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A study on acceptability of fortification of rice flour in Sri Lankan practice - a pilot scale study

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Abstract

Iron deficiency anaemia is the most prevalent nutritional deficiency in Sri Lanka. The recent nutritional surveys highlighted, significant differences exist in the prevalence of anaemia with relation to geographic areas and socio-economic groups indicating the higher proportion of children at age of 6-59 months (25.2%) and women; pregnant, non pregnant and lactating (8.3%, 33.6% and 30.2% respectively) in the estate sector. The aim of present study is to popularize and increase the consumption of iron fortified rice flour among the estate population, who suffers from high rate of anaemic. Present study focuses to determine if rice flour, fortified as per WHO recommendations (i.e. 40 ppm of iron as a sodium iron EDTA and 2.6 ppm of folic acid), could be used to make common traditional Sri Lankan rice flour-based food products such as roti, string hoppers and hoppers, without negative impact on colour, texture, flavour, taste and consumer acceptability. Mixing of mineral and vitamin premix into rice flour was carried out at pilot scale in a ribbon blender (pilot Model; Gardner) and physico-chemical properties of fortified flour, iron content and sensory evaluation of products were investigated. Results were shown that the mixing time for homogenous distribution of fortificant could be achieved after 15 min blending in a ribbon blender. The percent iron losses during processing of products, roti had shown a significant higher value (34.2%, on db) than string hoppers and hoppers (-3.8% and 4.3%, on db) from the original fortified flour at 40 ppm level. Products prepared from fortified flour were accepted by the sensory panel and processing with fortified flour has not imparted any significant organoleptic changes on products. Therefore the fortification of iron into rice flour at level of 40 ppm can be recommended for formulation of products. Further, fortified flour was kept under the normal room temperature for three months from the initial time of fortification.

Keywords: Iron deficiency, iron fortification, rice flour, aneamia**.**

Introduction

Iron deficiency anaemia is a worldwide public health problem with global prevalence estimated at 24.8% with more than 3.5 Mn people affected in the developing countries[1,2]. It occurs when the concentration of haemoglobin (Hb) falls below 11g/ dL in pregnant women, 12g/dL in non-pregnant women aged 15 - 49, and 11g/dL in children under five. It is well documented that anaemia causes maternal mortality associated with childbirth, in adults it lowers physical work performance, reduces immunity and lowers resistance to infections[3-5]. In children, iron deficiency causes impaired their attention, memory, learning ability and in early ages of iron deficiency causes an irreparable damage to brain cells.

In Sri Lanka more than one third of population is anaemic. According to the survey carried out in 2001, it was estimated that nearly one third (31.2%) of pre-school children, 20.0% primary school children, 22.3% adolescents and 30.2% pregnant women are anaemic[6]. A Report on Nutrition and Food Security Survey had highlighted that higher prevalence of anaemia in estate sector among children at age of 6-59 months (25.2%) and women; pregnant, non pregnant and lactating 8.3%, 33.6% and 30.2% respectively. According to the survey, prevalence of aneamia among pregnant women was considerably low due to the iron supplementation given in the form of tablets from their maternal clinics.

The majority of the iron deficiency burden is shouldered by developing countries with high levels of rice consumption. Rice is mainly consumed as polished rice and the degree of polishing is inconsistent in rice available at markets. Polishing of rice results in the loss of nutrients namely, lipids, proteins, fibre, reducing sugars, vitamins and minerals as well as, free amino acids and fatty acids from the rice grain. It was reported that polishing of rice removes 15% of protein, 85% of fat, 90% of calcium, 75% of phosphorus, 80% thiamine, 70% of riboflavin and 68% niacin[8]. A study done by Herath *et. al*, reported that over 80% of the dietary iron and 18-40% of phytate were removed by polishing[9].

The low concentration of iron in the endosperm of polished rice is one reason for widespread prevalence of iron deficient anaemia in people of Asian countries consuming rice as the staple food including Sri Lanka[10].

In generally, polished rice is processed into rice flour, resulting less nutrient dense end product with improved palatability that is at high rate of consumption in Sri Lanka. In Asian countries like Thailand, Japan, China and Philippines, rice based products such as crackers, noodles, snack products, extruded products and baby products are very popular and consumed in addition to cooked rice but this situation is not common in Sri Lanka. Since there are many home made traditional rice flour based products (e.g. roti, string hoppers and hoppers) are in common practice in Sri Lankan homes, formulation of products from fortified rice flour and unfortified rice flour were carried out. Ministry of Health in collaboration with Industrial Technology Institute (ITI) which functions under the Ministry of Science, Technology and Research set up a rice flour fortification programme with intension of increase the consumption of iron fortified rice flour among the estate population who suffers from high anaemic rate. The objective of the present study is to determine if rice flour, fortified as per new WHO recommendations (i.e. 40ppm of iron as a sodium iron EDTA and 2.6ppm of Folic acid), could be used to make common Sri Lankan traditional rice flour-based food products, without negative impact on colour, texture, flavour, taste or consumer acceptability.

Materials and methods

Materials: Three bags of 25kg rice flour and premix pack containing iron and folic acid 420g, manufactured by DSM Nutritional Products, Asia Pacific (Pte) Ltd., Singapore, were received by Industrial Technology Institute to initiate the fortification trials.

Analytical grade Ferrous Ammonium Sulphate (Iron standard) with at 99.9% purity was used for quantification of iron content. Other reagents and chemicals used for chemical analysis were purchased from Sigma Aldrich Company.

Ingredients used for formulation of products were purchased from local market at Borrella, Colombo, Sri Lanka.

Methods: Fortification trials: Fortification trail was carried out in 50kg batch size of rice flour in a ribbon blender (Model: Gardner, Germany) and premix containing iron and folic acid 20.00g was added to achieve the required level of 40ppm iron into rice flour.

Premix (20.00g) was carefully mixed with 1kg of rice flour prior to blending. Then 49kg of rice flour was loaded to the ribbon blender and carefully spread rice flour mixture containing 20.00g of iron and folic acid premix mixture over the flour in a ribbon blender. Blending was performed in predetermined time intervals of 10, 15 and 20min. Samples were drawn separately from left corner, middle and right corner of the ribbon blender after 10, 15 and 20min mixing intervals and packed in sealed polypropylene bags for analysis.

Determination of physico-chemical properties of fortified and unfortified rice flours: Unfortified rice flour was used as a control. Fortified rice flour indicates at 40 ppm level of fortification of iron into rice flour.

Moisture Content: Moisture content was determined using a method described in AOAC, 2000: 925.10[11].

Gelatinization Temperature and Viscosity: Tests were carried out according to the standard operational instructions given in the Brabender Amylograph (OHG Duisburg, Germany).

Colour: Colour of unfortified and fortified rice flour were measured as operational instructions given in Chromameter (Minolta, Japan) and results were expressed as standard appeared in CIELAB 1976 denoting L*, a* and b* colour scale.

Where L* = Lightness, a* = (-a* = greenness, +a*= redness), b* = (-b* = blueness, +b* = yellowness)

pH: pH was determined by as method described in Official Analysis Method AOAC, 2000 : 943.02[11].

Particle size: Sieve analysis test was carried using 150, 125,106 micron standard sieve set using a sieve shaker (Rotak, Germany).

Iron content: Iron content of flours were determined using dry ashing followed by spectrophotometric method as described in Official Analysis Method AOAC, 2000 :944.02[11].

Percentage loss in fortified 'Fe' during processing: The loss of iron content in processing was estimated. The correction was made for the iron content that may get added through other ingredients (e.g. eggs/coconut). Therefore the calculation of percentage loss of fortified iron during processing was performed as follows;

[(Total 'Fe' in fortified flour – 'Fe' in rice flour) – (Total 'Fe' in fortified product –'Fe' in unfortified product)] / [Total 'Fe' in fortified flour – 'Fe' in rice flour] × 100

Product formulation: Commonly consumed traditional Sri Lankan food products of roti, string hoppers and hoppers were prepared from fortified and unfortified flours separately.

Preparation of Roti: Rice flour (500g), scraped coconut (250 g) and salt (5g) were dry mixed in a stainless container and warmed water (~250mL) was added to form dough. Coconut oil (50mL) was added and mixed properly into the dough to obtain a non-sticky form. The dough was divided into equal size balls (around 21 numbers) and kept 30 min for fermentation while covered with a container. After 30 min balls were fattened, rounded and cooked on cooking pan on medium fire.

Preparation of string hoppers: Rice flour (500g) was properly dry mixed with salt (5g) in a stainless container. Then hot water (580 mL at 80 ^oC) was added to form non-sticky dough while applying coconut oil (10mL). Dough was passed through a hand extruder to form mats out of the strings. The strings were steamed in a steamer for 4 min.

Preparation of hoppers: Rice flour (500g) was mixed with yeast (1.5 g) and kept in a bowl. Initially, coconut milk (750mL) was added and mixed well. Then the mixture was kept for 3 h in a warm place while covered with a wet cloth. After fermentation, extra coconut milk (200mL), egg and sugar (5g) were added and mixed well. Salt (6g) was added to obtain required taste. Then the pan was rubbed with a piece of cloth soaked in oil and kept on the gas cooker. Then ¼ of cup of batter was poured to the pan and rotated the pan to form a round thin hopper. The hopper was covered with a lid of the pan and cooked under medium fire. Finally edge of the hopper was loosen with a butter knife and hopper was taken out of the pan.

Sensory Evaluation of products formulated from control and fortified rice flours: Sensory evaluation was conducted according to paired comparison test. The three food products formulated from unfortified and fortified flours (i.e. roti, string hoppers and hoppers) were subjected to 15 trained panelists in order to evaluate sensory attributes such as Color, Taste, Flavour, Texture and Overall Acceptability. A nine point hedonic scale in a ballet card was used for comparison of fortified and unfortified products (where Like extremely - 9, Like very much - 8, Like moderately – 7, Like slightly- 6, Neither like nor dislike -5, Dislike slightly - 4, Dislike moderately - 3, Dislike very much - 2, Dislike extremely-1).

Data were analyzed by Mann Whitney U test. Acceptability data of fortified products were analyzed via Kruskal Wallis test. Statistical software Minitab 14 was used for data analysis.

Shelf-life evaluation: Samples of fortified flour and unfortified flour in a sealed pack were kept for 3 months time duration for the shelf-life evaluation under normal environmental conditions.

Results and discussion

Physico-chemical properties of iron fortified and unfortified rice flour samples are summarized in Table-1.

According to the results given in Table-1 the physico-chemical properties of moisture, viscosity and pH in fortified flour did not show considerable variation with respect to unfortified flour. Gelatinization Temperature is slightly higher unfortified flour than fortified flour. Colour of the samples of unfortified flour showed a higher value for Lightness (70.46) than fortified flour (63.25). This could be depicted that the iron fortification affected the reduction of lightness of rice flour (i.e. less whiteness).

Particle size of fortified flour was not determined due to the level of fortification was very low to affect this parameter.

The iron content of samples withdrawn from different location of ribbon blender is presented in Table-2.

Table-1: Physico-chemical properties of fortified flour compared to unfortified flours.

Test parameters	Unfortified flour (Control)	Fortified flour
Moisture (% w/w)	9.43 ± 0.06	10.9 ± 0.42
Colour	L*=70.46, a*= -2.77, b*=+4.62	L*=63.25,a*=-4.12, b*=+5.61
Max. GT (C^0)	93.8	89.3
Max. Viscosity (B.U.)	1660	1680
pH	6.52 ± 0.33	6.72 ± 0.01
Iron content (ppm)	17.4 ± 0.64	*62.1 ± 1.31
Particle size (microns - % passed through) 150 125 106	 99.2 97.2 91.6	ND

ND: Not Determined, B.U.: Brabender Unit, ppm: mg/kg, GT: Gelatinization Temperature, *Level of iron content in fortified flour was given after homogeneous mixing of 15 min time interval.

Table-2: Iron content in rice flour in relation to mixing time.

Time	Iron content in fortified flour (ppm)			
	Left Corner	Middle	Right Corner	Mean ± SD
10 min	53.5 ± 2.65	57.7 ± 1.40	60.7 ± 0.11	57.3 ± 3.62
15 min	63.6 ± 0.21	61.7 ± 0.56	61.1 ± 0.32	62.1 ± 1.31
20 min	57.9 ± 2.15	62.4 ± 1.73	61.4 ± 4.50	60.6 ± 2.36

All the values were calculated and expressed on dry weight basis with Mean ± Standard Deviation (SD).

According to the results obtained for the iron content in rice flour in relation to the mixing time (Table-2), the mean value with less variation (standard deviation) was obtained after mixing time of 15 min. Therefore the mixing time for homogenous distribution of fortificant could be achieved after 15 min.

The iron content in food products prepared from fortified and unfortified rice flours presented in Table-3.

Iron content in products (values depicted as ppm) formulated from fortified and unfortified flours were expressed in both wet and dry basis (Table-3). Consideration into iron content on wet basis of the product is more important in the present study because it is the form of practice in human consumption. Iron content of the products could be varied depending on the ingredients added.

The highest iron content among the products formulated from unfortified flour was obtained in the product; roti. It is due to the addition of scraped coconut (~50%) has increased the iron content in the unfortified product. According to the results obtained, addition of coconut is beneficial to unfortified flour products as coconut kernel contains higher iron content than unfortified rice flour (i.e. 25ppm). In case of string hoppers (Table 3, iron content; 16.9ppm DB), were entirely made from unfortified rice flour (Table-1, iron content; 17.4 ppm) and did not show variation in iron content with respect to original flour. Similar to roti, in hoppers, iron content in unfortified product slightly increased due to the addition of coconut milk (Table-3).

In comparison of iron content in fortified products on dry basis, roti had shown significantly low iron content due to the percentage contribution from fortified flour portion is reduced with addition of scraped coconut during formulation of products. Comparison of iron content in products should be done in dry weight basis due to the different products had different moisture contents and results will not reflect reliability. The study in losses in iron during preparation of product should be taken into seriously, as it affects the final product and it should be minimized. % iron losses in the products on wet weight basis had taken into consideration due to the mode of human consumption of these products is in the form of wet basis. The results of iron loss indicated that the iron loss in roti is significantly higher ($p \leq 0.05$) than other two products due to contribution of iron from fortified rice flour portion is reduced with addition of scraped coconut (Approx. 50%). The percent iron losses during processing on wet basis or dry basis, roti had shown a significantly ($p \leq 0.05$) higher values than string hoppers and hoppers from the original fortified flour at 40 ppm level.

Interpretation of sensory evaluation: Acceptability of products: Probability values of acceptability of food products prepared from unfortified and fortified flour samples are indicated in Table- 4 (95 % confidence interval).

Comparison of control and fortified samples: The probability values are greater than 0.05 which interprets that the sensory evaluation of panelists has accepted the product without significant difference. The control and fortified samples of roti, string hoppers and hoppers were not significantly different (p>0.05) in terms of all parameters evaluated i.e. colour, texture, flavour, taste and overall acceptability.

Mean scores and standard deviations calculated for five organoleptic parameters of three product types, are indicated in Table-5.

All the samples including controls have been accepted and pleasant to eat (above category of "moderately liked" category) in terms of their colour, texture, flavour, taste and overall acceptability of the product.

Table-3: Iron content in food products prepared from fortified and unfortified rice flours.

Product name	Unfortified product			Fortified product			% iron loss in products	
	% Moisture Content	Iron content (ppm)		% Moisture Content	Iron content (ppm)		Wet basis	Dry basis
		Wet basis	Dry basis		Wet basis	Dry basis		
Roti	28.8±0.97	20.4±2.17	28.6^{a}±3.05	29.3±0.45	41.0±0.13	58.0^{b}±0.19	48.1^{a}± 4.9	34.2±6.3
String-hoppers	50.1±0.56	8.40±0.09	16.9^{b}± 0.18	48.3±0.67	32.5±1.86	63.3^{a}±3.62	39.3^{b}±4.9	-3.8
Hoppers	43.7±1.50	11.2±0.54	19.8^{b}± 0.95	41.9±0.95	36.4±2.67	62.6^{a}±4.60	36.5^{b}±7.8	4.3±2.1

Results were expressed in Mean ± SD of triplicate sample analysis, Significant different is based on $p \leq 0.05$.

Table-4: Probability values of acceptability of different product types processed with control flour and fortified flour.

Product	Sample	Parameter				
		Colour	Texture	Flavour	Taste	Overall acceptability
Roti	Control	0.450	0.450	0.450	0.450	0.450
	Fortified	0.450	0.450	0.450	0.450	0.450
String hoppers	Control	0.448	0.448	0.448	0.448	0.448
	Fortified	0.448	0.448	0.448	0.448	0.448
Hoppers	Control	0.451	0.451	0.451	0.451	0.451
	Fortified	0.451	0.451	0.451	0.451	0.451

Note: Samples having probability values less than 0.05 are significantly different.

Table-5: Mean scores allocated for organoleptic parameters of product types prepared with unfortified flour and fortified flour.

Product	Sample	Mean score ± SD				
		Colour	Texture	Flavour	Taste	Overall acceptability
Roti	Control	7.80 ± 0.56	6.93± 0.80	7.27 ± 0.96	7.33 ± 0.98	7.33 ± 0.98
	Fortified	6.53 ± 1.41	7.40 ± 0.91	7.40 ± 1.06	7.40 ± 1.35	7.37 ± 1.29
String hoppers	Control	7.64 ± 0.63	7.14 ± 0.77	7.29 ± 0.99	7.07 ± 1.00	7.43 ± 0.85
	Fortified	7.43 ± 0.94	6.21 ± 1.37	7.07 ± 0.92	6.86 ± 1.17	6.86 ± 1.03
Hoppers	Control	7.53 ± 0.81	7.50 ± 0.89	7.38 ±0.96	7.50 ± 0.89	7.56 ± 0.73
	Fortified	7.44 ± 0.63	7.56 ±0.73	7.50 ± 0.82	7.56 ±0.96	7.69 0.79

Shelf-life evaluation: The values of parameters determined in shelf-life evaluation after three month time duration, pH (6.5 ± 0.01), moisture (10.3 ± 0.04) and colour (visually) in fortified flour did not show remarkable change with respect to unfortified flour. Therefore the fortified flour could be kept for three months time duration from initial time of fortification.

Conclusion

The mixing time for homogenous distribution of fortificant could be achieved after 15 min. The percent iron losses during processing, roti had significantly higher value than string hoppers and hoppers did not show any significant difference ($p \leq 0.05$) from the original fortified flour of 40ppm level. Therefore the fortification of iron into rice flour of 40ppm level can be recommended for the formulation of products.

Roti, string hoppers and hoppers prepared with fortified flour were accepted by the sensory panel of ITI and processing with fortified flour has not imparted any significant organoleptic changes on roti, string hoppers and hoppers.

Fortified flour could be kept for three months time duration from initial time of fortification.

Rice flour could be fortified as per WHO recommendation with premix containing iron and folic acid without negative impact on iron loss and consumer acceptability.

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