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Original Research Article

Effect of Turmeric Extracts on Nutritional and Antioxidant Properties of Germinated Korean Brown Rice

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Abstract - Brown rice is more nutritious than the commonly consumed white rice, however, the former is not widely accepted because of its coarse texture and difficulty in cooking. Germination is an easy technique to minimize the drawback of normal brown rice. The objective of this study was to investigate the effect of three different concentrations (1, 3, and 5% w/v) of turmeric extracts on the nutrient and antioxidant activities of germinated brown rice (GBR). The *b* (yellowness) values of the turmeric-treated GBR were significantly higher than that of the untreated control. Lower concentration (1%) slightly increased (3395.5 ㎎/㎏) but higher concentrations (3 and 5%) reduced (1735.8 - 2393.7 ㎎/㎏) the total mineral content in GBR, as compared to the control (3377.4 ㎎/㎏). The amount of essential, non-essential, and total amino acids, including GABA, were increased with the concentration of turmeric extracts. The amount of essential amino acids was increased by 58.3, 71.5, and 88.3% with the application of 1, 3, and 5% extracts, respectively. The antioxidant potential of GBR was also enhanced with turmeric treatment. Overall results indicated that 1 or 3% turmeric treatment could be appropriate to enhance the nutritional and functional value of GBR.

Key words – Amino acid, Brown rice, Germination, Mineral, Phytochemical

Introduction

Rice is the staple food for about half of the world's population (FAO, 2007). Simply, rice refers to white rice, also known as polished rice, which is produced by further milling brown rice and removing the bran and most of the germ layers from it. A significant proportion of nutrients of white rice are removed during the milling because most of them remain in the outer bran layer of rice (Saleh *et al*., 2019; Zhou *et al*., 2002). Compared with white rice, brown rice is richer in nutrient components, such as fibers, vitamins, iron, calcium, and γ-aminobutyric acid (GABA) (Patil and Khan, 2011). Although brown rice is healthier than white rice (Dinesh Babu *et al*., 2009), brown rice is not widely accepted as an appropriate staple food because of its coarse texture and difficulty in cooking (Komatsuzaki *et al*., 2007). Therefore, a technique that helps overcome these limitations could be of great significance.

The development of germinated brown rice (GBR) technique appeared to overcome some of the limitations of brown rice. GBR is prepared after soaking the brown rice in water and thereby keeping it moist for an extended period of time. The soaking and germination of brown rice not only soften the texture and make it easily cookable but also enhance the nutritional value. Germination modifies the contents of existing nutrients as well as releases new nutrient components (Kayahara *et al*., 2001), making GBR more nutritious. GBR is considered healthier than white rice and unterminated brown rice, especially in the prevention of diet-related diseases, such as obesity,

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type 2 diabetes, and colorectal cancers (Imam *et al*., 2014). Consumption of GBR is better for controlling postprandial blood glucose levels without increasing insulin secretion in subjects with hyperglycemia (Ito *et al*., 2005) than white rice. Similarly, intake of GBR is regarded as a protectant of cell proliferation and apoptosis as well as of heart failure owing to myocardial ischemia (Petchdee *et al*., 2020).

Lately, elicitation approaches have been emphasized with the aim of enhancing the phytochemical and biological activity of germinated seeds (Liu *et al*., 2019). The treatment of brown rice with sugars, calcium chloride, and glutamic acid increased the concentration of GABA, polyphenols, and flavonoids (Jeong *et al*., 2018; Oh, 2003; Sim *et al*., 2020). In a separate study, calcium chloride in GBR enhanced the accumulation of bioactive compounds and antioxidant capacities (Choe *et al*., 2021). *Lactobacillus acidophilus*-fermented GBR activated apoptotic pathway, which may inhibit preneoplastic lesions of the colon (Li *et al*., 2019). Cold plasma treatment increased the concentration of gamma oryzanols in the GBR (Yodpitak *et al*., 2019) which is considered to increase muscle strength (Eslami *et al*., 2014). The treatment of brown rice with cellulase solution greatly increased GABA content in GBR (Zhang *et al*., 2019). Similarly, red onion solution enhanced the antioxidant capacity and GABA content as well as made the rice slightly softer and stickier than that germinated in water (Nakamura *et al*., 2020).

Turmeric (*Curcuma longa* L.) contains a number of nutrients and bioactive constituents, including curcumin that has antioxidant, anti-inflammatory, antibacterial, antidepressant, antidiabetic, antitumor properties (Farhood *et al*., 2019; Naeini *et al*., 2019; Soleimani *et al*., 2018). Different extracts obtained from plant sources have been used as elicitors to treat the germinating grains. Considering the health benefits of GBR and turmeric, this study aimed to investigate the effect of turmeric extracts on the nutritional and antioxidant properties of GBR.

Materials and Methods

Materials

Brown rice of a Korean rice cultivar Ilpum Byeo was used in this study. Turmeric powder (Jindo Turmeric Agricultural Cooperative Corporation, Jeollanam-do, Korea) was purchased from a local market in Daegu, Korea. Three concentrations 1, 3, and 5% (w/v) of turmeric solutions were prepared by mixing the turmeric powder with tap water.

Cultivation of germinated brown rice and preparation of sample powder

Brown rice (1 ㎏) was washed with tap water and soaked in the three different concentrations (1, 3, and 5%, w/v) of turmeric solutions or tap water alone (0%) for 1 h. Each treatment consisted of three replicates. After 1 h of soaking, the moistened brown rice samples were put into netted plastic bags and incubated at 35℃ for 36 h to allow germination. During the 36-h of incubation, the germinating brown rice was moistened every 1 h by brief dipping into the respective solutions (0, 1, 3, and 5%) used for soaking. The germinated brown rice (GBR) samples were named based on the concentration of turmeric used for soaking the brown rice i.e., TE-0: GBR cultivated with 0% turmeric powder, TE-1: GBR cultivated with 1% turmeric powder, TE-3:GBR cultivated with 3% turmeric powder, and TE-5: GBR cultivated with 5% turmeric powder, respectively.

The 36-h old GBR samples were harvested and kept in a deep freezer (-70℃) for 24 h before lyophilization. The lyophilized GBR samples were ground into powder using a commercial grinder (HIL-G-501, Hanil Co., Seoul, Korea).

Color measurement

The Hunter's color values of the powdered GBR samples were measured following a method described earlier (Kim *et al*., 2014). The *L* (lightness), *a* (redness), and *b* (yellowness) values were determined using a Chroma Meter (CR-300, Minolta Corp, Tokyo, Japan). A calibration plate (Minolta Corp.; YCIE = 94.5, XCIE = 0.3160, YCIE = 0.330) and a standard plate (Hunter Associates Laboratory Inc., Reston, VA, USA; $L = 97.51$, $a = -0.18$, $b = 1.67$) were used to standardize the instrument with D65 illuminant.

Free amino acid analysis

The free amino acid profile was determined following the methods described earlier (Je *et al*., 2005; Kim *et al*., 2016). In brief, 1.5 g sample powder was homogenized (12,000 rpm,

2 min) with 10 mL of ice-cold 6% (v/v) perchloric acid in an ice bath using an ACE homogenizer (Nissei AM-7, Nihonseikei Kaisha Ltd, Tokyo, Japan), followed by an ice-incubation for 30 min and centrifugation (4,600 × *g*, 15 min). The supernatant was filtered through a filter paper (Whatman No. 41). The filtrate pH was adjusted to 7 using a 33% (w/v) KOH solution, and centrifuged (4,600 × *g*, 10 min). The precipitate of potassium perchlorate was separated and the pH of the mixture was adjusted to 2.2 using 10 M HCl and then distilled water was added to make the final volume 50 mL. The mixture and lithium citrate buffer (pH 2.2) were mixed at a 2:1 ratio to determine the amino acid profile using an automatic amino acid analyzer (Biochrom-20, Pharmacia Biotech Co., Uppsala, Sweden).

Determination of mineral content

A previously described method (Skujins, 1998) was followed to measure the amount of mineral elements using an inductively coupled plasma atomic emission spectrometer (ICP AES, Varian Vista, Victoria, Australia). Sample powder (500 ㎎) was digested in a mixture of 65% HNO_3 (15 mL) and 35% H_2O_2 (2 mL). The mixture was diluted with an equal volume of distilled water. The amount of mineral elements was determined using ICP AES after calibrating the instrument with known standards.

Preparation of sample extracts for antioxidant assays

The extracts for antioxidant assays were prepared as in a previous report (Park *et al*., 2020). One gram of sample powder was extracted with 10 mL of absolute methanol using a shaking incubator (250 rpm, 25℃) for 6 h. The mixture was centrifuged (1660 × *g*, 10 min), followed by filtration of the supernatant using a syringe filter (0.2 ㎛). The filtrate was used for antioxidant analyses.

Determination of 1,1-diphenly-2-picrylhydrazyl (DPPH) radical scavenging activity

The DPPH free radical scavenging potential was determined following the methods described earlier (Blois, 1958; Dhungana *et al*., 2015). In short, 100 mL of the extracts and 100 mL of freshly prepared 0.05% (w/v) methanolic solution of DPPH were mixed in a 96-well microplate, followed by 30 min of incubation at room temperature at dark conditions. Immediately, the absorbance of the reaction mixtures was examined at 517 nm using a spectrophotometer (Multiskan GO, Thermo Fisher Scientific Oy, Vantaa, Finland).

Determination of peroxidase (POD) activities

The POD activities were measured using the guaiacol method as described earlier (Zhang and Kirkham, 1994) with some modifications. One hundred milliliters of supernatant was added to the reaction mixture containing 1.0 mL of 2% H_2O_2, 2.9 mL of 50 mM phosphate buffer (pH 5.5), and 1.0 mL of 50 mM guaiacol. For the control, phosphate buffer was used instead of the enzyme. The absorbance values were measured at 470 nm for 3 min, and the POD activity was determined as a unit change per minute.

Determination of total polyphenol content

The total polyphenol content (TPC) was measured according to the Folin-Ciocalteau method (Singleton *et al*., 1999) as described by Dhungana *et al*. (2016). The sample extract (50 mL) and 2% (w/v) aqueous Na_2CO_3 (1000 mL) were mixed in microtubes and allowed to react at room temperature for 3 min. Then, 50 mL of 1 N Folin-Ciocalteau reagent was added to the mixture and incubated for 30 min at room temperature under dark conditions. After the incubation of 30 min, the absorbance was measured at 750 nm using a microplate spectrophotometer (Multiskan GO; Thermo Fisher Scientific). The TPC of the samples was determined using the calibration curve plotted using gallic acid (GA) as standard.

Total flavonoid content analysis

The total flavonoid content (TFC) was determined following the methods described earlier (Dhungana *et al*., 2016; Zhishen *et al*., 1999). The sample extract (100 mL), absolute methanol (500 ㎕), 10% $AlCl_3$ (50 ㎕), 1 M HCl (50 ㎕), and distilled water (300 ㎕) were mixed in microtubes and incubated for 30 min at room temperature under dark condition. Then, the absorbance values of the reaction mixtures were measured at 510 nm using a microplate spectrophotometer (Multiskan GO; Thermo Fischer Scientific). The TFC was calculated using the calibration curve drawn using quercetin as a standard.

Determination of superoxide dismutase (SOD)-like activity

The methods described by Adhikari *et al*. (2019) and Dubey *et al*. (2015) were adopted to determine the SOD-like activities on the basis of 50% reduction of nitro blue tetrazolium. Sample powder (0.5 g) was homogenized in a phosphate extraction buffer (5 mL). The homogenized mixture was centrifuged (15,000 × *g*) for 20 min. One hundred microliters of supernatant were added to the reaction mixture consisting of nitro blue tetrazolium (2.25 mM), 100 mM phosphate buffer (pH 7.8), methionine (200 mM), sodium carbonate (1.5 M), and EDTA (3 mM). The reaction was initiated by adding 0.4 mL (2 μM) of riboflavin and placing it under fluorescent light (15 W) for 15 min. A reaction mixture without the sample extract was considered as a control. The reaction was stopped by turning the light off and keeping the reaction mixtures in dark. The absorbance of reaction mixtures was measured at 560 nm using a microplate spectrophotometer (Multiskan GO, Thermo Fischer Scientific).

Statistical analysis

Data were analyzed using analysis of variance in SAS 9.4 (SAS Institute, Cary, NC, USA). The significant differences between treatment means were determined using the Tukey test ($p < 0.05$). The average values of three replicates were reported unless otherwise mentioned.

Results

Hunter's color value

The treatment of turmeric extracts did not significantly affect the color value of GBR except for the yellowness value (Table 1). In the case of the yellowness value, the turmeric-treated GBR samples had significantly higher values. However, the difference in concentration of turmeric did not show any significant variation among TE-1, TE-3, and TE-5.

Table 1. Hunter color value of germinated brown rice produced with turmeric extracts

Sample[z]	Color value[y]		
	L (Lightness)	*a* (Redness)	*b* (Yellowness)
TE-0	83.8±1.31a[x]	0.7±0.20a	8.4±0.65b
TE-1	82.3±1.63a	0.7±0.24a	10.2±1.01a
TE-3	82.5±1.90a	0.5±0.21a	10.6±1.20a
TE-5	82.8±1.95a	0.4±0.20a	10.8±1.15a

[z]TE-0: germinated brown rice (GBR) produced with 0% turmeric solution; TE-1: GBR produced with 1% (w/v) turmeric extracts; TE-3: GBR produced with 3% (w/v) turmeric extracts; TE-5: GBR produced with 5% (w/v) turmeric extracts.

[y]*L*: lightness (100, white; 0, black); *a*: redness (-, green; +, red); *b*: yellowness (-, blue; +, yellow).

[x]Values are means±SD of triplicate measurements. The values followed by different letters in the same column are significantly different by Tukey test ($p < 0.05$).

Table 2. Mineral content (㎎/㎏) of germinated brown rice produced with turmeric extracts

Element	Sample[z]			
	TE-0	TE-1	TE-3	TE-5
Ca	611.9±8.42a[y]	617.3±13.14a	421.7±9.29b	249.8±4.09c
Cu	3.8±0.02d	11.3±0.04a	10.0±0.02c	10.7±0.06b
Fe	11.3±0.11a	9.7±0.09b	9.0±0.06c	8.1±0.05d
K	1455.1±42.29a	1462.9±17.38a	1002.7±9.12b	760.4±1.69c
Mg	905.2±22.59a	900.2±12.41a	660.1±7.21b	515.7±5.79c
Mn	28.3±0.25a	25.2±0.16b	18.0±0.30c	14.1±0.01d
Na	335.6±8.82a	341.9±3.85a	252.1±2.96b	161.3±1.32c
Zn	26.3±0.15b	27.1±0.04a	20.2±0.02c	15.7±0.06d
Total	3377.4	3395.5	2393.7	1735.8

[z]TE-0: germinated brown rice (GBR) produced with 0% turmeric solution; TE-1: GBR produced with 1% (w/v) turmeric extracts; TE-3: GBR produced with 3% (w/v) turmeric extracts; TE-5: GBR produced with 5% (w/v) turmeric extracts.

[y]Values are means±SD of triplicate measurements. The values followed by different letters in the same row are significantly different by Tukey test ($p < 0.05$).

Table 3. Free amino acid composition (μg/g) of germinated brown rice produced with turmeric extracts

Amino acid	Sample[z]			
	TE-0	TE-1	TE-3	TE-5
Essential amino acid				
L-Threonine	38.3±2.11b[y]	62.1±4.00a	63.7±3.17a	65.7±3.01a
L-Valine	119.3±6.27d	172.3±8.12c	201.3±7.66b	220.2±2.39a
L-Methionine	15.3±1.62c	25.3±1.79b	27.9±3.21ab	31.7±3.66a
L-Isoleucine	47.7±2.78c	84.8±5.12b	90.1±3.91b	98.9±3.05a
L-Leucine	70.0±8.92c	118.3±7.66b	125.3±6.98ab	138.7±7.01a
L-Phenylalanine	54.8±5.00c	86.3±5.61b	90.9±3.17b	105.1±5.00a
L-Lysine	64.7±3.25b	100.6±9.98a	108.2±7.72a	116.5±8.12a
L-Histidine	52.5±5.31c	82.2±2.05b	85.8±2.57b	94.1±3.00a
Sub-Total	462.4	731.8	793.2	870.8
Non-essential amino acid				
L-Aspartic acid	41.2±3.13c	53.7±4.52b	61.3±5.66b	72.3±6.21a
L-Serine	58.3±9.21b	110.2±8.17a	108.2±9.22a	105.3±8.99a
L-Glutamic acid	327.7±18.99b	420.3±20.12a	440.0±33.22a	459.3±30.12a
Glycine	21.2±2.61b	35.0±2.30a	34.0±2.78a	34.9±3.12a
L-Alanine	153.3±11.02a	193.8±9.27a	200.4±5.17b	222.7±3.99a
L-Tyrosine	52.4±6.27c	83.6±8.12b	92.3±9.00ab	101.8±4.24a
L-Arginine	137.0±10.53d	203.2±12.12c	235.1±9.21b	282.7±11.22a
Proline	63.2±8.17c	85.3±5.92b	91.2±7.12b	107.3±8.99a
Sub-Total	854.3	1185.0	1262.49	1386.1
Other free amino acid				
1-Methyl-L-histidine	12.1±1.25b	17.0±2.21a	17.1±1.98a	17.9±1.91a
Cystathionine	ND	1.2±0.12b	5.7±1.37a	7.7±1.02a
D,L-b-Aminoisobutyric acid	5.3±1.20c	11.2±1.81b	23.3±2.01a	19.0±3.05a
Ethanolamine	12.7±1.98d	30.2±2.12a	25.4±2.88b	19.1±1.90c
Hydroxy proline	2.1±0.15	ND	ND	ND
Hydroxy lysine	19.1±2.22a	20.2±1.91a	20.1±2.18a	21.1±2.01a
L-Anserine	ND	ND	ND	ND
L-Carnosine	ND	ND	ND	ND
L-Citrulline	ND	ND	ND	ND
L-Cystine	ND	ND	ND	ND
L-Ornithine	9.2±1.40a	11.3±1.01a	11.7±1.35a	12.1±2.66a
L-Sarcosine	ND	ND	ND	ND
L-a-Amino adipic acid	4.1±0.81b	5.3±0.27ab	5.2±0.71ab	6.3±1.21a
L-a-Amino-n-butylric acid	3.1±0.27	ND	ND	ND
O-Phospho ethanol amine	10.2±1.21d	25.4±1.13c	30.1±1.02b	32.2±0.21a
O-Phospho-L-serine	ND	ND	ND	ND
Taurine	ND	ND	ND	ND
Urea	ND	ND	ND	ND
β-Alanine	10.3±1.15c	26.3±2.27a	29.3±2.01ab	31.2±3.05a
γ -Amino-n-butyric acid	500.6±20.12d	575.3±19.81c	698.1±18.88b	872.0±16.27a
Sub-Total	588.8	723.5	865.9	1038.6
Total	1905.5	2640.3	2921.6	3295.6

[z]TE-0: germinated brown rice (GBR) produced with 0% turmeric solution; TE-1: GBR produced with 1% (w/v) turmeric extracts; TE-3: GBR produced with 3% (w/v) turmeric extracts; TE-5: GBR produced with 5% (w/v) turmeric extracts.

[y]Values are means±SD of triplicate measurements. The values followed by different letters in the same row are significantly different by Tukey test ($p < 0.05$).

Mineral content

Turmeric treatment significantly influenced the mineral content of GBR (Table 2) although the effect was not consistent for an individual mineral element with the concentration of the extract. The amount of Fe and Mn were reduced in the turmeric-treated samples in a concentration-dependent manner. Four mineral elements Ca, K, Mg, and Na were significantly lower in TE-3 followed by TE-5 as compared to the control and TE-1. The Cu and Zn contents were significantly highest in TE-1. Treatment of lower concentration (1%) slightly increased (33.95.5 ㎎/㎏) but higher (3 and 5%) concentrations of turmeric extract reduced (1735.8 - 2393.7 ㎎/㎏) the total mineral content in germinated brown rice.

Amino acid content

Unlike mineral content, a positive influence of turmeric extract was observed on the availability of amino acids in GBR. The amount of many amino acids was significantly increased with the concentration of turmeric extracts (Table 3). All three components (essential, non-essential, and other free amino acids) were increased in a concentration-dependent manner. A total of 25 amino acids were detected, whereas 8 amino acids were not detectable in four treatments. The amount of essential amino acids was increased by 58.3, 71.5, and 88.3% with the application of 1, 3, and 5% concentrations of turmeric, respectively. The increment for non-essential amino acids was lower i.e., 38.7, 47.8, and 62.3% in TE-1, TE-3, and TE-5, respectively.

Antioxidant potential

As found in the free amino acid profile, the overall antioxidant potential of GBR was significantly improved although DPPH free radical scavenging potential was decreased by turmeric treatment (Table 4). The DPPH free radical scavenging potential of GBR was reduced with the increasing concentrations of turmeric extracts. The peroxidase and SOD-like activities and total polyphenol content were significantly highest in TE-5, indicating a concentration-dependent incremental effect of turmeric.

Discussion

The effect of three (1, 3, and 5% w/v) concentrations of turmeric extracts on the color, nutrient, and antioxidant properties of germinated brown rice was investigated considering Hunter's color; amino acid, mineral, total polyphenol, and total flavonoid contents; and DPPH, POD, and SOD-like activities. Although measurement of specific plant growth regulars in turmeric extracts was not carried out in the present study, roles of some growth regulators can be expected to alter the nutrient and antioxidant activities of GBR as in the previous studies with calcium chloride (Choe *et al*., 2021), selenium (Liu and Ning, 2021), the extracts of persimmon fruit powder (Kim *et al*., 2017), Pu-erh tea (Kim *et al*., 2020),

Table 4. DPPH radical scavenging, SOD-like, and peroxidase activities and total polyphenol and flavonoid contents of germinated brown rice produced with turmeric extracts

	Sample[z]			
	TE-0	TE-1	TE-3	TE-5
DPPH (%)	18.8±0.67a[y]	12.4±1.73b	8.2±0.78c	4.3±0.87d
Peroxidase (%)	38.2±0.01d	50.7±0.01c	53.1±0.02b	56.7±0.01a
SOD-like (%)	77.5±3.21b	78.4±2.33b	80.9±1.30b	84.7±1.12a
Total polyphenol (ug GAE[x]/㎎)	19.4±1.05c	22.9±1.56b	23.7±1.35b	25.4±0.91a
Total flavonoid (ug QE[w]/㎎)	22.4±1.57b	24.4±3.27ab	25.0±1.25a	27.7±2.89a

[z]TE-0: germinated brown rice (GBR) produced with 0% turmeric solution; TE-1: GBR produced with 1% (w/v) turmeric extracts; TE-3: GBR produced with 3% (w/v) turmeric extracts; TE-5: GBR produced with 5% (w/v) turmeric extracts.

[y]Values are means±SD of triplicate measurements. The values followed by different letters in the same row are significantly different by Tukey test ($p < 0.05$).

[x]Gallic acid equivalent.

[w]Quercetin equivalent.

and lacquer stem (Kwak *et al*., 2017). The alterations in the nutrient and antioxidant activities of GBR might be due to the absorption of various phytochemicals present in turmeric (Zhang and Kitts, 2021) during soaking and subsequent germination (Lintschinger *et al*., 2000).

The higher yellowness value of the turmeric-treated GBR samples might be owing to the color of turmeric although such reports are not available. The color of a food product is one of the major visible traits that could determine the willingness of consumers to buy the product (Udomkun *et al*., 2018).

The soaking and subsequent dipping of brown rice in the mineral-containing turmeric (Kotha and Luthria, 2019) extracts might have increased the mineral contents of GBR at low concentration (TE-1), however, inhibitory (Akter *et al*., 2018) and herbicidal (Ibáñez and Blázquez, 2019) effects of turmeric might have adversely influenced to reduce the mineral content at high concentrations (TE-3 and TE-5). In the previous studies, the mineral content of germinating seeds was increased with zinc sulfate application in soybean sprouts (Xu *et al*., 2012; Zou *et al*., 2014) and selenium treatment in cereal sprouts (Lintschinger *et al*., 2000). Elements like Zn, Cu, Ca, and Mg commonly lack in human diets (White and Broadley, 2009). Mg, K, and Ca are beneficial against hypertension (Houston and Harper, 2008) and Zn contributes to growth, development, differentiation, DNA synthesis, RNA transcription, and cellular apoptosis (MacDiarmid, 2000). Thus, the treatment of brown rice with low concentrations of turmeric could be useful to increase mineral content.

The essential amino acids must be supplied through diets because they cannot be synthesized de novo by an organism at the required rate. In this perspective, turmeric treatment could be an effective way to increase the availability of essential amino acids in GBR. The content of glutamic acid, a precursor for γ-amino-n-butyric acid (GABA) synthesis (Nikmaram *et al*., 2017), was increased in GBR with turmeric treatments. The mineral elements present in turmeric might have played an influential role in the activation of diamine oxidase activity resulting in elevated GABA content in the turmeric-applied GBR (Wang *et al*., 2016). In previous studies, similar results with an increased amino acid content, including GABA, were found with lacquer (Kwak *et al*., 2017) and Pu-erh tea (Kim *et al*., 2020) treatment in soybean sprouts. Glycine and GABA, two of the many other non-essential amino acids increased in the turmeric-treated GBR, have beneficial roles related to brain and memory enhancement, neurological diseases; anxiety relief, sedation, anticonvulsant, and muscle relaxation functions (Krogsgaard-Larsen, 1989; Mody *et al*., 1994; Oh and Oh, 2004).

Several enzymes, including peroxidases and superoxide dismutases (SODs), are reactive oxygen scavengers that protect living organisms against harmful oxidative damages (Dvořák *et al*., 2021). Peroxidase may increase the accumulation of phenolic compounds in germinated brown rice as in olive fruits (Cirilli *et al*., 2017). Similarly, the substantial increment in the antioxidant potentials in the turmeric-treated GBR might be owing to the elements such as calcium (Kotha and Luthria, 2019) and/or phenolic compounds (Mughal, 2019; Li *et al*., 2011) in turmeric. Similar results of high phenolic contents in GBR were found after treatment of high phenolic-containing onions (Gennaro *et al*., 2002; Griffiths *et al*., 2002; Nakamura *et al*., 2020) and soybean sprouts produced with lacquer treatment (Kwak *et al*., 2017). Various enzymatic and non-enzymatic antioxidants, including SOD, catalase, glutathione transferase, carotenoids, glutathione peroxidase, vitamin C, vitamin E, and polyphenols contribute to antioxidant activities (Kurutas, 2015). Additionally, several factors like the oxidation conditions, partitioning characteristics, and condition of oxidizable substrate collectively define the antioxidant potential of foods (Frankel and Meyer, 2000). Hence, a visible difference in the content of an antioxidant polyphenol, for instance, not necessarily contributes to higher antioxidant activity. In the present study, the turmeric- treated GBR had higher total polyphenol content than the control but the latter showed a higher DPPH free radical scavenging than the turmeric-treated ones.

In conclusion, the effect of turmeric extracts on the nutrient content and antioxidant potential of GBR was investigated. The yellowness of turmeric-treated GBR was significantly higher than that of the untreated control. Treatment of 1% turmeric extract slightly increased but 3 and 5% concentrations reduced the total mineral content in GBR. The amount of essential, non-essential, and total amino acids, including, GABA were increased with the concentration of turmeric extract. Similarly, the overall antioxidant potential of GBR was higher with the higher concentration of turmeric treat-

ment. The results indicated that turmeric treatment could enhance the nutritional and functional value of GBR.

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

Adhikari, B., S.K. Dhungana, M. Waqas Ali, A. Adhikari, I.-D. Kim and D.-H. Shin. 2019. Antioxidant activities, polyphenol, flavonoid, and amino acid contents in peanut shell. J. Saudi Soc. Agric. Sci. 18:437-442.

Akter, J., Md.Z. Islam, K. Takara, Md.A. Hossain, S. Gima and D. Hou. 2018. Plant growth inhibitors in turmeric (*Curcuma longa*) and their effects on *Bidens pilosa*. Weed Biol. Manag. 18:136-145.

Blois, M.S. 1958. Antioxidant determinations by the use of a stable free radical. Nature 181:1199-1200.

Choe, H., J. Sung, J. Lee and Y. Kim. 2021. Effects of calcium chloride treatment on bioactive compound accumulation and antioxidant capacity in germinated brown rice. J. Cereal Sci. 101:103294.

Cirilli, M., G. Caruso, C. Gennai, S. Urbani, E. Frioni, M. Ruzzi, M. Servili, R. Gucci, E. Poerio and R. Muleo. 2017. The role of polyphenoloxidase, peroxidase, and β-glucosidase in phenolics accumulation in *Olea europaea* L. fruits under different water regimes. Front. Plant Sci. 8:717.

Dhungana, S.K., B.-R. Kim, J.-H. Son, H.-R. Kim and D.-H. Shin. 2015. Comparative study of *CaMsrB2* gene containing drought-tolerant transgenic rice (*Oryza sativa* L.) and non-transgenic counterpart. J. Agron. Crop Sci. 201:10-16.

Dhungana, S.K., I.-D. Kim, H.-S. Kwak and D.-H. Shin. 2016. Unraveling the effect of structurally different classes of insecticide on germination and early plant growth of soybean [*Glycine max* (L.) Merr.]. Pestic. Biochem. Physiol. 130:39-43.

Dinesh Babu, P., R.S. Subhasree, R. Bhakyaraj and R. Vidhyalakshmi. 2009. Brown rice-beyond the color reviving a lost health food - A review. Am. Eurasian J. Agron. 2:67-72.

Dubey, P., A.K. Mishra and A.K. Singh. 2015. Comparative analyses of genotoxicity, oxidative stress and antioxidative defence system under exposure of methyl parathion and hexaconazole in barley (*Hordeum vulgare* L.). Environ. Sci. Pollut. Res. 22:19848-19859.

Dvořák, P., Y. Krasylenko, A. Zeiner, J. Šamaj and T. Takáč. 2021. Signaling toward reactive oxygen species-scavenging enzymes in plants. Front. Plant Sci. 11:618835.

Eslami, S., N.M. Esa, S.M. Marandi, G. Ghasemi and S. Eslami. 2014. Effects of gamma oryzanol supplementation on anthropometric measurements & muscular strength in healthy males following chronic resistance training. Indian J. Med. Res. 139:857-863.

FAO. 2007. Quarterly Global Report. Food and Agriculture Organization of the United Nations, Rome, Italy.

Farhood, B., K. Mortezaee, N.H. Goradel, N. Khanlarkhani, E. Salehi, M.S. Nashtaei, M. Najafi and A. Sahebkar. 2019. Curcumin as an anti-inflammatory agent: Implications to radiotherapy and chemotherapy. J. Cell. Physiol. 234:5728-5740.

Frankel, E.N. and A.S. Meyer. 2000. The problems of using one-dimensional methods to evaluate multifunctional food and biological antioxidants. J. Sci. Food Agric. 80:1925-1941.

Gennaro, L., C. Leonardi, F. Esposito, M. Salucci, G. Maiani, G. Quaglia and V. Fogliano. 2002. Flavonoid and carbohydrate contents in tropea red onions: Effects of homelike peeling and storage. J. Agric. Food Chem. 50:1904-1910.

Griffiths, G., L. Trueman, T. Crowther, B. Thomas and B. Smith. 2002. Onions - A global benefit to health. Phytother. Res. 16:603-615.

Houston, M.C. and K.J. Harper. 2008. Potassium, magnesium, and calcium: Their role in both the cause and treatment of hypertension. J. Clin. Hypertens. 10:3-11.

Ibáñez, M. and M. Blázquez. 2019. Ginger and turmeric essential oils for weed control and food crop protection. Plants 8:59.

Imam, M.U., A. Ishaka, D.-J. Ooi, N.D.M. Zamri, N. Sarega, M. Ismail and N.M. Esa. 2014. Germinated brown rice regulates hepatic cholesterol metabolism and cardiovascular disease risk in hypercholesterolaemic rats. J. Funct. Foods 8:193-203.

Ito, Y., M. Shen, M. Kise, K. Hayamizu, G. Yoshino, R. Yoshihara and J. Yokoyama. 2005. Effect of pre-germinated brown rice on postprandial blood glucose and insulin level in subjects with hyperglycemia. Jpn. J. Food Chem. Saf. 12:80-84.

Je, J.-Y., P.-J. Park, W.-K. Jung and S.-K. Kim. 2005. Amino acid changes in fermented oyster (*Crassostrea gigas*) sauce with different fermentation periods. Food Chem. 91:15-18.

Jeong, H., J. Sung, J. Yang, Y. Kim, H.S. Jeong and J. Lee. 2018. Effect of sucrose on the functional composition and antioxidant capacity of buckwheat (*Fagopyrum esculentum* M.) sprouts. J. Funct. Foods 43:70-76.

Kayahara, H., K. Tsukahara and T. Tatai. 2001. Flavor, health and nutritional quality of pre-germinated brown rice: *In* Spanier, A.M., F. Shahidi, T.H. Parliment, C. Mussinan, C.-T. Ho and E.T. Contis (eds.), Food Flavors and Chemistry: Advances of the New Millennium, Royal Society of Chemistry, Cambridge, UK. pp. 546-551.

Kim, I.-D., J.-W. Lee, S.-J. Kim, J.-W. Cho, S.K. Dhungana, Y.-S. Lim and D.-H. Shin. 2014. Exogenous application of natural extracts of persimmon (*Diospyros kaki* Thunb.) can help in maintaining nutritional and mineral composition of dried persimmon. Afr. J. Biotechnol. 13:2231-2239.

Kim, I.-D., S. Dhungana, Y.-S. Park, D. Kim and D.-H. Shin. 2017. Persimmon fruit powder may substitute Indolbi, a synthetic growth regulator, in soybean sprout cultivation. Molecules 22:1462.

Kim, I.-D., S.K. Dhungana, Y.-G. Chae, N.-K. Son and D.-H. Shin. 2016. Quality characteristics of 'Dongchul' persimmon (*Diospyros kaki* Thunb.) fruit grown in Gangwondo, Korea. Korean J. Plant Res. 29:313-321.

Kim, J.-H., Y.-H. Yoon, I.-D. Kim, S.K. Dhungana and D.-H. Shin. 2020. Pu-erh tea extract treatment could be an efficient way to enhance the yield and nutritional value of soybean sprout. Molecules 25:3869.

Komatsuzaki, N., K. Tsukahara, H. Toyoshima, T. Suzuki, N. Shimizu and T. Kimura. 2007. Effect of soaking and gaseous treatment on GABA content in germinated brown rice. J. Food Eng. 78:556-560.

Kotha, R.R. and D.L. Luthria. 2019. Curcumin: biological, pharmaceutical, nutraceutical, and analytical aspects. Molecules 24:2930.

Krogsgaard-Larsen, P. 1989. GABA receptors. Receptor Pharmacology and Function. in: Williams M, R.A., Glennon and P.M.W.M. Timmermans (eds). Marcel Dekker Inc., New York, NY (USA). pp. 349-383.

Kurutas, E.B. 2015. The importance of antioxidants which play the role in cellular response against oxidative/nitrosative stress: current state. Nutr. J. 15:71.

Kwak, H.-S., S.K. Dhungana, I.-D. Kim and D.-H. Shin. 2017. Effect of lacquer (*Toxicodendron vernicifluum*) extract on yield and nutritional value of soybean sprouts. Korean J. Food Sci. Technol. 49:415-420.

Li, S., W. Yuan, G. Deng, P. Wang, P. Yang and B.B. Aggarwal. 2011. Chemical composition and product quality control of turmeric (*Curcuma longa* L.). Pharm. Crops 5:28-54.

Li, S.-C., H.-P. Lin, J.-S. Chang and C.-K. Shih. 2019. *Lactobacillus acidophilus*-fermented germinated brown rice suppresses preneoplastic lesions of the colon in rats. Nutrients 11:2718.

Lintschinger, J., N. Fuchs, J. Moser, D. Kuehnelt and W. Goessler. 2000. Selenium-enriched sprouts. A raw material for fortified cereal-based diets. J. Agric. Food Chem. 48:5362-5368.

Liu, H., Y. Kang, X. Zhao, Y. Liu, X. Zhang and S. Zhang. 2019. Effects of elicitation on bioactive compounds and biological activities of sprouts. J. Funct. Foods 53:136-145.

Liu, K. and M. Ning. 2021. Antioxidant activity stability and digestibility of protein from Se-enriched germinated brown rice. LWT 142:111032.

MacDiarmid, C.W. 2000. Zinc transporters that regulate vacuolar zinc storage in *Saccharomyces cerevisiae*. EMBO J. 19:2845-2855.

Mody, I., Y. De Koninck, T.S. Otis and I. Soltesz. 1994. Bridging the cleft at GABA synapses in the brain. Trends Neurosci. 17:517-525.

Mughal, M.F. 2019. Turmeric polyphenols: A comprehensive review. Integr. Food Nutr. Metab. 6.

Naeini, M.B., A.A. Momtazi, M.R. Jaafari, T.P. Johnston, G. Barreto, M. Banach and A. Sahebkar. 2019. Antitumor effects of curcumin: A lipid perspective. J. Cell. Physiol. 234: 14743-14758.

Nakamura, S., K. Kaneko, T. Mitsui and K. Ohtsubo. 2020. Evaluation of the palatability and biofunctionality of brown rice germinated in red onion solution. Cereal. Chem. 97: 836-848.

Nikmaram, N., B. Dar, S. Roohinejad, M. Koubaa, F.J. Barba, R. Greiner and S.K. Johnson. 2017. Recent advances in γ - aminobutyric acid (GABA) properties in pulses: An overview. J. Sci. Food Agric. 97:2681-2689.

Oh, C.-H. and S.-H. Oh. 2004. Effects of germinated brown rice extracts with enhanced levels of GABA on cancer cell proliferation and apoptosis. J. Med. Food 7:19-23.

Oh, S.-H. 2003. Stimulation of γ-aminobutyric acid synthesis activity in brown rice by a chitosan/glutamic acid germination solution and calcium/calmodulin. BMB Rep. 36:319-325.

Park, J.-J., Y.-S. Park, S.K. Dhungana, I.-D. Kim and D.-H. Shin. 2020. Phytochemical and antioxidant properties of Korean wheat sprouts. Korean J. Plant Res. 33:170-182.

Patil, S.B. and Md.K. Khan. 2011. Germinated brown rice as a value added rice product: A review. J. Food Sci. Technol. 48:661-667.

Petchdee, S., W. Laosripaiboon, N. Jarussophon and S. Kumphune. 2020. Cardio-protective effects of germinated brown

rice extract against myocardial ischemia reperfusion injury. High Blood Press. Cardiovasc. Prev. 27:251-258.

Saleh, A.S.M., P. Wang, N. Wang, L. Yang and Z. Xiao. 2019. Brown rice versus white rice: Nutritional quality, potential health benefits, development of food products, and preservation technologies. Compr. Rev. Food Sci. Food Saf. 18: 1070-1096.

Sim, U., J. Sung, H. Lee, H. Heo, H.S. Jeong and J. Lee. 2020. Effect of calcium chloride and sucrose on the composition of bioactive compounds and antioxidant activities in buckwheat sprouts. Food Chem. 312:126075.

Singleton, V.L., R. Orthofer and R.M. Lamuela-Raventós. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *In*: Methods in Enzymology. vol. 299. Packer, L. (ed.), Elsevier B.V. Amsterdam, Netherlands. pp. 152-178.

Skujins, S. 1998. Handbook for ICP-AES (Varian-Vista). A short guide to vista series ICP-AES operation. Varian Int. AG, Zug, Version 1.0. *Switzerland Soc. Food Sci. Technol*. 29:221-227.

Soleimani, V., A. Sahebkar and H. Hosseinzadeh. 2018. Turmeric (*Curcuma longa*) and its major constituent (curcumin) as nontoxic and safe substances: Review. Phytother. Res. 32: 985-995.

Udomkun, P., J. Ilukor, J. Mockshell, G. Mujawamariya, C. Okafor, R. Bullock, N.L. Nabahungu and B. Vanlauwe. 2018. What are the key factors influencing consumers' preference and willingness to pay for meat products in Eastern DRC? Food Sci. Nutr. 6:232102336.

Wang, X., R. Yang, X. Jin, C. Shen, Y. Zhou, Z. Chen and Z. Gu. 2016. Effect of supplemental Ca_{2+} on yield and quality characteristics of soybean sprouts. Sci. Hortic. 198:352-362.

White, P.J. and M.R. Broadley. 2009. Biofortification of crops with seven mineral elements often lacking in human diets - iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 182:49-84.

Xu, N., T. Zou, J.W. Pang and G.L. Hu. 2012. Effects of exogenous zinc soaking on the seed germination, sprout growth of soybean and zinc accumulation in the sprouts. Soybean Sci. 31:932-936.

Yodpitak, S., S. Mahatheeranont, D. Boonyawan, P. Sookwong, S. Roytrakul and O. Norkaew. 2019. Cold plasma treatment to improve germination and enhance the bioactive phytochemical content of germinated brown rice. Food Chem. 289:328-339.

Zhang, H.A. and D.D. Kitts. 2021. Turmeric and its bioactive constituents trigger cell signaling mechanisms that protect against diabetes and cardiovascular diseases. Mol. Cell. Biochem. 476:3785-3814.

Zhang, J. and M.B. Kirkham. 1994. Drought-stress-induced changes in activities of superoxide dismutase, catalase, and peroxidase in wheat species. Plant Cell Physiol. 35:785-791.

Zhang, Q., N. Liu, S. Wang, Y. Liu and H. Lan. 2019. Effects of cyclic cellulase conditioning and germination treatment on the γ-aminobutyric acid content and the cooking and taste qualities of germinated brown rice. Food Chem. 289:232-239.

Zhishen, J., T. Mengcheng and W. Jianming. 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem. 64:555-559.

Zhou, Z., K. Robards, S. Helliwell and C. Blanchard. 2002. Composition and functional properties of rice. Int. J. Food Sci. Technol. 37:849-868.

Zou, T., N. Xu, G. Hu, J. Pang and H. Xu. 2014. Biofortification of soybean sprouts with zinc and bioaccessibility of zinc in the sprouts. J. Sci. Food Agric. 94:3053-3060.

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