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Development of Pasta Products from High-Iron Rice and Iron-Fortified Rice Flour

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ABSTRACT

Rice pasta in the form of macaroni was developed from two brown rice varieties, Suphan-Buri 90 (SB) and Homnin 313 (HW). SB is a normal breeding while HW is a specially hybridized variety. SB brown rice flour gave higher amylose content (30.4% w/w) than that of HW (19.1%) but lower iron (1.24 mg/100 g) compared to 2.04 mg/100 g found in HW. To determine the physicochemical properties and acceptability of the rice pasta, different percentages (5, 10, 15%) of modified starch and rice starch were used. The results indicated that adding 15% modified starch and 15% rice flour could produce the rice pasta with highest firmness and stickiness. The rice pasta was fortified with ferrous sulphate at the levels of 0, 30, 60% iron of RDI per serving to determine its sensory acceptability. The results showed that increasing the amount of iron content in the mixtures, decreased the L* value and increased a* value for the color of rice pasta. Fortification of ferrous sulphate at 30% iron of RDI resulted in higher preference scores in terms of color and overall acceptability comparing to fortification of ferrous sulphate at 60% iron of RDI. The percentage of the acceptability scores for the pasta made from HW and SB brown rice flour were 82 and 88%, respectively.

Key words: rice pasta, iron, brown rice flour, texture

INTRODUCTION

Iron deficiency is considered to be the common nutritional deficiency worldwide and affects approximately 20% of the world population (Martinez-Navarrete *et al.,* 2002). Women and young children are especially at risk. Iron deficiency effects include lower growth rate and impaired cognitive scores in children and poor pregnancy outcome and lower working capacity in adults (Walker, 1998). The fortification of foods is often regarded as the most cost-effective, long-term approach to reduce prevalence of iron deficiency (Hurrel, 1997).

A combination of an iron fortificant compound and food vehicle must be selected which is safe, acceptable to and consumed by the target population. It does not affect the organoleptical qualities and shelf-life of food vehicles, and provides iron in a highly stable, bioavailability form (Martinez-Navarrete *et al.,* 2002).

The different forms of iron have been used to fortify different food products and it could be divided into four groups (Hurrel, 1997) ; freely water soluble (ferrous sulfate, ferrous gluconate, ferrous lactate, ferric ammonium citrate) ; soluble in diluted acids (ferrous fumarate, ferrous

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succinate, ferric saccharate) ; water soluble (ferric orthophosphate, ferric pyrophosphate) and Fe powders and protected iron compounds (Fe EDTA and hemoglobin).

Food vehicles and iron compounds have to be compatible in order to optimize iron bioavailability and to avoid rancidity in food. Cereal flour and products are currently the most frequently used for iron fortification. However, these products present two main disadvantages for iron fortification; containing high levels of phytic acid (potential inhibitor of iron absorption) and extremely sensitive to lipid oxidation (Martinez-Navarrete *et al.,* 2002).

Rice can serve as a suitable vehicles for iron fortification as it constitutes a very significant source of calories worldwide and especially in developing countries (Kapanidis, *et al.,* 1996). For this study high iron rice was introduced to prepare rice pasta. Thai recommended daily intakes (RDI) of dietary iron for healthy Thai people is 15 mg per day (Ministry of Public Health, Food and Drug Administration, 2002).

The objective of this study was to develop rice pasta from high iron rice and iron-fortified rice flour with ferrous sulfate at levels of 0, 30, 60% iron of RDI per serving and furthermore to evaluate the physical, chemical properties of the products.

MATERIALS AND METHODS

Preparation of raw materials and properties.

Brown rice variety of Suphan-Buri 90 (SB) was purchased from Rice Research Center Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives. Another brown rice, Homnin 313 (HW) variety, a specially hybridized variety of high iron content, was donated by Rice Gene Discovery Unit, National Center for Genetic Engineering and Biotechnology, Kasetsart University, Kampangsaen. All brown rice flours samples were prepared by dry milling method using pin mill (Alpine, Augbury, Germany) with particle size approximately 100-150 mm. Iron in the form of dry ferrous sulphate was provided by the Asia Drug Chemicals, Ltd. Acetylated modified tapioca starch (M) and native, nonwaxy rice starch (RS) were obtained from Adinop Co., Ltd. The flours samples were analyzed for moisture, protein, fat, ash, dietary fiber according to AOAC (2000).

Pasta preparation

Rice macaroni were prepared from brown rice flour and added with M and RS at the levels of 0, 5, 10 and 15 g/100 g. No M and RS added in pasta formulation served as control sample. A mixture of flour and water (60 g/100 g) mixed by KitchenAid mixer (Model K5SS, Heavy Duty, USA) for 5 min and cooked using a steamer with boiling water for 2 min. The cooked dough was then kneaded by the KichenAid mixer for 2 min in order to distribute the heat to gelatinize starch in the dough, then was extruded through a pasta machine (Regina Atlas, Marcato, Italy) with a 10 mm macaroni die. The extruded pasta had the dimension of 50 mm in length, hollow and 1.0 mm thickness. The extruded pasta was dried at 45°C for 3.30 h in hot air oven (WTB, Binder, Germany). Each formulation was prepared in duplicates.

Experimental design

A 3 × 3 full factorial design was used. Brown rice flour, HW in pasta formulation was added with 5, 10, 15% modified starch and 5, 10, 15% rice starch of rice flour (w/w). The best formulation based on firmness value and stickiness by texture measurement, was used for fortification with three levels of iron content (0, 30, 60% iron of RDI).

Pasting properties

Each brown rice flour was analyzed in duplicate for pasting properties using a Rapid

Visco Analyser (RVA) model 3 D (Newport Scientific Pty Ltd., Australia). A suspension of 3.0 g flour (dry basis) in 25 g of distilled water was heated from 50 to 95°C at the rate of 12°C/min with constant stirring at 160 rpm and held at 95°C for 2.5 min then cooled to 50°C at the rate of 13°C/min and held for 2 min. The total cycle was 12.5 min. Pasting temperature was recorded as the temperature at which an increase in viscosity was first observed. The reported values included pasting temperature (°C), peak viscosity (RVU), final viscosity (RVU), trough (lowest viscosity, RVU), breakdown (different between peak viscosity and trough, RVU), setback from peak (the difference between final viscosity and peak viscosity, RVU) and setback from trough (the difference between final viscosity and trough, RVU).

Amylose determination

The amylose content (%) was determined according to the method of Juliano (1971). Duplication was performed for each flour sample.

Iron determination

The pasta samples were analysed for total iron content according to AOAC (2000) by using Inductively Couple Plasma–Atomic Emission Spectrophotometer (ICP–AES). The iron content of pasta were calculated in % RDI. The recommended daily intake (RDI) of dietary iron is 15 mg/day, and serving size of sample is 50 g. All measurements were carried out in duplicate.

Color measurement

Colorimetric measurements of the experimental flour and noodle were determined in triplicate at three random locations on the surface of each sample using spectrophotometer (Spectraflash 600 plus, Datacolor International, USA). The CIE color values were recorded as L* = lightness (0 = black, 100 = white), a* (-a* = greenness, + a* = redness) and b* (-b* = blueness, +b* = yellowness).

Texture measurement

The textural qualities of the cooked pasta, in firmness and stickiness were measured on a Texture Analyser model TA – XT_{2i} , Stable Micro System Ltd. (Surrey, England) using cylinder probe 100 mm, pretest speed 2.0 mm/s, test speed 2.0 mm/s, post test speed 2.0 mm/s, strain 75%. The pasta were tested individually, the results of each sample was an average of ten measurements.

Sensory acceptability

The cooked samples were evaluated by 18 untrained panelists, using balanced incompleted block design (t = 10, k = 5, r = 9, b = 18, r = 4). A 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) was used to evaluate acceptability of product attributes (color, flavor, elasticity, smoothness, firmness, and overall acceptance). For the consumer acceptance of rice pasta the samples were evaluated by 100 untrained panelists. The panelists were asked to evaluate acceptability of the best sample from the experiments.

Statistical analysis

Experimental data and data collected from the sensory evaluation were analysed using ANOVA and mean procedure of SAS (1989). Duncan's Multiple Range Test was applied to determine the significant differences among the means at 95 % confident levels.

RESULTS AND DISCUSSION

1. Properties of raw materials

SB brown rice was normal breeding rice, having white color seed. HW which was specially hybridized between Khao-Dowk Mali 105 and Homnin, contained white color seed.

Chemical compositions of raw materials

are shown in Table 1. The protein content of SB brown rice flour (9.99%) was significantly lower than high iron HW brown rice flour (11.05%). The amylose content of SB brown rice flour (30.4%) was greater than HW brown rice flour (19.1%). The amylose content of acetylated modified tapioca starch and native, nonwaxy rice starch were shown at 17.1% and 22.2%, respectively. The iron content of HW brown rice flour (2.04 mg/ 100 g) was higher than the regular breeding SB brown rice flour (1.24 mg/100 g).

For the color measurement in terms of L* a* b* of raw materials were significantly different (Table 2). The HW brown rice flour was darker and more reddish (L* = 86.72, a* = 1.06, b* = 10.43) than SB (L* = 89.09, a* = 0.59, b* = 10.14). Modified starch and rice starch were whiter than other flour samples (L* = 97.08-98.32, a* = 0.06-0.14, b* = 1.93-2.03).

The results from RVA measurement are shown in Table 3. The results revealed that the peak viscosity of HW brown rice flour (447.17 RVU) was greater than SB (329.92 RVU). Peak viscosity could relate to thickening property, therefore, HW brown rice flour has higher thickening than SB brown rice flour. The modified starch showed the highest peak viscosity value which implied that this starch can improve swelling and water absorption of the mixes more than the other flour samples. The final viscosity of SB and HW brown rice flour was 654.25 and 400.75 RVU, respectively. The amylose content of SB and HW brown rice flour was 30.4% and 19.1%, respectively. The final viscosity of rice

Table 1 Chemical composition of raw material used in rice pasta production (n = 2).

Brown rice flour	Moisture %	% dry basis					
		Protein	Fat	Ash fiber	Dietary content	Amylose mg / 100 g	Fe content
Suphanburi 90 (SB)	10.34a	9.99b	3.80a	1.47a	3.95a	30.40a	1.24b
Homnin 313 (HW)	11.61a	11.05a	3.92a	1.57a	3.98a	19.10b	2.04a

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

Table 2 Color measurement of raw materials (n = 2).

Rice flour and starch	L*	a*	b*
Suphanburi 90 (SB)	89.09b	0.59b	10.14a
Homnin 313 (HW)	86.72b	1.06a	10.43a
Modified Starch (M)	97.08a	0.06c	2.03b
Rice Starch (RS)	98.32a	0.14c	1.93b

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

Table 3 Pasting properties of raw materials (n = 2).

Flour and starch	RVU						
	Peak viscosity	Trough	Final viscosity	break down	Set back from peak	Set back from trough	Pasting Temp (°C)
Suphanburi 90 (SB)	329.92c	203.58b	654.25a	126.33c	324.33a	450.67a	72.25c
Homnin 313 (HW)	447.17b	194.92c	400.75b	252.25a	-46.42b	205.83b	75.35b
Modified Starch (M)	550.08a	328.42a	411.33b	221.67b	-138.75c	82.91d	70.30c
Rice Starch (RS)	257.50d	120.16d	224.04c	137.33c	-33.46b	103.88c	83.25a

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

paste is related to the amylose content. Flour with higher amylose content gives higher final viscosity. Lai (2001) reported that rice contained 28.8% amylose had higher final viscosity than the one with 17.9%. The setback from trough values of SB and HW brown rice flour were 450.67 and 205.83 RVU, respectively. The setback from peak of SB were also higher than HW.

Properties of rice pasta

1. Chemical properties

For chemical properties of rice pasta with different ratio of starches as shown in Table 4, the results showed that as the amount of starch increased, the protein content in rice pasta decreased. The protein content of rice pasta with different ratio of starches were significantly different ($P \leq 0.05$). Rice pasta prepared from the 100% HW brown rice flour had average protein content of 10.87%. Adding the brown rice flour with 15% of modified starch and 15% of rice starch could result in decreasing the protein content (5.84%).

2. Physical properties

For the textural characteristics of cooked rice pasta, the composite brown rice ratio with modified starch and rice starch affects on firmness and stickiness (Table 5). As the modified starch and rice starch increased from 5.0 to 15% of rice flour weight, firmness and stickiness increased. The lower firmness value indicates a softer texture of product, therefore the rice pasta of 100% HW brown rice flour had softer texture than other products. Correlation among color parameters, texture properties and protein content were calculated (Table 6). Lightness had significantly negative correlation to a* ($r = -0.987$, $P < 0.01$), b* ($r = -0.870$, $P < 0.01$), protein content ($r = -0.548$, $P < 0.05$) and positive correlation with firmness ($r = 0.593$, $P < 0.01$). Firmness was significantly positive correlated to stickiness ($r = 0.561$, $P < 0.01$) and negative correlated to protein content ($r = -0.906$, $P < 0.01$). Stickiness had significantly negative correlation to protein ($r = -0.578$, $P < 0.01$). Rice pasta made from of HW brown rice flour with 15% modified starch and 15% rice starch had the highest firmness and stickiness. Stickiness of this formulation is significantly different from other samples, therefore, this formulation was chosen to be fortified with iron content at the levels of 0, 30, 60% iron of RDI.

Table 4 Chemical properties of brown rice pasta from Homnin 313 added modified starch and rice starch (n = 2).

Rice pasta	Dry basis	
	% Moisture	% Protein (N × 5.7)
HW : M : RS		
100 : 5 : 5	11.43a	8.24b
100 : 5 : 10	11.59a	7.68c
100 : 5 : 15	11.98a	7.35d
100 : 10 : 5	9.43a	7.06d
100 : 10 : 10	10.79de	6.73e
100 : 10 : 15	9.36e	6.40ef
100 : 15 : 5	9.96cd	6.73e
100 : 15 : 10	11.50c	6.39f
100 : 15 : 15	10.23c	5.84g
100 : 0 : 0	10.15c	10.87a

Means in each column followed by the same letters are not significantly different at $P > 0.05$ as determined by DMRT.

Table 5 Textural characteristic of cooked rice pasta made from brown rice flour Homnin 313 with modified starch and rice starch (n = 10).

Rice pasta	Firmness (g)	Stickiness (g)
HW : M : RS		
100 : 5 : 5	2,761.42 ± 138.45f	265.41 ± 51.73h
100 : 5 : 10	2,861.77 ± 117.48f	281.75 ± 26.05h
100 : 5 : 15	3,137.80 ± 152.56e	335.15 ± 17.70g
100 : 10 : 5	3,318.25 ± 147.10de	445.45 ± 14.76f
100 : 10 : 10	3,518.67 ± 121.97cd	550.27 ± 10.23d
100 : 10 : 15	3,690.94 ± 148.68c	661.50 ± 11.50b
100 : 15 : 5	3,966.46 ± 120.96b	509.66 ± 18.61e
100 : 15 : 10	4,305.83 ± 141.46a	622.98 ± 21.56c
100 : 15 : 15	4,490.27 ± 122.48a	718.57 ± 13.90a
100 : 0 : 0	2,638.10 ± 120.50f	257.65 ± 13.58h

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

Table 6 Pearson correlation coefficients for quality attributes of rice pasta.

	1	2	3	4	5	6
L*	…	…	…	…	…	…
a*	-0.987**	…	…	…	…	…
b*	-0.870**	0.921**	…	…	…	…
Firmness	0.593**	-0.516*	-0.291	…	…	…
Stickiness	0.432	-0.387	-0.355	0.561**	…	…
Protein	-0.548*	0.467*	0.220	-0.906**	-0.578**	…

*, ** Correlation is significant at P<0.05 and P<0.01 respectively.

Fortified rice pasta

Rice pasta of HW and SB brown rice flour added with 15% modified starch and 15% rice starch were fortified with three levels of ferrous sulfate (0, 30, 60% iron of RDI). The iron content significantly affected ($P \leq 0.05$) L*, a*, but did not affect b* (Table 7). The L* value of rice pasta of HW brown rice flour fortified with iron decreased, while a* value increased as the amount of iron content increased. The products became more reddish, and darker. The a* value of the rice pasta of high iron HW brown rice flour was greater than that of the rice pasta of SB therefore, the rice pasta product of HW brown rice flour became more reddish because the iron content in HW (Fe = 2.04 mg/100g) was greater than SB (Fe = 1.24 mg/100 g).

For the texture qualities of rice pasta, different rice variety showed significant effects on firmness and stickiness (Table 8). Rice pasta from SB brown rice flour had greater firmness, stickiness than those from HW because the SB had more amylose content than the HW. Our observation was supported by the study of Baik and Lee (2003) who reported that amylose content of starch correlated positively with hardness of cooked white salted noodles. Cooked noodles should remain firm and not lose solids in cooking water and should not become sticky and soggy when standing after cooking (Oh *et al.*, 1983). The iron content of rice pasta was analyzed by using ICP method, which had very small variation from addition of iron content (Table 8). The rice pasta (control) without iron fortification made from SB

Table 7 Color measurement of rice pasta from high iron rice flour (Homnin 313) and Suphan-Buri 90 fortified with ferrous sulphate at the levels of 30, 60% iron of RDI (n = 2).

Rice pasta	L*	a*	b*
Homnin 313 flour (HW)			
0% RDI	83.85a	1.85ab	13.96ns
30% RDI	82.14b	1.88ab	14.08ns
60% RDI	81.89bc	1.93a	13.42ns
Suphan-Buri 90 (SB)			
0% RDI	83.89a	1.39c	13.70ns
30% RDI	82.47b	1.47c	13.79ns
60% RDI	81.57c	1.62bc	14.03ns

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

Table 8 Textural characteristics of rice pasta from high iron rice flour (Homnin 313) and Suphan-Buri 90 (n = 10) fortified with ferrous sulphate at the levels of 30, 60% of RDI and analysed total iron content (n = 2).

Rice pasta	Analysed total iron content% RDI (dry basis)	Firmness(g)	Stickiness (g)
Homnin 313 flour (HW)			
0% RDI	2.13	4,490.27 ± 122.48b	718.57 ± 13.90b
30% RDI	29.40	4,483.42 ± 107.21b	725.13 ± 18.14b
60% RDI	59.03	4,473.28 ± 158.49b	732.28 ± 14.59b
Suphan-Buri 90 (SB)			
0% RDI	4.60	4,967.78 ± 189.11a	873.18 ± 38.21a
30% RDI	29.33	4,929.40 ± 190.50a	869.64 ± 29.45a
60% RDI	59.58	4,989.27 ± 172.61a	880.71 ± 15.28a

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

brown rice flour was more reddish and had more iron content than rice pasta made from HW brown rice flour.

Sensory properties

The mean values of the hedonic ratings for sensory attributes of rice pasta samples are shown in Table 9. The amount of iron content affected (P ≤ 0.05) sensory acceptability of color, flavor, elasticity, smoothness, firmness, and acceptability. The rice pasta with addition of iron content of 0, 30%, 60% iron of RDI had no significant difference based on flavor, elasticity, smoothness, firmness compared to the control. Their preference scores were 6.00 to 7.00 (slightly like to moderately like). The iron content showed significant effects on color and acceptability. The rice pasta with 30% iron of RDI were still accepted by sensory test which was not significantly different from the control (0% iron of RDI) at P > 0.05. The products with 60% iron of RDI of each flour sample were darker than those with 30% iron of RDI and significantly different in color from the control at P ≤ 0.05.

The rice pasta of both varieties fortified with 30% iron of RDI, were used for consumer test. The results as presented in Table 10, showed that the frequency of the acceptability scores of

Table 9 Sensory Scores of cooked rice pasta

Rice pasta	Color	Flavor	Elasticity	Smoothness	Firmness	Acceptability
Homnin 313 flour (HW)						
0% RDI	7.29a	6.57a	6.57a	6.50a	6.86a	6.76a
30% RDI	7.10ab	6.50a	6.50a	6.57a	6.76a	6.71ab
60% RDI	6.83b	6.48a	6.60a	6.62a	6.60a	6.68b
Suphan-Buri 90 (SB)						
0% RDI	7.50a	6.95a	6.98a	6.59a	6.98a	6.98a
30% RDI	7.20ab	6.85a	6.90a	6.68a	6.92a	7.00a
60% RDI	6.95b	6.82a	6.94a	6.45a	6.90a	6.90b

Means in each column followed by the same letters are not significantly different at P > 0.05 as determined by DMRT.

Table 10 Consumer test of acceptability scores of rice pasta of rural primary school children (100 persons)

Acceptability of consumer (100 persons)	Hedonic scale (1-9 scores)	% frequency* Homnin 313	% frequency* Suphan-Buri 90
Like extremely	9	60 } 82	65 } 88
Like very much	8	22	23
Like moderately	7	14	11
Like slightly	6	2	0
Neither like nor dislike	5	1	1
Dislike slightly	4	0	0
Dislike moderately	3	0	0
Dislike very much	2	0	0
Dislike extremely	1	1	0

* 82%, 88% the consumers like the rice pasta of HW and SB at the scores of 8-9

the pasta of HW and SB brown rice flour for the scores of like very much to like extremely (8-9), were 82, 88%, respectively.

CONCLUSION

Rice pasta in the form of macaroni was made from high iron rice, HW brown rice flour, fortified with ferrous sulphate at the levels of 0, 30 ,60% iron of RDI. Adding modified starch and rice starch could improve the texture of the rice pasta. The textural characteristics of rice pasta, HW and SB brown rice flour showed significant effect at P ≤ 0.05 on firmness and stickiness. The color of rice pasta fortified with 30%, 60% iron of RDI was significantly different at P ≤ 0.05 from the control. Rice pasta adding with 15% modified starch and 15% rice starch contained 5.84% protein (db) as compared to rice pasta made from 100% HW brown rice flour (10.87% db). The sensory scores in terms of color and acceptability of the rice pasta fortified with 30% iron of RDI were higher than those fortified with 60% iron of RDI.

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