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Nutritional qualities, antioxidant properties and sensory acceptability of fresh wheat noodles formulated with rice bran

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Abstract

The present work evaluated the potential of rice bran as a functional ingredient in fresh noodles. Fresh noodles supplemented with 0, 2, 5, and 10% (w/w) bran were evaluated for acceptability by a consumer sensory panel (n = 30). The noodles with the highest sensory acceptability were then characterised for their dietary fibre (DF), crude protein, crude ash, crude fat content, total phenolic content (TPC), and antioxidant capacity in terms of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity. Results showed that different levels (2, 5, and 10%) of either the bran of NSIC Rc 298, a non-pigmented rice variety, or Minaangan, a red rice, had generally no significant effect on the acceptability of all the sensory parameters, except for colour; in which noodles with 0% NSIC Rc 298 bran was more preferred. Regardless of the pigmentation, rice bran supplemented at 10% significantly enhanced the DF, crude fat, crude ash, TPC, and antioxidant capacity of the noodles without affecting the overall acceptability. Rice bran could therefore be used to produce high-quality fresh noodles with health-promoting properties.

Introduction

Rice (*Oryza sativa* L.) is one of the most economically important crops in the world and is a staple food of the large segment of the world's population, especially among Asian populations (Bird, 2000). In 2017, the Philippines produced 19.3 mil metric tons of paddy rice that is equivalent to 12.5 mil metric tons of milled rice, which translates to a high production of rice bran. It is estimated that 100 kg of paddy rice will generate approximately 5 - 10 kg of bran.

The optimised use of rice by-products reduces environmental pollution and generates huge economic benefits (Li *et al.,* 2019). Processing and utilisation of rice and its by-products greatly contribute to the added value of rice and in energy conservation, emission reduction, resource regeneration, and conversion of waste to wealth. Rice bran is one such by-product. A major agricultural by-product of rice, rice bran, constitutes around 10% of the total rough rice. It is widely available, cheap, and rich in health-promoting nutrients such as protein, fat, vitamins, minerals, as well as bioactive compounds and dietary fibre that reduce the risk of non-communicable diseases (Gul *et al.,* 2015).

Development of high fibre products is one of the approaches that can be used to help solve prevalent health problems. Utilisation of rice bran for enriching various snacks such as bread, cakes, noodles, pasta, and ice creams has been reported elsewhere with no significant changes on the technological and textural properties (Goufo and Trindade, 2014; Pengkumsri *et al.,* 2015).

Noodle is a convenient and tasty wheat-based food product popularly consumed throughout the world, including in the Philippines. Consumption of noodles has been rapidly increasing as a result of its simple preparation, convenience, desirable sensory profile, and suitability for diverse variants (Chhikara *et al.,* 2019; Panghal *et al.,* 2019a; Sofi *et al.*, 2020). Commercially, it is rich in carbohydrates but usually deficient in essential nutrients, such as proteins, dietary fibre (DF), vitamins, minerals, and antioxidants (Kudake *et al.,* 2017; Panghal *et al.,* 2019b). These qualities make it a highly suitable vehicle for fortification or enrichment purposes. Fibre-enrichment has been tested using non-conventional sources, such as *kimchi* by-product (Kim *et al.,* 2017) and unripe banana flour (Agama-Acevedo *et al.,* 2009). Hence, upgrading the use of rice bran from animal feed and waste material to a functional food ingredient will be of great benefit to meet food demands and application. Various cereal brans, including rice bran, were previously evaluated as ingredients in similar products, such as Asian noodles (Izydorczyk *et al.,* 2005), sweet potato pasta (Krishnan *et al.,* 2012), wheat pasta (Kaur *et al.,* 2012),

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and rice pasta (Wang *et al.,* 2018). However, the effects of these ingredients were focused on the physico-mechanical and functional characteristics, and other nutritional content besides DF. Ertaş (2014) and Tuncel *et al.* (2017) tested rice bran in Turkish noodles *erişte* and found improving macro and micronutrient enhancement with increasing levels of bran, but the levels of phytochemicals were not determined. The present work therefore aimed to develop an acceptable functional fresh wheat noodles and characterise the product in terms of its nutritional quality, particularly DF content, its antioxidant properties, and sensory acceptability.

Materials and methods

Samples and materials

Selection of rice varieties as source of bran was first done based on their DF content. Eleven (11) Philippine rice varieties (four pigmented heirloom and seven non-pigmented modern varieties) were screened for their DF content. The pigmented rice varieties were: (1) Ominio (with purple pericarp), (2) Balikwadang, (3) Chong-ak, and (4) Minaangan (red). The non-pigmented varieties were: (1) NSIC Rc 152, (2) NSIC Rc 160, (3) NSIC Rc 242, (4) NSIC Rc 298, (5) PSB Rc 10, (6) PSB Rc 14, and (7) PSB Rc 82. All chemicals used were of analytical grade.

Sample processing

Samples in panicles were first threshed, then dehulled using a Satake THU-35A dehulling machine (Hiroshima, Japan). The bran was collected from the unpolished samples using a polisher (McGill No. 3, Dayton Industrial Motor). The bran was then passed through a 0.634 mm sieve to remove impurities before further analysis.

Dietary fibre (DF)

Dietary fibre of the bran samples was determined based on the Sigma TDF100a (MO, USA) method, with some modifications. Bran (1 g) was weighed onto 500 mL beakers and dispersed in 50 mL of 0.08 M phosphate buffer (pH 6.0) and 0.1 mL of heat-stable alpha-amylase (A3306, Sigma Aldrich, MO, USA). The beaker was covered with aluminium foil and placed in a boiling water bath for 30 min with agitation of contents every 5 min. The pH of the solution was adjusted to 7.5 using 10 mL of 0.275 N NaOH after cooling to room temperature. Then, 0.1 mL of freshly prepared protease in phosphate buffer (50 mg/mL) was added. The samples were then incubated in a shaking water bath (LSB-045S, Labtech, France) set at 100 rpm, 60ºC for 30 min. The pH of the solution was again adjusted to 4.3 by adding 10 mL of 0.325 N HCl solution. Amyloglucosidase (0.2 mL) was added and the mixture was incubated in a shaking water bath (100 rpm, 60ºC) for 30 min. Four volumes of hot (~60ºC) 95% ethanol (200 mL) were added and the mixture was left for 1 h at room temperature to allow for precipitation. The beaker contents were filtered through a FOSS Fibertec™ 1023 (Denmark) dietary fibre filtration module. The insoluble residue was washed with 78% ethanol (20 mL, 3×), 95% ethanol (10 mL, 2×) and acetone (10 mL, 2×). The fritted crucible with the residue was tared in an oven set at 105ºC for 1 h. Finally, the crucibles were ignited at 330ºC for 1 h and then at 550ºC for 2 h. The DF was reported based on 100 g sample.

Selection of rice bran sample for noodle preparation

One pigmented and one non-pigmented rice bran samples with the highest DF were selected for developing the noodles. The selected bran samples were sieved at 149 μm for a uniform particle size distribution prior to incorporation.

Optimisation of formulation of rice bran-supplemented noodles

The noodles were prepared using the following ingredient: all-purpose flour, 280 g; egg, 90 g; vegetable oil, 9.5 g; and salt, 3.1 g. All-purpose flour was replaced with rice bran at different supplementation levels: (0, 2, 5, and 10%) (w/w flour). In a separate bowl, the salt and flour were mixed evenly and then, the flour and egg were combined gradually. A soft dough was formed, which was kneaded, folded, flattened, and allowed to stand for 30 min. The dough was flattened into a thick disk and fed into the noodle roller. The noodles were placed on wax paper and sprinkled with little flour to prevent them from sticking together. The noodles were cooked for 5 min in a medium pot with boiling water of about 2,500 mL water mixed with 3 g vegetable oil and 2 g salt. Chicken stock was prepared separately using chicken, onion, garlic, ginger, salt, bay leaf, and pepper.

Selection of the best formulation of rice bran-supplemented noodles

To determine the most acceptable formulation per type of bran, different treatments of noodles with the selected bran samples were first screened using an untrained panel consisting of fifteen (15) staff from the Philippine Rice Research Institute (PhilRice) in Science City of Muñoz, Nueva Ecija. For each treatment, noodles (15 g) mixed with 50 mL chicken stock were presented to each panellist. The panellists evaluated the appearance, odour, hardness, texture / mouthfeel, taste, and overall acceptability using a 9-point Hedonic scale, with 9 representing "like extremely" and 1 as "dislike extremely". The panellists were provided with water for rinsing and given additional sample upon request.

To determine and compare the acceptability between the two bran-supplemented noodles with the highest acceptability ratings, the most preferred samples based on the screening were subjected to another round of consumer sensory evaluation, along with a non-supplemented control. Thirty (30) PhilRice staff evaluated the acceptability of the products using the same scorecard.

Nutritional analysis of the bran-supplemented noodles

The samples subjected to consumer sensory evaluation were tested for their proximate composition. Cooked noodle products were stored overnight at -20ºC and lyophilised. The dehydrated noodles were ground to a fine powder at 100-mesh (149 µm). The levels of crude protein, crude fat, crude ash, and dietary fibre of the powdered noodles were determined based on the AOAC approved methods (AOAC, 2006).

Extraction of antioxidant compounds

Lyophilised and ground noodles samples were weighed to 1.0 g and added with 10 mL of 85% aqueous methanol solution. The tubes were mixed thoroughly using a vortex mixer and then using an orbital shaker at 300 rpm for 12 - 14 h. The tubes were centrifuged at 3,000 rpm for 15 min and the extracts were obtained for further analysis.

Total phenolic content

The total phenolic content (TPC) was measured using the Folin-Ciocalteau based on the method of Singleton *et al.* (1999), with modifications. Sample extract (500 µL) was mixed with 2.5 mL of freshly prepared Folin-Ciocalteau reagent (1:10 dilution), incubated for 15 min at room temperature, and added with 2 mL of 7.5% sodium carbonate. The mixture was incubated for 1 h. The absorbance of the resulting blue colour was measured at 760 nm against the blank. Gallic acid (GA) was used as standard and the TPC was expressed as mg GA equivalent (GAE)/g sample.

DPPH radical scavenging activity

The total antioxidant activity of the noodles was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity assay as described by Brand-Williams *et al.* (1995). Noodle extract (0.5 mL) were mixed with 5 mL of freshly prepared 0.10 mM of DPPH solution. The mixtures were incubated for 1 h and the absorbance was measured against blank (methanol) at 517 nm. Results were reported as mg Trolox equivalents (TE)/g sample.

Statistical analysis

ANOVA was performed on the nutritional and antioxidant values and multiple comparisons were carried out using Tukey's studentised range test using IBM SPSS Statistics version 20. The level of significance used was $p < 0.05$. All measurements were performed in triplicates, unless otherwise stated.

Results and discussion

Selection of bran sample with high dietary fibre for product development

The DF content of the bran samples ranged from 34.57 to 44.89% (Table 1). These values were higher than that reported by Faria *et al.* (2012), which was 24.15%. Among non-pigmented samples, DF ranged between 34.57 - 41.16%, with NSIC Rc 298 having the highest value. However, there were no statistical differences in the DF values of the non-pigmented rice varieties. No significant differences in the DF values of the pigmented rice were likewise observed, although the values (36.20 - 44.89%) were slightly higher than in non-pigmented rice varieties. Due to their availability at high quantities during the experimentation, the bran of NSIC Rc 298 (non-pigmented) and Minaangan (pigmented) were selected as samples in fresh wheat noodle supplementation.

Table 1. Dietary fibre of rice bran samples.

Variety	Pericarp colour	Dietary fibre (%)
Non-pigmented		
NSIC Rc 152	Brown	37.06 ± 4.10^{ab}
NSIC Rc 160	Brown	36.48 ± 0.10^{ab}
NSIC Rc 242	Brown	36.98 ± 1.27^{ab}
NSIC Rc 298	Brown	41.16 ± 0.98^{ab}
PSB Rc 10	Brown	40.18 ± 1.43^{ab}
PSB Rc 14	Brown	39.97 ± 5.97^{ab}
PSB Rc 82	Brown	34.57 ± 0.21^{b}
Pigmented		
Ominio	Purple	36.20 ± 0.68^{ab}
Balikwadang	Red	44.59 ± 1.65^{a}
Chong-Ak	Red	38.77 ± 0.62^{ab}
Minaangan	Red	44.89 ± 1.90^{a}

Data are means ± SD of triplicates ($n = 3$). Means with the same letter within the same column per variety classification are not significantly different at $p < 0.05$.

Selection of best rice bran noodles formulation

Tables 2 and 3 show the mean sensory acceptability scores of noodles with bran of NSIC Rc 298 (NBN) and Minaangan (MBN), respectively. The supplementation of NSIC Rc 298 and Minaangan bran at different levels (0, 2, 5, and 10%) had no significant effect on the acceptability of all the sensory parameters, except for the colour of NSIC Rc 298 supplemented product. The brown colour of the NBN intensified as the supplementation increased, and this was apparently less preferred by the panellists. However, this was not observed in the MBN, which also had evident of darkening with increase in bran level. For the two products, however, the overall acceptability scores were both unaffected by the colour (Table 4). NBN and MBN were both moderately liked by the panellists and had comparable acceptability ratings as the control sample (0% bran).

Consumer sensory evaluation of rice bran noodles

Comparing the NBN and MBN noodles, the consumer acceptability scores showed that except for colour, all properties of the supplemented samples were not significantly different from those of the control (Table 4). Colour is an important quality factor directly related to consumer acceptability. MBN registered a slightly lower acceptability for colour. However, this did not affect the overall acceptability of the product. In a study by Kaur *et al.* (2012), pasta enriched with cereal brans, including rice bran, were acceptable up to 15% level, but the acceptability decreased with further increase in level

Table 2. Consumer sensory evaluation of cooked noodles with NSIC Rc 298 bran at different levels of supplementation.

Sensory properties	Levels of bran supplementation (% w/w)			
	0	2	5	10
Appearance (colour)	7.40 ± 0.91^{b}	7.20 ± 1.03^{ab}	6.73 ± 1.46^{ab}	6.47 ± 1.58^{a}
Odour	7.20 ± 0.94^{a}	7.13 ± 0.83^{a}	7.00 ± 0.93^{a}	7.33 ± 0.82^{a}
Hardness	7.53 ± 0.83^{a}	7.40 ± 0.63^{a}	7.00 ± 1.20^{a}	7.07 ± 1.03^{a}
Texture / mouthfeel	7.73 ± 0.70^{a}	7.60 ± 0.63^{a}	7.27 ± 0.88^{a}	7.33 ± 0.90^{a}
Taste	7.13 ± 0.10^{a}	7.27 ± 0.70^{a}	6.73 ± 1.22^{a}	7.00 ± 0.76^{a}
Overall acceptability	7.60 ± 0.73^{a}	7.47 ± 0.52^{a}	7.07 ± 0.88^{a}	7.13 ± 0.64^{a}

Data are means ± SD (n = 15). Means with the same letter within the same column are not significantly different at $p < 0.05$. Scale: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; and 9 = like extremely.

Table 3. Consumer sensory evaluation of cooked noodles with Minaangan bran at different levels of supplementation.

Sensory properties	Levels of bran supplementation (% w/w)			
	0	2	5	10
Appearance (colour)	7.40 ± 0.91	6.73 ± 1.03	7.13 ± 1.46	6.93 ± 1.58
Odour	7.20 ± 1.08	7.07 ± 1.03	7.13 ± 1.13	7.20 ± 1.01
Hardness	7.33 ± 0.82	7.13 ± 0.83	7.40 ± 1.06	7.20 ± 1.32
Texture / mouthfeel	7.60 ± 0.83	7.27 ± 0.88	7.47 ± 1.06	7.00 ± 1.25
Taste	7.27 ± 0.80	7.20 ± 0.77	7.13 ± 1.06	7.07 ± 1.10
Overall acceptability	7.27 ± 0.80	6.93 ± 1.10	7.27 ± 1.10	7.00 ± 1.25

Data are means ± SD (n = 15). Means with the same letter within the same column are not significantly different at $p < 0.05$. Scale: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; and 9 = like extremely.

Table 4. Consumer sensory evaluation of cooked noodles with NSIC Rc 298 and Minaangan bran.

Sensory properties	**Treatment**		
	Control	**10% NSIC Rc 298**	**10% Minaangan**
Appearance (colour)	7.63 ± 1.13^{a}	7.03 ± 0.93^{ab}	6.37 ± 1.45^{b}
Odour	7.00 ± 1.29^{a}	6.70 ± 1.29^{a}	6.90 ± 1.24^{a}
Hardness	7.20 ± 0.10^{a}	7.03 ± 1.07^{a}	7.37 ± 0.96^{a}
Texture / mouthfeel	7.27 ± 1.34^{a}	7.33 ± 1.08^{a}	7.40 ± 0.86^{a}
Taste	7.57 ± 1.17^{a}	7.63 ± 1.08^{a}	7.57 ± 0.68^{a}
Overall acceptability	7.57 ± 1.14^{a}	7.50 ± 0.52^{a}	7.53 ± 0.73^{a}

Data are means ± SD (n = 30). Means with the same letter within the same row are not significantly different at $p < 0.05$. Scale: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; and 9 = like extremely.

of bran primarily due to colour. Odour, hardness, texture / mouthfeel, and taste of bran-supplemented fresh wheat noodles did not differ significantly from the control. The overall acceptability ratings of all the products were about 7.5, or moderately liked.

Nutritional quality of bran-supplemented noodles

Table 5 shows the nutritional properties of the NBN and MBN. DF was higher than that of the control by 42.45 and 80.46% in NBN and MBN, respectively. DF plays an important role in human health. Fibre-rich diets are associated with cholesterol and blood pressure lowering effects and improvement in insulin sensitivity (Gul *et al.,* 2015). DF in foods primarily come from whole-grain cereals, vegetables, and fruits. However, intake of these foods, and consequently DF, are often inadequate. Consumption of fibre-enriched products, such as the rice bran-supplemented noodles, could provide additional DF for the body's needs.

The crude protein content of the noodles was not affected by supplementation (Table 5). In their study, Kong *et al.* (2012) reported improved protein content using black rice bran at the same level of supplementation from 10.94 to 11.47%. Additional 2% protein were also contributed by rice bran when it was used to replace sweet potato flour in pasta (Kaur *et al.,* 2012). Majority of proteins in the rice grain are found in the bran, which can contain as much as 15%. Its potential as a functional food ingredient and nutritional supplements has been reported previously by Fabian and Ju (2011). In the present work, however, protein content in the brans used were insufficient to induce an increase in protein content in the noodles at the specified supplementation level.

The crude fat of the noodles slightly increased by more than 1% when supplemented with either NSIC Rc 298 or Minaangan rice bran (Table 5). A similar improvement was noted by Kong *et al.* (2012). This is because bran contains lipids, such as tocols, oryzanol, essential fatty acids, and other sterols (Gul *et al.,* 2015). Similarly, the ash or mineral content of the noodles were enhanced by rice bran, as rice bran is a rich source of vitamins, particularly B-complex vitamins, and minerals such as silicon, magnesium, and potassium (Gul *et al.,* 2015, Jang and Seo, 2016).

In traditional wheat noodles, most of the essential nutrients are lacking, including dietary fibre, vitamins, and minerals. These are lost during refinement of wheat (Kaur *et al.,* 2013). As shown in the present work, rice bran could therefore serve as enrichment ingredients in fresh wheat noodles.

Antioxidant properties of fresh wheat noodles enriched with bran

Table 5 shows the antioxidant properties

Table 5. Nutritional and antioxidant properties of cooked noodles with 10% rice bran.

Noodle sample	**Dietary fibre (%)**	**Crude protein (%)**	**Crude fat (%)**	**Crude ash (%)**	**TPC (mg GAE/g)**	**DPPH (mg TE/g)**
Control	6.19 ± 0.39^{c}	19.14 ± 0.18^{a}	7.29 ± 0.01^{b}	1.45 ± 0.02^{b}	13^{c}	7^{c}
NSIC Rc 298	8.82 ± 0.05^{b}	19.32 ± 0.11^{a}	8.65 ± 0.37^{a}	1.64 ± 0.02^{a}	28^{a}	28^{a}
Minaangan	11.16 ± 0.16^{a}	19.39 ± 0.17^{a}	8.30 ± 0.21^{a}	1.66 ± 0.01^{a}	22^{b}	21^{b}

Data are means ± SD (n = 30). Means with the same letter within the same row are not significantly different at $p < 0.05$.

(TPC and DPPH) of noodles made with 100% wheat flour, NBN, and MBN. TPC of NBN and MBN were significantly improved by 15.0 and 9.0 mg GAE/g, respectively. These results are higher than the TPC value of the cooked noodles supplemented with 10% black rice bran of Kong *et al.* (2012), which was 8.0 mg GAE/g. Phenolic compounds are the main phytochemicals in plants and are the major contributors in their antioxidant capacities (Takebayashi *et al.,* 2013; Kameya *et al.,* 2014). In rice, the bran is the richest source of phenolic compounds (Goufo and Trindade, 2014).

The DPPH radical scavenging activities of the supplemented noodles were also significantly higher than the unsupplemented control (Table 5). NBN and MBN had antioxidant capacities of 28 and 21 mg TE/g, respectively. These were equivalent to 300 and 200% improvements, respectively, in the DPPH radical scavenging activity of the unsupplemented noodles. These enhancements in antioxidant capacities are in agreement with the TPC results. Phenolic compounds in rice bran include ferulic acid and anthocyanins, which are particularly found in pigmented varieties. Rice bran also contains other antioxidant compounds such as oryzanols, tocopherols, and tocotrienols (Chotimarkorn *et al.,* 2008). These phytochemicals exert health-promoting effects (Hu *et al.,* 2003), particularly in reducing the risk of several chronic diseases such as cancer, diabetes, and cardiovascular diseases (Nam *et al.,* 2006; Zhang *et al.,* 2013). They do this by inhibiting the formation and reducing the concentration of reactive cell-damaging agents. Hence, in addition to DF, phytochemicals found in brans of cereals, such as rice, have been implicated with the health-enhancing effects of high consumption of whole grains in humans (Hu, 2002). In the present work, supplementation of NSIC Rc 298 and Minaangan bran at 10% level significantly increased the phenolic content and antioxidant capacities of fresh wheat noodles.

Conclusion

Fresh wheat noodles supplemented with rice bran at different levels (2, 5, and 10%) were similarly acceptable to consumers as unsupplemented control sample, although the colour of noodles with NBN was less preferred than the control. Incorporation at 10% level of bran, either from non-pigmented or pigmented rice variety, increased the DF content of fresh wheat noodles up to 80.5%. Furthermore, it enhanced the fat and mineral content, and improved the total phenolic content and antioxidant capacity by up to 300%. Traditional noodles are generally lacking in dietary fibre and macro- and micronutrients due to refining of wheat flour. Incorporation of rice bran in fresh wheat noodles could enhance the nutritive value of the product. Lastly, the improvements in nutritional and antioxidant properties of the noodles did not affect the sensory acceptability of the product.

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