly influenced the moisture content, color, antioxidant potential, and sensory characteristics of the rice. The antioxidant potential measured through DPPH free radical scavenging potential and total polyphenol content of the autoclaved rice sample was significantly lower than the other samples. Also, acceptability of the autoclaved sample was decreased as compared to the other samples. This study showed that greater antioxidative potential with higher acceptability of rice-germ rice could be obtained by mixing rice and water (10°C) at a 60:90 ratio followed by heat treatment (100°C) for 30 min.

Keywords: Antioxidant Potential, Heat Treatments, Quality Characteristics, Rice Germ

Introduction

Rice germ, a part of the rice kernel, has drawn a wide interest of food scientists and nutritionists because of its nutraceutical properties (Bhatnagar et al. 2014; Rohrer and Siebenmorgen, 2004). It is one of the by-products of rice milling process and is obtained with rice bran. Rice germ can also be obtained by vibrating and straining the rice bran. A study on 13 rice varieties shows that vitamin E contents in rice germ is five times higher than that in rice bran but the amount of γ-oryzanol in rice germ is five times lower (Yu et al., 2007). The oil content of rice germ is nearly two times higher than that of rice bran (Juliano, 1985). The oil extracted from rice germ has been considered, in Korea, as a condiment oil like that of sesame and perilla (Kim et al. 2002). Rice germs are rich in protein, fat, dietary fiber and other essential nutrients, including phenolic compounds, vitamins, minerals and γ-amino-butyric acid (GABA) for humans (Kim et al., 2002; Mori et al., 1999; Zhang et al., 2006).

Several phytochemicals that are obtained from rice germs have been extensively utilized in medications, health and functional foods, cosmetics and food additives that include GABA (Mabunga et al., 2015; Shizuka et al. 2004; Yoto et al., 2012) and γ-oryzanol (Wilson et al., 2007). Further, the nutritional values of some of the bioactive constituents found in rice germ are enhanced following fermentation (McGovern et al., 2004), for instance, α-ethylglucoside contained in fermented rice germ, is reported to prevent ultraviolet B-mediated disorder of epidermal permeability barrier (Hirotsune et al., 2005). The defatted rice germ enriched with GABA exhibit positive effects against the most common mental symptoms during the menopausal and presenile period such as sleeplessness, somnipathy, and depression (Okada et al., 2000). Application of defatted rice germ or rice germ during the initiation or post-initiation phase significantly reduced the occurrences of azoxymethane-induced large bowel carcinogenesis (Mori et al., 1999) and colon cancer (Kawabata et al., 1999) in rats.

The GABA-rich foods are regarded as brain foods and regulate different bioactive functions involved in preventing and controlling various health disorders. The GABA-containing foods show neuroprotective (Cho et al., 2007), neurological disorder prevention (Kim et al., 2019; Yamatsu et al., 2016), anti-hypertensive (Jang et al., 2015; Tung et al., 2011), anti-diabetic (Liu et al., 2017; Untereiner et al.,

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2019), anti-cancer (Huang et al., 2011; Schuller et al., 2008), antioxidant (Tang et al., 2018; Zhu et al., 2019), anti-inflammatory (Han et al., 2007; Prud'homme et al., 2013), anti-microbial (Kim et al., 2018; Mau et al., 2012), anti-allergic (Hori et al., 2008; Kawasaki et al., 2014), hepatoprotective (Lee et al., 2010; Oh et al., 2003), renoprotective (Ali et al., 2015; Sasaki et al., 2007), and intestinal protective (Chen et al., 2014; Chen et al., 2015) effects.

Considering the antioxidants and nutrients, including GABA contents of rice germ and lack of reports on the effect of heat treatment on the rice containing rice germ, this study aimed to investigate the physicochemical characteristics and antioxidant potential of the rice.

Materials and Methods

Chemicals and materials

Folin–Ciocalteu phenol reagent and 1,1-diphenyl-2-picrylhydrazyl (DPPH) were purchased from Sigma Aldrich (St. Louis, MO, USA). All the chemicals and reagents were of analytical grade. Rice (*Oryzae sativa* L.) cv. Samkwang was purchased from a local market.

Preparation of rice-germ rice

The rice-germ rice was obtained from the rice grain using a milling machine (Mikang Nara, K-25, Korea). The machine was adjusted to rice germ mode to obtain the rice sample. Since the milled rice contained rice germs, they are denoted as rice-germ rice in the present study. The rice-germ rice was processed adopting different methods and the samples were named as follows: RG-A: rice-germ rice heated in an autoclave at 120°C and 1.5 atm for 30 min with rice-germ rice: water (70°C) ratio of 60: 60 (w/v), RG-B: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-C: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v), RG-D: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-E: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v). After preparation, the rice samples were kept in air-tight containers and stored at –20°C until subsequent analyses.

Moisture content

The moisture content of rice-germ rice samples was calculated by following the procedure of AOAC (1990). The samples (5.0 g) were oven-dried (60°C) to constant weight and their moisture contents were determined as follows:

$$\text{Moisture content (\%)} = [(Wb - Wa)/Wb] \times 100$$

where Wb= weight (g) of the sample before drying and Wa= weight (g) of the sample after drying.

Color measurement

L^* (lightness), a^* (redness, + or greenness, –), and b^* (yellowness, + or blueness, –) values of the rice samples were determined using a Chroma Meter (CR-300, Minolta Corp., Tokyo, Japan) and a calibration plate (Minolta Corp.; YCIE = 94.5, XCIE = 0.316, YCIE = 0.330). A standard plate (Hunter Associates Laboratory Inc., Reston, VA, USA; L^* = 97.51, a^* = -0.18, b^* = -1.67) was used for standardization of the instrument with D65 illuminant. Color values were measured on three places of the samples placed onto Petri dishes and the mean value was reported (Kim et al, 2014).

DPPH radical scavenging activity

The antioxidant potential of the rice-germ samples was determined through the DPPH free radical scavenging activity (Dhungana et al., 2015; Shimada et al., 1992). The samples (1 g) were extracted with absolute methanol (10 mL) at 25 °C for 24 h at 150 rpm. Equal amounts of 0.01% methanol solution of DPPH and sample extracts were mixed and incubated in dark for 30 min and the absorbance values of samples were measured at 517 nm using a spectrophotometer (Multiskan GO; Thermo Fisher Scientific Oy, Vantaa, Finland).

Total polyphenol content

The total polyphenol content of the samples was determined by following the Folin-Ciocalteu method (Singleton et al., 1999) as described by Dhungana et al. (2016). The methanolic sample extract (50 µL) was mixed with 1 mL of 2% (w/v) sodium carbonate solution and left for 3 min. A 50-µL of 1 N Folin–Ciocalteu reagent was added to the reaction mixture and allowed to react for 30 min at room temperature in the dark. A calibration curve was plotted using gallic acid (GA) of six concentrations 0, 100, 250, 500, 750, and 1000 ppm prepared in deionized water. Absorbance values were measured at 750 nm using a spectrophotometer (Multiskan GO, Thermo Fisher Scientific). The total polyphenol content was calculated as GA equivalents (µg GAE/mg fresh weight of sample).

Sensory characteristics evaluation

Fresh samples were utilized for the determination of sensory characteristics. The samples were graded for flavor, color, glossiness, taste, adhesiveness, and acceptability on the following scale: 1= very bad, 2= bad, 3= fair, 4= good, 5= very good. The sensory characteristics were evaluated by 20 volunteer panelists (10 women and 10 men) identified from the graduate students of the College of Agriculture and

Life Sciences of Kyungpook National University, Daegu, Korea.

Data analysis

Analysis of variance (ANOVA) was conducted using SAS9.4 (SAS Institute, Cary NC, USA). The significant differences among sample means were determined at $p<0.05$ using Tukey test.

Results and Discussion

Moisture content

The moisture content of rice-germ rice samples varied significantly (Table 1). RG-E and RG-C contained the highest and lowest amounts of moisture, respectively.

The variations in moisture content among the samples might be due to the difference in preparation methods (Syafutri et al., 2016).

Table 1. Moisture content of rice-germ rice prepared by different heat treatments

	Sample[1)]				
	RG-A	RG-B	RG-C	RG-D	RG-E
Moisture content (%)	22.1±0.1[b2)]	22.0±0.2[b]	20.5±0.1[c]	21.7±0.2[b]	22.9±0.1[a]

[1)]RG-A: rice-germ rice heated in an autoclave at 120°C and 1.5 atm for 30 min with rice-germ rice: water (70°C) ratio of 60: 60 (w/v), RG-B: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-C: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v), RG-D: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-E: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v).
[2)]Values are presented as the mean±standard deviation of three replicates. Values followed by different superscripts in the same row indicate a significant difference ($p<0.05$).

Color measurement

The color of rice samples was significantly influenced by the treatment methods (Table 2). The highest lightness, redness, and yellowness values were found in RG-E (74.38), RG-B (1.39), and RG-B (11.56), respectively.

Color is one of the key factors in relation to consumers' preference for a product. It plays a great role in making consumers purchase the product. The variations in color parameters of different rice samples were possibly due to the processing time and/or temperature (Syafutri et al., 2016). Heat treatment may cause non-enzymatic browning effects like the Maillard reaction and chemical oxidation of phenolic compounds. The browning effects may lead to form some antioxidants (Osada and Shibamoto, 2006).

Table 2. Hunter's color values of rice-germ rice prepared by indirect heat treatments

Sample[1)]	Color Value[2)]		
	L* (lightness)	a* (redness)	b* (yellowness)
RG-A	64.50±1.00[c3)]	-0.23±0.23[b]	8.95±0.74[b]
RG-B	64.85±1.13[c]	1.39±0.31[a]	11.56±1.52[a]
RG-C	68.62±0.99[b]	-0.32±0.01[c]	6.90±0.93[c]
RG-D	65.83±0.82[c]	-0.67±0.23[d]	6.72±1.54[c]
RG-E	74.38±0.55[a]	-0.24±0.10[b]	6.38±0.92[c]

[1)]RG-A: rice-germ rice heated in an autoclave at 120°C and 1.5 atm for 30 min with rice-germ rice: water (70°C) ratio of 60: 60 (w/v), RG-B: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-C: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v), RG-D: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-E: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v).
[2)]L*, Lightness (100, white; 0, black); a*, redness (–, green; +, red); b*, yellowness (–,blue; +, yellow).
[3)]Values are presented as the mean±standard deviation of three replicates. Values followed by different superscripts in the same column indicate a significant difference ($p<0.05$).

Antioxidant potential

The DPPH free radical scavenging potential and total polyphenol content of rice samples significantly varied with the processing method (Table 3). The DPPH scavenging potential and total polyphenol content of the autoclaved sample, RG-A (6.28% and 7.561.51 µg GAE/mg) were about more than thirteen and eight times lower than RG-E (84.21% and 62.18 µg GAE/g sample), respectively.

The reduced total polyphenol content in the autoclaved sample might be due to the high heat treatment (Xu et al., 2007). Moreover, the higher temperature in the presence of oxygen and moisture may accelerate the breakdown of phenolic compounds (Min et al., 2014). Similar results of reduced phenolic composition with increased heat treatment in cooked rice were found in a previous report (Chmiel et al., 2018). The reduced DPPH scavenging potential of autoclaved rice sample as compared to the rest of the samples could be due to the higher heat treatment which resulted in reduced total polyphenol content (Jastrzebski et al., 2007). Since antioxidant-rich foods are good for the prevention and control of various diseases, RG-E could offer a good option to prepare healthy rice-germ rice.

Table 3. DPPH scavenging potential and total phenol content of rice-germ rice prepared by different heat treatments

Sample[1)]	DPPH (% Inhibition)	Total phenol content (μg GAE/mg)
RG-A	6.28±0.19[e3)]	7.56±0.13[e]
RG-B	29.80±0.12[d]	17.88±0.10[d]
RG-C	82.00±0.29[b]	57.35±0.04[b]
RG-D	38.94±0.07[c]	27.93±0.13[c]
RG-E	84.21±0.07[a]	62.18±0.06[a]

[1)]RG-A: rice-germ rice heated in an autoclave at 120°C and 1.5 atm for 30 min with rice-germ rice: water (70°C) ratio of 60: 60 (w/v), RG-B: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-C: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v), RG-D: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-E: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v).
[2)]GAE: gallic acid equivalent.
[3)]Values are presented as the mean±standard deviation of three replicates. Values followed by different superscripts in the same column indicate a significant difference (p<0.05).

Sensory characteristics

The sensory parameters of rice-germ rice were significantly different among the samples (Table 4). Acceptability of the rice-germ rice prepared by autoclaving was significantly low as compared to other samples. The acceptability of RG-C, RG-D, and RG-E was not significantly different. However, parameters like flavor, taste, and adhesiveness varied among these three samples.

The disparity in sensory characteristics of rice samples might have caused due to the difference in cooking method of rice (Crowhurst and Creed, 2001; Jinakot and Jirapakkul, 2019). Sensory characteristics of food may be a key factor for consumers while selecting any product (Jabalpurwala et al., 2009). Consumers are not only concerned with the intrinsic quality like the nutritional value of food but also consider many extrinsic factors like sensory characteristics (Creed, 1998).

Table 4. Sensory characteristics of rice-germ rice prepared by different heat treatments

Sample[1)]	Sensory characteristics[2)]					
	Flavor	Color	Glossiness	Taste	Adhesiveness	Acceptability
RG-A	4.25±0.35[a3)]	3.30±0.13[c]	1.75±0.35[b]	1.90±0.27[c]	1.75±0.35[c]	2.25±0.35[c]
RG-B	3.00±0.41[d]	3.50±0.71[b]	3.25±0.35[a]	1.90±0.57[c]	3.25±0.35[b]	2.90±0.14[b]
RG-C	3.25±0.06[c]	4.25±0.35[a]	3.75±0.35[a]	2.75±0.35[b]	3.00±0.71[b]	3.25±0.35[ab]
RG-D	3.50±0.71[b]	4.25±0.35[a]	3.25±0.35[a]	3.35±0.21[a]	3.50±0.71[a]	3.50±0.35[a]
RG-E	2.55±0.19[e]	4.25±0.35[a]	3.25±0.35[a]	2.60±0.85[b]	3.00±1.41[b]	3.35±0.49[ab]

[1)]RG-A: rice-germ rice heated in an autoclave at 120°C and 1.5 atm for 30 min with rice-germ rice: water (70°C) ratio of 60: 60 (w/v), RG-B: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-C: rice-germ rice heated at 100°C for 20 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v), RG-D: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (70°C) ratio of 60: 90 (w/v), RG-E: rice-germ rice heated at 100°C for 30 min with rice-germ rice: water (10°C) ratio of 60: 90 (w/v).
[2)]Values are means±standard deviations (n=20) based on 5-point score (very bad, 1; bad, 2; fair, 3; good, 4; very good, 5).

[3)]Values followed by different superscripts in the same column indicate a significant difference ($p<0.05$).

In conclusion, rice-germ rice was prepared with different heat treatments for 20 or 30 min. The physical and sensory characteristics and antioxidant potential of the processed rice samples were investigated. The processing methods significantly affected the quality characteristics and antioxidant potentials of the rice samples. The DPPH free radical scavenging potential, total polyphenol content, and acceptability of the autoclaved sample were significantly reduced as compared to other methods. The results suggested that higher antioxidant potentials with better acceptability of rice-germ rice could be prepared by mixing rice and water (10°C) at a 60:90 ratio followed by heat treatment (100°C) for 30 min.

Conflict of Interest

The authors declare no conflict of interest.

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