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Physicochemical and sensory characteristics of brown rice (*Oryza sativa*) noodles substituted with mung bean (*Vigna radiata*) powder

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ABSTRACT

Introduction: Rice noodles are widely consumed as a staple food in Asia. The main ingredient of rice noodle is polished white rice flour which lacks in nutritional components. Substitution of white rice flour with brown rice flour often results in noodles with better nutrient content but less favourable for cooking, textural and sensory characteristics. Thus, this study aimed to develop and characterise brown rice noodles substituted with mung bean powder at the level of 5% (g/100 g) and compared with other formulations. **Methods:** Four formulations of rice noodles were prepared using: a. 100% white rice flour; b. 100% brown rice flour; c. white rice flour with 5% mung bean powder; and d. brown rice flour with 5% mung bean powder. The rice noodles were produced by conventional extrusion method and evaluated for their proximate composition, cooking qualities and sensorial properties. **Results:** The results of proximate analysis indicated that protein (8.70g/100 g), dietary fibre (3.10g/100 g), ash (1.50g/100 g) and fat (2.40g/100 g) contents were significantly ($p<0.05$) higher in mung bean powder substituted brown rice noodles than that of white rice noodles (control). The blending of mung bean powder with brown rice flour had significantly reduced noodle cooking time and cooking loss. The sensory evaluation revealed that mung bean powder substituted brown rice noodles had similar consumer preference to control sample. **Conclusion:** The blending of mung bean powder with brown rice flour had substantially improved the nutritional value and cooking qualities of the brown rice noodles while maintaining consumer acceptability.

Keywords: Brown rice, mung bean, noodles, physicochemical, sensory

INTRODUCTION

Noodles are globally consumed especially in Asian countries such as China, Korea, Malaysia, the Philippines and Thailand (Akanbi *et al.*, 2011). Rice noodles are the most consumed form of rice product next to cooked rice grain in Asia (Ahmed *et al.*, 2016). Rice noodles are regarded as traditional food in China where the noodles are known as *bee hoon* (Li *et al.*, 2015). According to Li *et al.* (2015), the ease of preparation has made rice noodles popular as home-cooked foods and in restaurants in southern China for many years.

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Rice (*Oryza sativa L.*) is a staple food for many countries. During the milling process, rough rice is milled to produce polished edible white rice grain by removal of the rice bran (brownish layer). This process generates rice bran and rice hull as by-products which are considered as agricultural waste (Friedman, 2013). According to Issara & Rawdkuen (2016), rice bran contains high nutritional components such as protein, lipid and phytochemicals and is beneficial for human health in terms of good antioxidant, antibiotic as well as anti-cholesterolemic values. Nutritious brown rice with intact bran and germ layers are of interest for development of various functional foods including brown rice noodles. However, findings by Baek & Lee (2014) indicated the need for future study as the percentage of cooking loss of brown rice noodles was higher than that of white rice noodles which leads to sticky texture of the former sample.

Blending of legume with white rice flour (WRF) to produce nutritious and good quality rice noodles have been reported by Yadav, Yadav & Kumar (2011), Wu *et al.* (2015) and Rathod & Annapure (2017). Legumes are valuable sources of nutrition in a healthy diet. They are known as dietary source of protein, fibre and low glycemic index carbohydrate with potential health benefits (Lee, Puddey & Hodgson, 2008; Clemente & Olias, 2017; Becerra-Tomas *et al.*, 2018). However, different legumes have unique physicochemical and functional properties (Ma *et al.*, 2017). Selection of legumes to be blended with rice flour is crucial to produce good quality noodles.

Mung bean (*Vigna radiata*) starch has been regarded as an excellent material in the processing of high quality starch noodles (Tan, Li & Tan, 2009). Mung bean is a type of green legumes which contains approximately 62.3g of carbohydrates, 27.5g of protein, 1.9g of fat, 4.6g of fibre, and substantial amount of vitamins and minerals (Mubarak, 2005). Commonly produced product from this legume is the transparent, glossy and elastic mung bean starch noodle (Tan *et al.*, 2006).

Therefore, this study aimed to study the effects of including mung bean powder (MBP) on the physicochemical and sensory characteristics of brown rice noodles.

MATERIALS AND METHODS

Raw materials and equipment

The raw materials used for this study were WRF, brown rice flour (BRF), MBP, salt and water. Stone ground WRF, whole grain BRF and mung bean (Bob's Red Mill brand) were procured from a grocery store in Selangor. The equipment used were electronic weighing scale, Panasonic blender (PSN-MX900M model), noodle extruder and steamer.

Preparation of MBP

Mung beans were soaked in water overnight. The soaked beans were drained completely the next day and left to dry at room temperature (25°C) for 24 hours. The dried beans were then ground to powder using a blender and sieved using a 40 mesh screen to obtain uniform particles. The powder was packed in airtight plastic bags and stored in a refrigerator (4˚C) until further use.

Preparation of noodles

The dough for noodles was prepared by mixing 500g-batch flour with salt and water. Four formulations of the noodles were developed, namely 100% WRF, 100% BRF, 95% WRF and 5% MBP, and 95% BRF and 5% MBP (Table 1). Preliminary studies were carried out to determine the optimum level of MBP to be added to white rice or BRF. It was found that addition of >5% MBP resulted in slightly bitter taste of the noodles.

Table 1. Formulations of noodles prepared from WRF, BRF, and mixture of rice flour and MBP

Ingredients	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF + 5% MBP*	*95% BRF + 5% MBP*
WRF (g)	500	0	475	0
BRF (g)	0	500	0	475
MBP (g)	0	0	25	25
Salt (g)	8	8	8	8
Water (ml)	185	185	185	185
Total (g)	693	693	693	693

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
Adapted and modified from Garcia *et al.* (2016)

The noodles that were prepared with 100% white rice (WRF) and brown rice (BRF) were considered as controls. The ingredients as indicated in Table 1 were mixed and dough was kneaded manually. The dough was extruded through a small hand operated noodle extruder to produce noodles with a diameter of 2mm. The rice noodles were next steamed (80-90˚C) for ten minutes prior to drying to facilitate starch gelatinisation (Ahmed *et al.*, 2016). The noodles were completely dried at room temperature (25˚C) for 12 hours and then packed in airtight plastic bags until further analysis.

Proximate analysis

AOAC methods (2005) were used to analyse the following proximate composition of noodles: moisture, fat, dietary fibre, protein and ash. Moisture content was determined by calculating the loss in weight after oven-drying of samples (AOAC 934.01). Fat was determined by Soxhlet's method (AOAC 963.15) while Kjedahl method (AOAC 960.52) was used for determining protein content. Dietary fibre was determined gravimetrically (AOAC 985.29) while ash was determined by incineration of samples using muffle furnace (AOAC 923.03). The carbohydrate content was calculated by difference, subtracting from 100 the values of moisture, ash, protein, fat and fibre. The energy value was estimated using the Atwater factors (carbohydrates = 4.0kcal g^{-1}; lipid = 9.0kcal g^{-1}; protein = 4.0kcal g^{-1}) as described by Garcia *et al.* (2016).

Cooking qualities

The cooking qualities of the rice noodles were evaluated with respect to cooking time, cooking loss and water uptake as reported by Gatade & Sahoo (2015). Noodles were cut into 3 cm length prior to cooking. Ten grams of dried rice noodles were boiled in 200 ml of distilled water to determine the cooking qualities.

Cooking time

Cooking time was determined by the removal of a piece of noodle every two minutes and pressing the noodle between two pieces of glass slides. Optimum cooking of rice noodles was achieved when the centre of the noodles becomes soft and transparent and the white core of noodles has faded away. Cooking was stopped by rinsing the noodles briefly in distilled water (Gatade & Sahoo, 2015).

Cooking loss

Cooking loss (%) was determined by measuring the amount of solid substance lost into the cooking water. Cooking water was collected in a pre-weighed glass dish and placed in a hot air oven at temperature of 105˚C and evaporated to dryness. The dry residue was weighed and cooking loss was calculated based on the following equation (Gatade & Sahoo, 2015).

Cooking loss (%) = [dried residue (g) / noodle weight before cooking (g)] x 100

Water uptake

Water uptake (%) was calculated as shown in the following equation. Cooked noodles were rinsed with water and drained for 30 seconds then weighed to determine the gain in weight of noodles (Purwandari *et al.*, 2014).

$$\text{Water uptake (\%)} = \frac{[\text{weight of cooked noodles (g) - weight of uncooked noodles (g)}]}{\text{weight of uncooked noodles (g)}} \times 100$$

Sensory evaluation

Sensory evaluation was carried out using Hedonic test with 30 semi-trained panellists consisting of students from Food Service Technology program at Management and Science University (MSU). Ethics approval was obtained from University Ethics Committee, MSU for sensory analysis. The attributes evaluated were appearance, colour, aroma, taste, texture, mouth feel and overall acceptability of the noodles. The four cooked noodle samples were prepared and filled in identical containers, coded with three-digit random numbers and each sample (10g) was presented with different codes. The randomised orders of the sample were presented one at a time to each panellist. Each panellist was requested to rate the liking on quality attributes using a nine-point hedonic scale, where one and nine represent 'dislike extremely' and 'like extremely', respectively (Ojure & Quadri, 2012; Abidin *et al.*, 2014).

Data analysis

The data obtained was subjected to one-way analysis of variance (ANOVA) and the significant difference between mean values of triplicate analyses of all parameters tested were determined by Tukey's multiple range test (p<0.05) using SPSS version 23.0 (IBM Corp., Armonk, New York).

RESULTS

Proximate composition of rice noodles

Table 2 shows the proximate compositions of four different

Table 2. Proximate composition of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP

Proximate composition (Present as mean±SD, n=3)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF + 5% MBP*	*95% BRF + 5% MBP*
Energy (kcal/100g)	349.0±1.0^{b}	345.0±2.0^{a}	348.0±1.0^{b}	344.0±2.0^{a}
Protein (%)	6.8±0.1^{a}	7.6±0.2^{b}	8.4±0.2^{c}	8.7±0.1^{d}
Carbohydrate (%)	78.7±0.1^{d}	75.3±0.3^{b}	76.2±0.2^{c}	73.5±0.5^{a}
Fat (%)	1.0±0.1^{a}	2.1±0.1^{c}	1.4±0.2^{b}	2.4±0.3^{d}
Ash (%)	0.5±0.2^{a}	1.3±0.1^{c}	0.8±0.1^{b}	1.5±0.2^{c}
Moisture (%)	13.0±0.1^{a}	13.7±0.2^{b}	13.2±0.1^{a}	13.9±0.2^{b}
Dietary fibre (%)	1.2±0.1^{a}	2.7±0.2^{b}	1.4±0.1^{a}	3.1±0.2^{c}

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder

$^{a\text{-}d}$ Means followed by different superscripts indicate significant differences (p<0.05) within row by Tukey's HSD test

Table 3. Cooking qualities of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP

Cooking quality (Present as mean±SD, n=3)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF +5% MBP*	*95% BRF +5% MBP*
Cooking time (min)	6.36±0.05[b]	6.28 ±0.12[b]	5.61±0.37[a]	5.47±0.09[a]
Cooking loss (%)	20.00±2.00[b]	23.33±3.06[b]	18.67±4.62[a]	16.00±4.00[a]
Water uptake (%)	12.40±0.30[a]	12.26±0.55[a]	12.60±0.36[a]	16.00±0.27[b]

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
[a-b] Means followed by different superscripts indicate significant differences ($p<0.05$) within row by Tukey's HSD test

formulations of rice noodles on dry weight basis. Noodles prepared using 100% BRF had significantly higher ($p<0.05$) protein, fat, ash, moisture and dietary fibre content as compared to 100% WRF noodles. It was also observed that 100% BRF noodles had significantly lower ($p<0.05$) carbohydrate than 100% WRF noodles. Meanwhile, among the four of noodles, those developed using 95% BRF + 5% of MBP had the highest dietary fibre (3.10g/100 g) and protein content (8.70g/100 g) with the lowest amount of carbohydrate (73.50g/100 g).

Cooking qualities of rice noodles

Cooking time, cooking loss and water uptake of the four different formulations of rice noodles are shown in Table 3. Rice noodles prepared with the inclusion of MBP took shorter time to cook, approximately one minute earlier than rice noodles prepared using 100% rice flour. Significant reduction ($p<0.05$) of cooking loss was also noted for rice noodles with MBP (16-19%) in comparison to rice noodles without MBP (20-23%). In terms of water uptake, noodles prepared using 95% BRF + 5% MBP had the highest water uptake.

Sensory characteristics of rice noodles

The noodles developed using 95% WRF + 5% MBP had a mean score of 6-7 for most of the sensory attributes (Table 4) with means in the range of 'slightly like' to 'moderately like'. Meanwhile, lower scores were observed for taste and mouth feel attributes for 95% BRF + 5% MBP noodles with a mean score of 5.

Table 4. Acceptability score of rice noodles prepared using WRF, BRF, and mixtures of rice flour and MBP using 9-point Hedonic scale

Sensory attribute (Present as Mean±SD, n=30)	*Noodle Formulations*			
	100% WRF	*100% BRF*	*95% WRF +5% MBP*	*95% BRF +5% MBP*
Appearance	6.83±1.42[a]	6.53±1.53[a]	6.93±1.31[a]	6.63±1.30[a]
Colour	7.33±1.54[a]	6.70±1.47[a]	7.00±1.39[a]	6.67±1.58[a]
Aroma	6.50±1.23[a]	6.83±1.21[a]	6.53±1.28[a]	6.73±1.26[a]
Texture	6.97±1.45[a]	6.47±1.80[a]	6.77±1.63[a]	6.20±1.75[a]
Taste	6.73±1.70[a]	6.13±1.83[a]	6.77±1.55[a]	5.97±1.83[a]
Mouth feel	6.73±1.48[a]	6.00±2.03[a]	6.63±1.54[a]	5.80±1.97[a]
Overall acceptability	6.93±1.48[a]	6.43±2.08[a]	6.93±1.55[a]	6.20±1.85[a]

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder
[a] Means followed by same superscripts indicate insignificant differences ($p>0.05$) within row by Tukey's HSD test

Table 5. Appearance of rice noodles prepared using WRF, BRF, and mixture of rice flour and MBP

Noodle formulation	*Description*
100% WRF	Creamy white colour, long and firm strand, less breakable
100% BRF	Yellowish brown colour, long and less firm strand, easily breakable
95% WRF + 5% MBP	Creamy white colour, long and firm strand, less breakable
95% BRF + 5% MBP	Yellowish brown colour, long and less firm strand, easily breakable

Note: WRF=white rice flour, BRF=brown rice flour, MBP=mung bean powder

However, the mean sensory score of the sensory attributes for all the noodles did not show statistical significant difference (p>0.05).

Appearance of rice noodles

From visual observation, 95% BRF + 5% MBP noodles were darker in colour than the control samples (Table 5). The breakability and surface smoothness of the noodles vary according to formulations.

DISCUSSION

Findings from this study showed that noodles prepared using BRF were more nutrient dense compared to 100% WRF noodles. Higher dietary fibre, protein, fat and ash content in 100% BRF noodles in comparison to that of 100% WRF noodles is contributed by the presence of rice bran contained in the BRF. As reviewed by Issara & Rawdkuen (2016), rice bran is a potential food ingredient which can be a good source of dietary fibre, protein, fat and minerals.

Lower carbohydrate content in 100% BRF noodles as compared to 100% WRF noodles could be attributed to the presence of bran and germ in BRF. These two components of the whole grain are rich in protein, lipid and fibre that resulted in lower starch content in the BRF. In contrast, WRF made from white rice grain, in which the rice bran layer has been removed, has higher starch content resulting in higher carbohydrate content in 100% WRF noodles. Inclusion of 5% of MBP further enriched the dietary fibre, protein and fat content of BRF noodles. Abdul Aziz, Azhar Yusri & Ho (2012) have reported that MBP has 16.1% of protein, 11.5% of moisture, 3.7% of ash, 3.7% of crude fibre, 0.8% of fat and 68.0% of carbohydrate content. This data lends support to the increased level of nutrients observed in 95% BRF + 5% MBP noodles, making it a potential value-added rice noodle.

Besides nutritional values, cooking and organoleptic qualities are equally important for newly developed functional food products. According to Ahmed *et al.* (2016), good quality rice noodles should cook quickly with little cooking loss as it significantly influences the sensory properties of cooked noodles. The cooking time of rice noodles is between 5-9 minutes and the cooking loss values of rice-based noodles ranged from 6-19% (Ahmed *et al.*, 2016). In this study, noodles with the addition of MBP (95% WRF + 5% MBP, 95% BRF +5% MBP) have significantly shorter (p<0.05) cooking time that can be influenced by their gelatinisation properties. As reported by Wu *et al.* (2015), shorter cooking time of noodles was positively correlated with slightly lower peak gelatinisation temperature of noodles prepared using WRF blended with mung bean starch.

Cooking loss is the total solid loss in cooking water (Ahmed *et al.*, 2016). It is also highly vital to maintain structural integrity of noodles throughout the cooking process (Thomas *et al.*, 2014). High cooking loss is undesirable as the high amount of soluble starch leads to cloudy cooking water and sticky mouth feel with lower cooking tolerance (Chen *et al.*, 2002; Thomas *et al.*, 2014). Significant reduction (p<0.05) of cooking loss was noted for rice noodles with MBP (16-19%) in comparison to rice noodles without MBP (20-23%) that can be linked to the higher fibre content of rice noodles with inclusion of MBP. According to Chandra & Samsher (2013), and Kumar & Prabhasankar (2015), the fibre in noodles holds the starch network strongly and prevents starch from leaching out quickly into the cooking water. Besides that, Wu *et al.* (2015) also have suggested that rice noodles with increased amount of MBP has higher amylose content (24%) which results in stronger rice gels and lowers the cooking loss of noodles.

In terms of water uptake, noodles prepared using 95% BRF + 5% MBP had the highest water uptake. This could be attributed to its high fibre and protein contents (Table 2). Fibres and proteins are known for their ability to absorb water (Chandra & Samsher, 2013). Higher percentage of water uptake can also be related to reduced cooking time of noodles (Gatade & Sahoo, 2015). Higher water uptake promotes hydration and swelling of starch granules that reduces the gelatinisation temperature and cooking time (Ahmed *et al.*, 2016).

Sensory attributes of cooked rice noodles include colour, appearance, aroma, taste, texture and overall acceptability (Fari, Rajapaksa & Ranaweera, 2011; Ahmed *et al.*, 2016). Colour is the first parameter assessed by customers in food product. Noodles prepared using 100% WRF and 95% WRF + 5% MBP were noted to have higher acceptability scores for colour (Table 4) on a nine-point hedonic scale as compared to 100% BRF noodles and 95% BRF + 5% MBP noodles. The latter samples might be less favoured by the panellists due to the dull brown colour of the noodles that can be linked to the presence of natural pigments (carotenoids) in rice bran layer which is a component of the BRF. The acceptability score of the cooked noodles' aroma were in the range of 6.50-6.83. Aroma is regarded as a minor quality factor in sensory evaluation especially in cooked noodles due to its minimal effect on a consumer's decision towards the acceptance of a product (Ahmed *et al.*, 2016). In terms of taste and mouth feel, the degree of likeness of 95% BRF + 5% MBP noodles was the least, followed by 100% BRF noodles which might be attributed to the bitter taste of rice bran and MBP. It is known that dietary fibre is an indigestible substance with hard and coarse texture which can generate rough texture of foods (Han *et al.*, 2017). This explains the lower acceptability scores for mouth feel of 100% BRF noodles and 95% BRF + 5% MBP noodles. Although the scores vary, the differences were not statistically significant (p>0.0.5).

Visual observation of the dried noodles was recorded as it is the end product that will attract consumers to purchase. The observation indicated that 95% BRF + 5% MBP noodles were darker in colour than the control (Table 5). The 100% WRF were creamy white while the 95% WRF + 5% MBP noodles were almost as white as the former. Polished rice had its bran removed therefore giving the white rice noodles a creamy white colour. On the other hand, 100% BRF noodles also appeared as darker as the 95% BRF + 5% MBP noodles. This is related to the presence of rice bran in brown rice grains. MBP had little or no effect on the appearance of the rice noodles as only 5% of powder has been substituted with the rice flour.

Noodles developed using 100% WRF were smooth while the 100% BRF noodles had rough surface as the latter is more fibrous than the former. Noodles prepared using 100% WRF and 95% WRF + 5% MBP were long, firm and the strands were less breakable. Meanwhile, noodles developed using 100% BRF and 95% BRF + 5% MBP were long, less firm and the strands were easily breakable that could be related to lower amylose concentration in brown rice. Low amylose concentration can result in high swelling volume of starch granules which could result in softer texture of noodles (Ahmed *et al.*, 2016). However, the texture was maintained throughout cooking process as the noodles were steamed prior to drying process. Steaming is a critical step in rice noodle preparation as it will ensure proper starch gelatinisation which acts as a binder during extrusion (Malahayati *et al.*, 2015; Ahmed *et al.*, 2016).

CONCLUSION

Noodles made from BRF blended with MBP had good physicochemical and sensorial properties. These noodles had substantially higher amounts of protein and dietary fibre and were comparatively lower in carbohydrate to that of white rice noodles. The noodles also exhibited good cooking qualities, especially shorter cooking time and lower cooking loss which are considered as desirable characteristics of rice-based noodles. Consumer acceptance level is moderate for the developed brown rice noodles substituted with MBP which is comparable to the white rice noodles. Findings from this study indicated that noodles of acceptable nutritional, cooking and sensorial properties could be produced from BRF with some blend of MBP.

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Authors' contributions

SDM, carried out the experimental work, performed the data analysis and prepared the draft of the manuscript as the main author; SPG, designed the study, advised on the experimental work and data analysis, and reviewed the manuscript.

Conflict of interest

The authors have no conflict of interest.

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