PJN
ISSN 1680-5194
ansinet.com/pjn

PAKISTAN JOURNAL OF NUTRITION

Science Alert
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OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2020.172.178

Research Article
Nutritionally Enriched Noodle Preparation from Wheat Flour Fortified with Rice Bran

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Abstract
Background and Objective: Rice is the staple food in Bangladesh. Rice bran is one of the major by-products during paddy processing and accounts for approximately 8% of the whole paddy field. Rice bran is usually thrown out as waste or is used as cattle feed. Rice bran contains high amounts of protein, fiber and fat. It is also a rich source of phenolic compounds and exhibits antioxidant properties. This study was conducted to determine the nutritional value of noodles prepared from wheat flour fortified with rice bran. **Materials and Methods:** This study explores the potential of incorporating rice bran into noodles. Proximate analysis, functionality and antioxidant properties were evaluated by established laboratory methods. **Results:** Proximate parameters such as the protein, fat and fiber contents of rice bran were found to be higher than those of wheat flour. Among the functional parameters studied, the water absorption, oil absorption and swelling capacity of rice bran were significantly ($p\leq 0.05$) higher than those of wheat flour. The substitution of wheat flour with rice bran in noodle preparation was testedat 2, 5, 10, 15 and 20% levels. As rice bran incorporation increased, the ash, fat, protein and crude fiber contents of the formulated noodles increased. The antioxidant activities and free fatty acid and phenolic contents of rice bran noodles were higher than those of the control noodles. Rice bran caused greater cooking loss and water uptake of noodles. An increasing level of rice bran negatively affected the sensory characteristics of noodles compared to the control. However, there was no significant ($p<0.05$) difference between the control noodles and rice bran-fortified ($\leq$5%) noodles in terms of sensory rating. **Conclusion:** In conclusion, wheat flour may be fortified with rice bran up to a 5% substitution level to yield acceptable noodles with improved nutrition and functional properties.

Key words: Rice bran, noodle, protein, fiber, fat, phenolic compounds cooking quality

Received: September 05, 2019 Accepted: February 21, 2020 Published: March 15, 2020

Citation: Rokeya Begum, Shahnaj Parvin, Kanak Chandra Madok, Obaidur Rashid and Binu Akter, 2020. Nutritionally enriched noodle preparation from wheat flour fortified with rice bran. Pak. J. Nutr., 19: 172-178.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa*) is the most important staple food for a large part of the world's population[1]. More than one hundred countries produce more than 715 million tons of paddy rice annually, as well as 480 million tons of milled rice[2]. Paddy rice is made up of an outer husk layer, germ, bran layers and the kernel. On average, paddy rice produces 25% husk, 10% bran and germ and 65% white rice[3]. Every year, approximately 60 million metric tons of rice bran are produced worldwide. Although, approximately 8% of the weight of the whole grain is bran and this bran contains the most nutrients (65% of the total nutrients in rice), almost all of it is either thrown away or used as low-level animal and poultry feed. Rice bran is the cheapest of all grain by-products, which costs 0.2 cents/pound in the international market and 20-25 Taka kg^{-1} in Bangladesh. Rice bran is a very rich source of nutrients, such as vitamins (B1, B2, B6, pantothenic acid, folic acid), minerals (manganese, magnesium, potassium, calcium, phosphorus, zinc, iron), fiber, proteins, lipids, phytosterols and bioactive phytochemicals (γ-oryzanol, tocopherols and tocotrienols), which have beneficial health properties and antioxidant activity; thus, rice bran has great potential to develop bran-based functional food products worldwide[4,5].

Since ancient times, noodles in various formulations and shapes have been used as staple food in many parts of Asia, such as South East Asia, Korea, the Philippines, Thailand, Malaysia, China and Japan. The use of noodles as snacks in Bangladesh has been increasing daily. Noodles can be prepared from wheat, rice and buckwheat and starches derived from cereals, potato and pulses[6]. In many studies, wheat flour has been fortified with other ingredients, resulting in different quality noodles[7]. The presence of multiple proline and glutamine residues in prolamine and glutenin proteins contained in wheat flour leads to inflammation, atrophy and hyperplasia of the small intestinal crypts of aceliac patient[8]. Rice bran is widely available and inexpensive and contains low amounts of prolamines and glutenins. To develop ready-to-use and ready-to-serve foodstuffs, an attempt has been made to prepare rice bran-fortified nutritionally enriched wheat-based noodles.

MATERIALS AND METHODS

The experiment was conducted in the laboratory of the Food Technology and Nutritional Science Department, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh.

Materials: The rice bran of a rice variety named "Lata" was purchased from Sahrawardi Auto Rice Mill", Sherpur, Bogra, Bangladesh. The wheat flour, egg, soybean oil and salt used in the noodle preparation were purchased from a local market. 2,2-Diphenyl–picrylhydroazyl, petroleum ether (Sigma-Aldrich, Germany), Folin-Ciocalteu reagent (Sisco, India), ethanol, methanol, potassium hydroxide, sodium hydroxide (NaOH), hydrochloric acid (HCl), potassium sulfate (K_2SO_4), phenolphthalein indicator, sulfuric acid (H_2SO_4), sodium carbonate, sodium benzoate (Merck, Germany), methyl red solution, bromo cresol green (Seohaean-ro, Korea), guar gum and petroleum benzene (Merck, India) were collected from the laboratory.

Methods

Microwave stabilization of rice bran: The rice bran sample was sieved to obtain a uniform particle size (100 μm). Approximately 100 g of rice bran sample was taken and microwave stabilization was performed at 2450 MHZ for 3 min (10 mL of water was added to preventchar in the bran)[9].

Chemical analysis of rice bran and wheat flour: The moisture, ash, protein, fat and fiber contents of rice bran were determined by standard methods[10]. The total carbohydrate content of the samples was calculated by subtracting the measured protein, fat, ash and moisture content from 100.

Functional properties of rice bran

Bulk density: The bulk density of the flour samples was determined by the method of Okaka and Potter[11] and was calculated as weight per unit volume of the sample.

Water and oil absorption capacity: The water and oil absorption capacities were determined by the method of Solsulki *et al.*[12]. The sample (1.0 g) was mixed with 10 mL distilled water or refined soybean oil, kept at ambient temperature for 30 min and centrifuged for 10 min at 2000 rpm in a centrifuge (Remi, India). Water or oil absorption capacity was expressed as milliliters of water or oil bound per gram of the sample based on Eq. 1.

$$\text{WOAC}(\text{mL / g})=\frac{\text{mL of water/oil added to the sample} - \text{mL of supernatant}}{\text{Sample weight (g)}}\times 100 \quad (1)$$

WOAC = Water or oil absorption capacity

Swelling capacity: Swelling capacity was determined according to Ukpabi and Ndimele[13]. Exactly 10 g of sample was placed in a 100 mL graduated cylinder and water was added up to 50 mL. The top of the graduated cylinder was tightly covered and the contents were mixed by inverting the cylinder. The suspension was inverted again after 2 min and allowed to stand for an additional 30 min. The volume occupied by the sample was measured after 30 min. The swelling capacity was calculated using Eq. 2:

$$SC = \frac{\text{Final volume of the sample} - \text{initial volume of sample}}{\text{Initial volume of the sample}} \times 100 \quad (2)$$

SC = Swelling Capacity

Preparation of rice bran-incorporated noodles: In the production of composite flour noodles, 2, 5, 10, 15 and 20% of wheat flour was replaced by rice bran. A sample of 100% wheat flour was prepared as a control. Rice bran, wheat flour and all other ingredients (egg, soybean oil, salt, gelatine and sodium benzoate) were weighed separately and all ingredients were mixed together manually. The dough was rounded and allowed to stand at ambient temperature for 20 min. The dough was passed through the reduction rolls of a noodle-making machine. The thickness of the dough sheet was reduced to 6 mm. Dough sheets were extruded into noodle strips by rotating the handle of the machine after placing the dough on the cutting and forming surface. The noodle strips were dried at 50°C for 4-4.5 h in a drying oven (JSON-150, Rep. of Korea). The different samples of noodles were kept in a low-density polyethylene (LDPE) pack for further analysis.

Chemical properties

Antioxidant activity or DPPH radical scavenging activity: The DPPH radical scavenging capacity of each extract was determined according to Miliauskas *et al.*[14]. A mixture containing DPPH (2,2-diphenyl-picrylhydroazyl) changes from deep violet to a yellow solution. The higher the antioxidant activity, the faster the discoloration rate. The absorption was measured using a spectrophotometer (MODEL: T60 U, PG Instruments Limited, United Kingdom) at 515 nm, which yielded the percent inhibition of the sample based on the following equation:

$$\left[\begin{array}{c}\text{DPPH}\\ \text{Scavenged}(\%)\end{array}\right] = \frac{\text{Absorbance of DPPH solution} - \text{Absorbance in the presence of sample extract}}{\text{Absorbance of DPPH solution}} \times 100 \quad (3)$$

Phenolic compounds: The total phenolic content was determined by the method of Singleton and Rossi[15] using Folin-Ciocalteu reagent and by measuring the absorbance of sample extracts at 765 nm against a blank solution; the content was expressed as gallic acid equivalents (mg GAE g^{-1} dry weight).

Free fatty acids: The standard AOAC procedure[16] was followed to determine free fatty acids. Approximately 10 g of ground sample was placed in a flask. Then, 50 mL of benzene was added; after 30 min, free fatty acids were extracted from the solution by filter paper. Approximately 5 mL extract was placed in a flask to which 5 mL benzene, 10 mL alcohol and 2 mL phenolphthalein as an indicator were added and titrated against 0.02N KOH.

The percentage of free fatty acids in most samples were calculated as oleic acid following Eq. 4:

$$\left[\begin{array}{c}\text{Free fatty acid as}\\ \text{oliec acid}(\%)\end{array}\right] = \frac{(\text{Titrant volume} - \text{blank volume}) \times \text{normality of alkali} \times 28.2}{\text{Sample weight}} \quad (4)$$

To convert percentage of free fatty acids (as oleic) to acid value, multiply the percentage of free fatty acids by 1.99.

Cooking quality of noodles: The cooking qualities of the dried noodles were evaluated with respect to cooking time, cooking loss and water uptake according to Gatade and Sahoo[17].

Cooking time: Optimal cooking time was evaluated by observing the time of disappearance of the core of the noodle strand during cooking (every 20 sec) by squeezing the noodles between two transparent glass slides.

Cooking loss: The cooking loss was determined by measuring the amount of solid substance lost to cooking water. Exactly 10 g of noodles were placed into 100 mL of boiling water in a 500 mL beaker. Cooking water was collected in a preweighed glass dish, placed in a hot air oven at 105°C and evaporated to dryness. The residues were weighed after cooling in desiccators to determine cooking loss. The cooking loss was calculated by measuring the amount of solid residues remaining in the cooking and rinsing water after drying.

Water uptake: The water uptake was calculated as the difference between the weight of cooked noodles and the weight of dried noodles. The cooked noodles were placed on filter paper for 5 min before weighing to blot the excess adhered water.

Sensory evaluation: The sensory evaluation of noodle samples was performed by semi-trained panel members of the

Department of Food Technology and Nutritional Science, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh. The sensory attributes, such as appearance, color, taste, flavor, texture, stickiness and overall acceptability, were evaluated by the judges using a 9-point hedonic score system. Each panelist awarded the product a score of 9-1, ranging from 'like extremely' to 'disliked extremely', to determine the most suitable composition of noodles.

Statistical analysis: Data were analyzed using analysis of variance. Duncan's multiple range test was used to determine significant differences among the samples. Data were analyzed using the statistical package for social science (SPSS) version 20.00, (SPSS Inc., Chicago, IL, USA), at the 0.05 level.

RESULTS AND DISCUSSION

Proximate composition of rice bran and wheat flour: Analysis of rice bran and wheat flour for proximate composition showed that rice bran was a rich source of fat, dietary fiber and protein (Table 1).

Functional properties of rice bran and wheat flour: Functional properties are those characteristics that govern the behavior of nutrients in food during processing, storage and preparation and in turn, they affect food quality and acceptability. The functional properties analyzed for both the rice bran and the wheat flour were bulk density, water absorption capacity, oil absorption capacity and swelling capacity (Table 2).

The bulk density of rice bran (0.354 g/cm^3) was significantly ($p<0.05$) lower than that of wheat flour (0.632 g/cm^3). The bulk density of rice bran reported by Sudha *et al.*[18] was 0.34 g/cm^3. This is similar to the results obtained in the present study. The bulk density obtained for wheat flour (0.68 g/cm^3) was similar to the previous findings obtained by Islam *et al.*[19].

Rice bran had a higher water absorption capacity (2.33 mL g^{-1}) than wheat flour (1.66 mL g^{-1}). However, the difference between them was not statistically significant ($p>0.05$) (Table 2).

The oil absorption capacity was also slightly higher in rice bran (3.33 mL g^{-1}) than in wheat flour (2.66 mL g^{-1}). The lower oil absorption capacity of wheat flour could be due to a low amount of hydrophobic proteins, which would not facilitate the interaction between proteins and oil, resulting in a decrease in the oil absorption capacity[20].

Table 1: Proximate composition of rice bran and wheat flour

Parameters (%)	Parboiled rice bran	Wheat flour
Moisture	7.73±0.009^b	11.36±0.008^a
Ash	12.66±0.007^a	1.30±0.019^b
Protein	20.87^a	18.18^a
Fat	28.03^a	1.16^b
Crude fibre	6.88^a	3.00^b
Carbohydrate	23.83^b	65.00^a

Each result is of three determinations. Values are expressed as Mean±standard deviation. Values followed by the different letter in the same row are significantly different ($p<0.05$)

Table 2: Functional properties of rice bran and wheat flour

Parameters	Rice bran	Wheat flour
Bulk density (g/cm^3)	0.354±0.002	0.632±0.008
Water absorption capacity (mL g^{-1})	2.330±0.05	1.660±0.05
Oil absorption capacity (mL g^{-1})	3.330±0.05	2.660±0.05

Rice bran exhibited significantly ($p>0.05$) higher swelling capacity (6.33 mL g^{-1}) than wheat flour (4.33 mL g^{-1}). Similar results were revealed by Sweta and Vijayalakshmi[9]. The higher swelling capacity of rice bran resulted in the greater water binding capacity of bran particles due to the presence of fiber[3]. The high swelling power suggests that rice bran could be useful in food products where swelling is essential, such as noodles.

Proximate composition of control and rice bran-incorporated noodles: The chemical compositions of the control and rice bran-incorporated noodles varied widely (Table 3). Rice bran addition significantly ($p<0.05$) contributed to the increase in the ash, crude fiber, fat and protein contents of noodles, especially at the levels ranging from 15-20%. This indicates that rice bran is an excellent source of dietary fiber, fat, protein and minerals. Similar results were reported by Maria *et al.*[21].

Cooking quality parameters of noodles: The cooking quality of the control and rice bran-incorporated noodles differed slightly (Table 4). The results revealed that the optimum cooking time of noodles decreased, whereas cooking loss and water uptake during cooking increased with the increase in the level of rice bran in the noodles. This indicates that rice bran absorbs water in greater amounts than wheat flour. This is associated with the fact that the bran particles disrupt the gluten matrix, providing a path of water absorption and requiring a reduced cooking time[22]. Similar findings were reported by Nithiya *et al.*[23].

Gruel or cooking loss is the total content of solids leached out in gruel obtained from the cooked noodles. A low amount of solids in cooking water indicates good cooking quality[24]. The addition of rice bran resulted in higher cooking loss and

Table 3: Chemical composition of control and rice bran incorporated noodles

Parameters	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
Moisture (%)	10.55±0.01[b]	13.00±0.01[a]	12.95±0.01[a]	12.00±0.13[ab]	10.50±0.02[b]	7.50±0.03[c]
Ash (%)	1.95±0.01[d]	2.33±0.0[cd]	2.65±0.0[bcd]	2.95±0.0[abc]	3.40±0.00[ab]	3.60±0.00[a]
Protein (%)	11.54±0.19[c]	14.22±0.3[bc]	16.21±2.4[abc]	17.96±0.0[ab]	18.10±1.9[abc]	18.34±0.3[ab]
Fat (%)	2.08±0.00[d]	2.46±0.00[e]	5.80±0.00[c]	9.23±0.00[b]	9.90±0.00[b]	14.30±0.02[a]
Crude fibre (%)	2.03±0.05[f]	3.48±0.02[e]	4.04±0.02[d]	6.11±0.03[c]	8.08±0.02[b]	9.90±0.00[a]
Carbohydrate (%)	71.81±0.0[a]	64.99±0.0[b]	58.36±0.0[c]	51.85±0.0[d]	49.98±0.0[e]	46.35±0.0[f]

Each result is of three replications. Values are expressed as Mean±standard deviation. Values with different subscript in same raw are significantly different at 95% level. Here, Sample 1 = Rice bran: Wheat flour- 0: 100, Sample 2 = Rice bran: Wheat flour- 2:98, Sample 3 = Rice bran: Wheat flour- 5:95, Sample 4 = Rice bran: Wheat flour- 10:90, Sample 5 = Rice bran: Wheat flour- 15:85, Sample 6 = Rice bran: Wheat flour- 20:80

Table 4: Cooking quality parameters of control and rice bran incorporated noodles

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Cooking time (min)	7.00	6.50	6.50	6.50	6.00	6.00
Cooking loss (%)	11.72	11.56	11.68	12.40	15.80	20.16
Water uptake (%)	180.00	193.34	193.52	199.40	211.06	212.34

Table 5: Mean sensory score with SD value of rice bran incorporated noodles

Sensory attributes	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
Appearance	8.85±0.37	8.42±0.53	8.85±0.37	7.85±0.69	7.42±0.53	6.42±1.13
Color	9.00±0	8.42±0.53	8.85±0.37	7.85±0.89	7.42±0.53	6.71±0.75
Flavor	8.71±0.48	8.57±0.53	8.71±0.48	8.28±0.48	7.57±0.53	6.85±0.69
Taste	8.85±0.37	8.42±0.53	8.85±0.37	8.14±0.69	7.28±1.10	6.71±0.75
Texture	8.85±0.37	8.28±0.48	8.57±0.53	7.57±0.53	7.42±0.78	6.28±0.48
Stickiness	8.85±0.37	8.42±0.78	8.28±0.75	8.14±0.89	8.14±1.20	7.42±0.97
Overall acceptability	9.00±0	8.57±0.53	8.85±0.37	8.14±0.69	7.71±0.48	6.42±0.53

9-point hedonic scale: 9 = Like extremely 8 = Like very much 7 = like moderately 6 = Like slightly 5 = Neither like or dislike 4 = Dislike slightly 3= Dislike moderately 2 = Dislike very much 1 = Dislike extremely. Values are expressed as means±standard deviation

the difference was found to be significant for all samples. The greater cooking losses from noodles made with rice bran than with whole wheat flour are due to disruptions in the gluten matrix by bran particles, along with the presence of water-soluble components within the bran and aleurone layers. These results are similar to those reported by Kaur *et al.*[22].

In the case of water uptake, the control noodles had the lowest water absorption (180%) and 20% bran-incorporated noodles had the highest water absorption (212.34%) during cooking. Similar findings were reported by Kaur *et al.*[22] and Sudha *et al.*[18].

Sensory evaluation of control and rice bran-incorporated noodles: The respondent scoring points using the 9-point hedonic scale were tabulated and analyzed statistically (Table 5).

Generally, compared with the control, the overall sensory quality of noodles decreased with increasing substitution level. However, for the taste attribute, noodles with 5% rice bran were comparable to the control. Noodles with 15 and 20% addition of rice bran produced a bitter taste and thus acquired very low scores. As expected, noodles with the addition of rice bran above 10% had a lower color acceptance compared to others due to their dark color. The acceptability of noodle appearance, texture, stickiness and flavor was the best for the control sample and the noodles containing 5% rice bran. All the sensory attributes for noodles fortified with more than a 10% level of bran were significantly ($p<0.05$) lower than those of the control. An increasing addition of rice bran to noodles resulted in a slight decrease in sensory scores given by the panelists for the different attributes studied. However, all noodles prepared with rice bran were moderately and slightly liked by all the panelists. Among the noodle samples containing rice bran, the sample with 5% rice bran received the highest sensory scores, which were statistically ($p<0.05$) similar to those of the control.

Chemical properties of control and rice bran-incorporated noodles: The free fatty acid percentage was the lowest for control noodles. The contents of free fatty acids (%) in the rice bran-incorporated noodles increased with increasing fortification level (Fig. 1a) of rice bran and noodles prepared with 20% rice bran had the maximum fat percentage (3.62%). The higher fat and oleic acid (monoun saturated fatty acid) contents in rice bran may have contributed to the higher fatty acid composition of the bran incorporated in the noodles. A previous study reported that rice bran-enriched pasta supplemented at the 15% level exhibited maximum values of free fatty acids (%)[22].

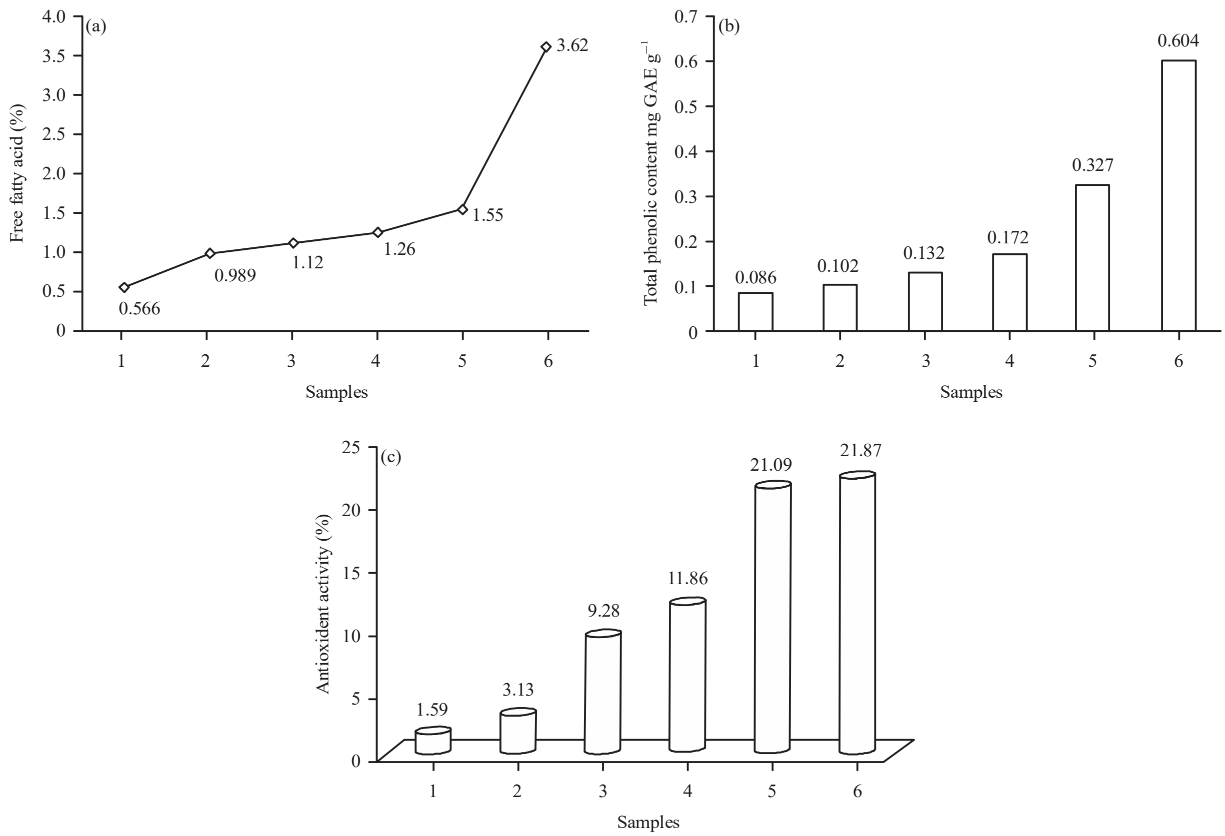

Fig. 1(a-c): Percentage of (a) Free fatty acid content as oleic acid, (b) Total phenolic content and (c) Antioxidant activity of rice bran incorporated noodles sample

Phenolic compounds have gained much attention due to their antioxidant activities and free radical-scavenging abilities. The total phenolic content was the highest for 20% bran noodles (0.604 mg GAE g^{-1}) and it decreased as the level of supplementation of rice bran in the noodles decreased (Fig. 1b). As rice bran is a rich source of various phenolic compounds, their percentage is naturally higher in noodles with elevated levels of rice bran supplementation. Maria *et al.*[21] and Nithya *et al.*[23] reported similar results in their research.

Rice bran-incorporated noodles had marked antioxidant activity in comparison with control noodles (Fig. 1c). The highest antioxidant activity was observed in the 20% bran-incorporated noodles (21.87%). Noodles made from 100% wheat flour showed negligible antioxidant activity compared to others (1.59%). The reason behind this is the higher antioxidative properties of rice bran. A similar result was also found by Nithya *et al.*[23].

CONCLUSION

Wheat flour can be successfully substituted with rice bran up to the 5% level to yield functional noodles of enhanced nutritional quality with acceptable sensory attributes. Noodles with this composition attained higher overall acceptability in sensory rating by panelists, while the level of acceptability decreased with the increase in the bran portion due to its bitter taste and dark color. The antioxidant activities and total phenolic content of the bran-incorporated noodles were significantly higher than those of the control. However, no significant variation in cooking time was obtained among the noodle samples. Although, the incorporation of rice bran improved the nutritional and biochemical properties of the noodles, the gruel loss also increased with bran incorporation. It is evident from the study that rice bran, as a natural and inexpensive nutraceutical rich material, could be used in the preparation of consumer-acceptable and nutritionally improved noodles.

This study discovered the critical area of value addition of waste produced from the rice milling industry that many researchers have not been able to explore. This valuable information on nutritionally enriched fortified noodle preparation is not only worthy of making a necessary decision from a manufacturing point of view but is also helpful to make a choice from a consumer point of view. Thus, a new theory on the application of this functional ingredient has been devised.

ACKNOWLEDGMENT

The authors would like to acknowledge Department of Food Technology and Nutritional Science and university research cell, MBSTU for logistic and financial support of the research project.

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