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Evaluation of Iron Fortified Parboiled Rice for Physical, Cooking and Organoleptic Properties

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ABSTRACT

The rice varieties are fortified with iron salt (Sodium iron (III) EDTA) at the concentration of 4.0g/kg paddy through parboiling technique. The treatment of paddy grains includes soaking and steaming at different temperatures and also soaking with germination and steaming at different temperatures. The kernel weight of the iron fortified rice ranged from 11.19 to 12.59 g. The highest kernel length was recorded in *Gangavati sona* (6.12mm). The length breadth ratio of the iron fortified rice was in the range of 2.4-3.0. *Gangavati sona* is classified as medium grain and *Thanu* as short grain according to kernel length. Minimum cooking time of the iron fortified rice ranged from 25.33 to 32.40 minutes. Water uptake ratio, gruel solid loss and elongation ratio were in the range of 2.61 to 3.08, 2.93 to 4.49 per cent and 1.08 to 1.14. Iron fortified rice *Gangavati sona* had soft gel types with low to intermediate gelatinization temperature whereas *Thanu* had medium gel types with low to intermediate gelatinization temperature. The iron fortified rice *Gangavati sona* and *Thanu* had good organoleptic scores with acceptable overall acceptability.

Keywords: Iron, Fortification, Parboiling, Gelatinization temperature and Organoleptic scores

MICRONUTRIENT deficiencies are the most common public health problems in developing countries such as Asian and African countries. Iron deficiency anaemia is one of the common nutritional disorders in the world. About one third of the world population suffers from iron deficiency anaemia. India has high prevalence rate of iron deficiency anaemia. It affects mainly pregnant women, children and adolescent girls. It causes economic losses and severe health impacts particularly to the economically disadvantaged group. The main reason is the predominance of vegetarian diets where lack of haeme iron reduces transportation and absorption of iron in the gut and cells and the problems of bio availabililty of this mineral with inhibitors of iron absorption like phytates, phosphates etc, which are present in the food; and limited access to iron rich foods (Prom-u-thai *et al.,* 2011). According to WHO (2015), anaemia affects around 800 million women and children. There are proposed short and long term solutions to tackle this problem. One of the solutions in alleviating iron deficiency anaemia is the fortification of iron in staple foods. Rice is the staple food of Asian and African countries specially India, China, Bangladesh and other neighbouring countries. Over 90 per cent of the world's rice is produced and consumed in Asia and pacific regions. Over 2 billion people in Asia derive their energy from rice. Therefore, it would be a good choice to fortify rice with iron.

There are different types of fortification techniques including dusting, coating, extrusion, etc. However, there are high chances of nutrient losses during washing, cooking and storage using these techniques. In this context, fortification of rice with iron through parboiling technique can be considered as an alternative to improve nutrient content. Parboiling of rice is a hydrothermal treatment where irreversible swelling of starch takes place. It involves soaking in hot or cold water followed by steaming, drying and milling. The parboiled rice kernel becomes translucent due to the occupation of the empty space in rice endosperm by gelatinized starch and protein bodies which give hardness to the rice kernel. It has the resistance to breakage during milling and nutrient loss is lesser in parboiled rice when compared to white rice due to the seepage of nutrients from the bran towards the endosperm during parboiling (Thiruselvam *et al.,* 2014). Therefore, it is a feasible method for fortification of rice with iron.

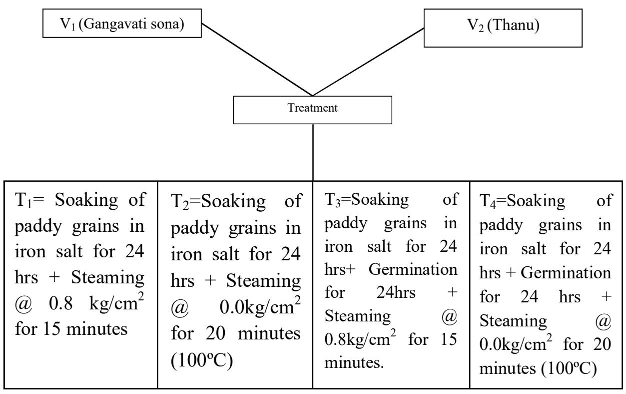
On the other hand, consumer preference of rice based on its quality is very important. Rice quality is influenced by various physico chemical properties that determine the cooking quality of rice. Nutrient composition and cooking quality of rice also depend on the genetic factors, surrounding environments where they are grown as well as the processing condition involved. Germination and soaking also affects the cooking quality and nutrient content of rice. The process of germination induces g-aminobutyric acid in rice grains (Sutharut and Sudarat, 2012). Gelatinization temperature and gel consistency can influence the eating and cooking qualities of rice. Sensory attributes of rice are also the factor to determine the eating quality of rice. Iron fortified rice should be able to camouflage with the non fortified rice in terms of eating quality, cooking properties etc. With this background, the study was taken up to evaluate the physical properties, cooking properties and sensory attributes of iron fortified parboiled rice.

Material and Methods

Procurement of Paddy Grain

Gangavati sona (IET 20594) and *Thanu* (KMP 101) were procured from ZARS, VC farm, Mandya.

Parboiling of paddy grain or rough rice



Note : 0.0kg/cm^2 means steaming of paddy grain without pressure

The iron salt (Sodium iron (III) EDTA) was added at the concentration of 4.0g/kg of paddy (Pandey *et al.*, 2016). The parboiled paddy grain was dried in tray drier at 45-50 ºC for 72 hours. The dried paddy was dehusked in laboratory scale rubber roll paddy sheller. The iron fortified brown rice was further subjected to physical, cooking and organoleptic evaluation.

Physical Properties

The grain dimensional parameters include kernel length, breadth, and length by breadth ratio, 1000 kernel weight, and bulk density. Kernel length and breadth was measured using the vernier calliper. Ten cumulative length and breadth of the grain was measured and average was taken. Length by breadth ratio was obtained by dividing the length of the grain by corresponding breadth. 1000 kernels of grain were counted randomly in triplicate and weighed separately to determine 1000 kernel weight (Anon, 2013).

Cooking Time (Minute)

Ten grams of rice grains after dehusking were dropped in boiling water and cooking time was noted by pressing the cooked grains between the glass slides and cooking time was noted when there was no opaque core of rice grains (Thomas *et al*., 2013).

Water Uptake Ratio and Gruel Solid Loss

Two gram of rice whole kernels was cooked in 20 ml distilled water for a minimum cooking time in boiling water and draining the superficial water. The cooked rice samples were weighed and the ratio of final cooked weight to the uncooked weight was calculated as the water uptake ratio (Eram *et al.,* 2014). Gruel solid loss was obtained after drying the aliquot of the cooked rice in a petridish. The solid obtained were weighed and the percentage of gruel solid loss was calculated.

Elongation Ratio and Volume Expansion Ratio

The volume expansion ratio was determined as the ratio of final increased in volume of cooked rice to the volume increased in uncooked rice. Fifteen ml of water was taken in 50 ml measuring cylinder and 5 g of rice was added. The increased in volume (Y) was recorded and soaked for ten minutes. Then increase in volume before cooking was noted (Y-15). Rice samples were cooked for twenty minutes in a water bath. Cooked rice was placed on blotting paper in 50 ml water taken in hundred ml measuring cylinder. Then increased in volume of cooked rice in 50 ml of water was measured (X). Again the increased in volume was recorded (X-50). Volume expansion ratio was calculated. Elongation ratio was determined by dividing the cumulative length of cooked rice by the corresponding length of uncooked rice kernel (Eram *et al.,* 2014).

Alkali Spreading Value (ASV) and Gelatinization Temperature (GT)

The degree of spreading of individual rice kernels in weak alkali solution (1.7 % KOH) was evaluated on a 7 point hedonic scale. 10 intact rice grains were placed on a petridish and 15 ml of 1.7 per cent KOH was added and incubated for 23 hours at room temperature to allow spreading of the grains. A seven point hedonic scale was used to determine the score of the alkali spreading value of the grains (Anon., 2013). The gelatinization temperature of the rice samples was determined from the alkali spreading value using the following equation.

Gelatinization temperature (GT) = 74.8-1.57 × Alkali spreading value

Gel Consistency

100 mg of rice flour was taken in a test tube (2 x19.5 cm). 0.2 ml of ethanol containing 0.25 per cent thymol blue was added to the test tube. Then 2.0 ml of 0.2 N KOH was again added to the test tube. Mixed well, kept in water bath for 8 min, cooled, shaked well and placed the test tubes in ice water bath for 20 minutes. Then, placed the test tubes horizontally in a graduated paper for 1 hour and take the measurements (mm) (Anon., 2013).

Organoleptic Evaluation of Iron Fortified Rice

Rice samples were soaked for 10 minutes and cooked in boiling water for 20 to 30 minutes and scored as per panel test performance on 5 point hedonic scale (Anon., 2004).

Statistical analysis

Mean and Standard deviation was calculated using the SPSS 16.0 software. One way ANOVA was used to test the significance of the data.

Results and Discussion

The fortified rice had iron content of 4 to 5.30 mg/100g in both rice varieties. Rice kernels length and breadth are important factor which influence the rice eating and cooking qualities. The kernel length and breadth of both the rice cultivars ranged from 5.12 to 6.12 mm and 2.00 to 2.17 mm respectively. There was significant difference among the treatments as well as between the varieties (Table 1). According to grain length (Anon., 2013), grain size of the brown rice kernel of *Gangavati sona* is classified as medium grain and that of *Thanu* is classified as short grain. Grain shape is determined by length: breadth ratio, hence, both *Gangavati sona* and *Thanu* is categorized as medium grain. Overall, highest length breadth ratio was found in *Gangavati sona* where steaming was done at 0.8kg/cm^2 and the lowest was recorded in germinated and parboiled *Thanu*. This might be due to increase starch gelatinization and elongation of the grain during the parboiling treatment resulting in structural changes of the grain in higher steaming pressure. Results of 1000 rice kernel weight indicated the difference between the two rice varieties. 1000 kernel weight of *Thanu* was higher than that of *Gangavati sona*. Bulk density also found higher in *Thanu*. With the increased in kernel weight, there is an increased in bulk density in both the rice cultivars (Table 1).

Results obtained from cooking properties of iron fortified rice are depicted in Table 2. Cooking time of rice is an important criterion in determining the eating quality of the rice. Cooking time of rice is usually established when there is no visible opaque center of the starch rice grain by 90 per cent. The rice varieties in all treatments showed longer cooking time. However, there is a significant difference in cooking time between the treatments in both rice varieties. Soaking and steaming of the paddy grain had higher minimum cooking time. Soaking of the paddy grain for 24 hours along with germination for 24 hours and steaming had recorded lower cooking time in both rice varieties. The higher cooking time (32.40 minutes) in parboiled brown rice may be due to the fibrous bran present in the rice grain. Therefore, longer time is needed to cook the rice.

TABLE 1

Physical characteristics of iron fortified rice

Sample	Treat-ment	1000 Kernel weight (g)	1000 Kernel Volume (ml)	Bulk density (g/ml)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
Gangavati sona	T_1	12.59 [c]	9.67 [b]	0.76 [a]	6.05 [b]	2.00 [d]	3.0 [a]
	T_2	11.85 [d]	9.0 [c]	0.75 [b]	6.12 [a]	2.08 [b]	2.9 [b]
	T_3	11.19 [e]	8.0 [d]	0.71 [d]	6.05 [b]	2.03 [cd]	3.0 [a]
	T_4	12.28 [c]	9.0 [c]	0.73 [c]	6.05 [b]	2.05 [bc]	2.9 [b]
Thanu	T_1	13.66 [a]	10.0 [a]	0.76 [a]	5.20 [d]	2.00 [d]	2.6 [c]
	T_2	13.25 [b]	10.0 [a]	0.75 [b]	5.37 [c]	2.17 [a]	2.5 [cd]
	T_3	13.11 [b]	10.0 [a]	0.73 [c]	5.12 [e]	2.16 [a]	2.4 [d]
	T_4	13.29 [b]	10.0 [a]	0.76 [a]	5.26 [d]	2.16 [a]	2.4 [d]
F-test		*	*	*	*	*	*
SEm±		0.24	0.22	0.04	0.07	0.03	0.06
CD		0.70	0.67	0.11	0.20	0.08	0.16

T_1 = Soaking and steaming @0.8kg/cm^2; T_2 = Soaking and Steaming @0.0 kg/cm^2; T_3 = Soaking, germination and steaming @0.8kg/cm^2; T_4 = Soaking, germination and steaming @0.0kg/cm^2; *Significant at 5 % level; Means at the same column followed by superscript letters differ significantly

TABLE 2

Cooking properties of iron fortified parboiled rice

Sample	Treat-ment	Minimum cooking time (minutes)	Water uptake ratio	Gruel solid loss (%)	Kernel elongation ratio	Volume expansion ratio
Gangavati sona	T_1	32.40 [a]	2.88 [b]	2.99 [e]	1.13	4.24 [c]
	T_2	30.77 [ab]	3.08 [a]	3.79 [b]	1.14	3.88 [de]
	T_3	27.33 [bcd]	3.00 [a]	4.49 [a]	1.13	5.20 [a]
	T_4	25.33 [d]	2.61 [e]	3.05 [de]	1.11	4.87 [b]
Thanu	T_1	30.47 [abc]	2.83 [bc]	3.31 [cd]	1.08	4.22 [c]
	T_2	30.93 [ab]	2.78 [cd]	2.93 [e]	1.13	4.13 [c]
	T_3	28.33 [bcd]	2.7 [d]	3.55 [bc]	1.09	4.06 [cd]
	T_4	26.67 [cd]	2.7 [de]	2.94 [e]	1.08	3.80 [e]
F-test		*	*	*	NS	*
SEm±		0.45	0.10	0.19	0.03	0.18
CD		1.34	0.31	0.57		0.54

T_1 = Soaking and steaming @0.8kg/cm^2; T_2 = Soaking and Steaming @0.0 kg/cm^2; T_3 and T_7= Soaking, germination and steaming @0.0kg/cm^2; T_4 and T_8= Soaking, germination and steaming @0.8kg/cm^2 ;*Significant at 5 % level; Means at the same column followed by superscript letters differ significantly.

A positive correlation between minimum cooking time and length breadth ratio is also revealed in Table 3. Breadth wise increase of cooked rice is an undesirable trait. However, increase in length during cooking is an indicator of high quality rice variety. Therefore, elongation of rice is also influenced by length breadth ratio. Similar findings were obtained by Thomas *et al.* (2013). There was no much significant difference in kernel elongation in all the treatments as well as both the rice varieties. With regard to water uptake ratio, it

TABLE III

Correlation coefficient for the relationship between physical and cooking properties of iron fortified rice

	1000 Kernel weight	BD	L/B ratio	MCT	WUR	GSL	ER
1000 kernel weight	1	0.051	-0.322	-0.394	-0.88 **	-0.531	-0.725 *
Bulk density		1	0.545	0.565	-0.047	-0.710 *	-0.231
Length breadth ratio			1	0.842 **	0.396	-0.289	0.500
Minimum cooking time				1	0.519	-0.138	0.386
Water uptake ratio					1	0.659	0.632
Gruel solid loss						1	0.312
Elongation							1

** Significant at 1 % level, * Significant at 5 % level

Note : BD-Bulk density, L/B ratio-Length/breadth ratio, MCT-Minimum cooking time, WUR-Water uptake ratio, GSL-Gruel solid loss, ER-Elongation ratio

ranged from 2.61 to 3.08. Negative correlation between water uptake ratio and kernel length is shown in Table 3. When the bulk density is high, the corresponding water uptake ratio will also be high. Gruel solid loss is also another important cooking property. Gruel solid loss of the iron fortified rice ranged from 2.93 to 4.49 per cent. A strong negative correlation between gruel solid loss and bulk density was revealed in the study (Table 3). Higher gruel solid loss was found in treatments where soaking and germination combines with steaming in both the rice cultivars. Highest gruel solid loss was found in 3rd treatment where paddy grain was treated with iron salts by soaking along with germination and steaming at high pressure (0.8kg/cm^2). Germination may play a role in increasing solid contents during cooking. It ranged from 3.80 to 5.20. The higher expansion ratio is not a desirable trait for the consumer as it gives only volume but less firmness.

Gelatinization temperature and alkali spreading value are the important quality parameters for establishing the high quality of the cooked rice as consumer prefers soft and firm texture cooked rice. In terms of alkali spreading value, iron fortified rice also can be classified as low (6-7), intermediate (4-5), intermediate high (3) and high (2). Gelatinization temperature can be classified into low (55-69ºC); low intermediate (69-70ºC); intermediate (70-74ºC) and high (>74ºC) (IRRI, 2013). Alkali spreading value, gelatinization temperature and gel consistency behaviour of iron fortified rice is shown in Table 4. Higher the alkali spreading value lower is the gelatinization temperature. Gelatinization temperature is associated with the cooking time and texture of cooked rice. The temperature at which rice starch gelatinizes is an important component of rice eating quality. A low or intermediate gelatinization temperature is required for a high quality rice variety. In the study, both *Gangavati sona* and *Thanu* had low or intermediate gelatinization temperature which was found in all the treatments of parboiling. Alkali spreading value ranged from 2.00 to 4.10 and gelatinization temperature ranged from 66.32 to 71.66ºC. All the four parboiling treatments in *Gangavati sona* showed low intermediate and intermediate gelatinization temperature which can be treated as high quality rice which produced firm textured rice on cooking. *Thanu* had low, low intermediate and intermediate gelatinization temperature.

Gel consistency is also another parameter for determining the rice eating quality. Iron fortified rice can also be determined based on gel types. Harder gel consistency is associated with harder cooked rice and hard cooked also tends to be less sticky.

Gangavati sona had soft gel types whereas; *Thanu* had medium gel types (Table 4). The highest gel consistency was observed in *Gangavati sona* where the parboiling treatment combines with germination. The lower gel consistency leads to harder texture of cooked rice. Gel consistency of rice over 60 mm was considered as soft gel types and 41-60 mm was categorized as medium and hard gel types is in the ranged of 27-40mm. Therefore, iron fortified *Gangavati sona* can be considered as soft gel types (61.33-81.57 mm) and *Thanu* has medium gel types (51.90 -56.50 mm).

The organoleptic properties of rice are very important for determining the eating quality and to identify the consumer preferences. In iron fortification of rice, sensory attributes namely appearance, textures, taste, aroma and acceptability are very important. The organoleptic scores of iron fortified *Gangavati sona* and *Thanu* is shown in Fig. 1 and 2. There was no significant difference in appearance of iron fortified *Gangavati sona* as the score was between 3.85-3.86. However, there was a significant difference between steaming temperature of fortified rice in terms of cohesiveness.

The parboiled iron fortification at 0.8 kg/cm^2 possessed a better score than treatment given at 0.0 kg/cm^2. Desirable taste, mild aroma with moderate elongation was observed in iron fortified *Gangavati Sona* with moderately hard texture on touching and chewing. The overall acceptability of iron fortified *Gangavati Sona* scored 2 to 3 on five point hedonic scale which was acceptable and good overall acceptability. There was no significant difference in appearance of iron fortified Thanu as it gives creamish white or yellow appearance (Score 4.00) in all the treatments. The higher overall acceptability was found in soaking, germination with steaming treatments in *Thanu*. Sensory attributes namely cohesiveness, tenderness on touching, chewing, aroma, taste and elongation had better scores in iron fortified *Thanu* which involved germination in the treatments.

Since iron fortified rice (both *Gangavati sona* and *Thanu*) had good cooking properties with overall good acceptability among the panellist, it can be used for improving iron level to the iron deficiency anaemic individuals. Cooking properties and physical properties are important determinants for promoting quality rice to the consumers. Sensory or organoleptic evaluation

TABLE 4

Gelatinization temperature and gel consistency behaviour of iron fortified rice

Samples	Treat-ment	Alkali spreading value	Gelatinization temperature (ºC)		GC	GCbehaviour
Gangavati sona	T_1	3.40	69.94	Low intermediate	63.67 [b]	Soft
	T_2	3.40	69.46	LowIntermediate	61.33 [b]	Soft
	T_3	3.50	69.54	Low intermediate	81.57 [a]	Soft
	T_4	2.30	71.43	Intermediate	81.43 [a]	Soft
Thanu	T_1	5.40	66.32	Low	52.00 [d]	Medium
	T_2	2.00	71.66	Intermediate	51.90 [d]	Medium
	T_3	4.10	68.44	Low	56.50 [c]	Medium
	T_4	2.60	70.88	Low intermediate	52.63 [d]	Medium
F-test		*	*		*	
SEm±		0.23	0.29		0.90	
CD		0.65	0.82		2.71	

GC- Gel consistency; T_1 = Soaking and steaming @0.8kg/cm^2; T_2 = Soaking and Steaming @0.0 kg/cm^2; T_3 = Soaking, germination and steaming @0.8kg/cm^2; T_4 = Soaking, germination and steaming @0.0kg/cm^2; *Significant at 5 % level; Means at the same column followed by superscript letters differ significantly

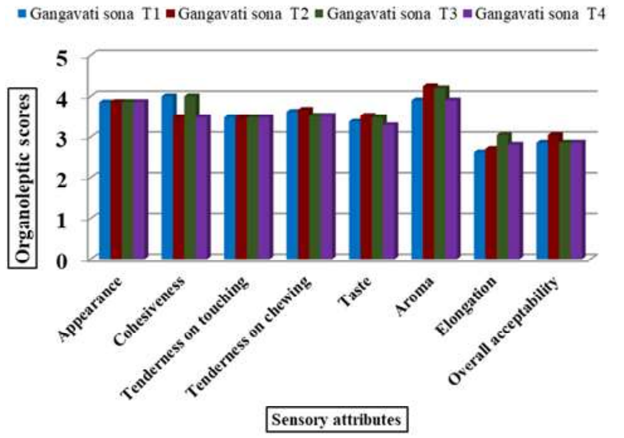


Fig. 1 : Organoleptic scores of iron fortified parboiled rice (Gangvati sona)

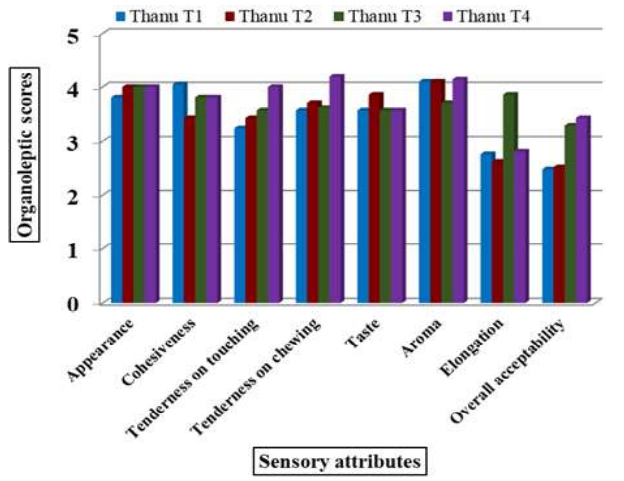


Fig. 2 : Organoleptic scores of iron fortified parboiled rice (Thanu)

of iron fortified rice is a must to do, so that the actual concentration of iron and consumer preferred fortified quality rice can be produced in the market as well as to act as vehicle for combating malnutrition in India. The fortification of rice through parboiling technique can be opted as an alternative to other fortification technique as parboiling reduces nutrient losses during milling and cooking of rice. Further, parboiling technique is cheaper than dusting, coating, extrusion and other fortification techniques.

References

Anonymous, 2004, Laboratory manual on rice grain quality procedure. Directorate of Rice Research, Rajendranagar, Hyderabad, India, pp : 120.

Anonymous, 2013, Standard evaluation system for rice. International Rice Research Insititute, Manilla, Phillipines, pp : 44 - 46.

Eram, S., Singh, A. K., Singh, A., Singh, N. K. and Singh, P. K., 2014, Physicochemcial characterization and organoleptic analysis in rice cultivars. *Indian J. Agric Sci.,* **48** (6) : 437 - 445.

Pandey, S., Asha, M. R. and Jayadep, A., 2016, Changes in physical, cooking, textural properties and crystallinity upon iron fortification of red rice (Jyothi). *J. Food Sci. Technol.,* **53** (2) : 1014 - 1024.

Prom-u-thai, C., Huang, L., Fukai, S. and Rerkasem, B., 2011, Iron fortification in parboiled rice-a rapid and effective tool for delivering nutrition to rice consumers. *Food and Nutrition Sciences*, **2** : 323 - 328.

Sutharut, J. and Sudarat, J., 2012, Total anthocyanin content and antioxidant activity of colored rice. *Int. Food Res. J.,* pp. : 215 - 221.

Thiruselvam, N., Cheong, S. W., Mohan, J., Paterson, J. and Arcot, J., 2014, Micronutrients fortification of rice by parboiling : lab scale and pilot scale studies. *Nutr. Food Sci.,* **4** (3) : 1 - 7.

Thomas, R., Wan-nadia, W. A. and Bhat, R., 2013, Physicochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. *Int. Food Res. J.,* **20** (3) : 1345 - 1351.

Who, 2015, The global prevalence of anaemia in 2011. World Health Organization, Geneva, Switzerland, pp.3.

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