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Nutritional Properties of Some BRRI HYV Rice in Bangladesh

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Abstract

Rice is relatively a better source of vitamins, minerals, protein and starch among cereals. In order to identify nutraceutically enriched HYV rice, a total of 35 BRRI released HYVs were subjected to analyze water soluble vitamins such thiamin and riboflavin along with physicochemical and cooking properties. In addition, some profound vitamin enriched HYVs were further subjected to analyze for mineral content such as zinc, iron, phytic acid (PA) and molar ratio of PA to minerals and these were evaluated over variation of degree of milling (DOM) and polishing time (Seconds). Our data reveals that BRRI dhan36 has the highest thiamin content (mg100^{-1}g) of 1.15 followed by BRRI dhan29 (1.14), BRRI dhan48 (1.12), BRRI dhan28 (1.09) and BRRI dhan43 (1.08), BR16 (1.09), BR25 (0.93), BRRI dhan38 (0.93), BRRI dhan64 (0.89) and BRRI dhan42 (0.85) among all tested 35 BRRI HYVs in Bangladesh. Both BRRI dhan43 and BRRI dhan42 have higher Zn content (ppm) of 27.17 and 27.12 among all tested BRRI HYVs rice varieties at 10% DOM. In addition, we have also observed that grain size and shape have significant impact on degree of milling (DOM) and mineral content trends to be decreased significantly over increasing the polishing time. Considering all nutritional values such as water-soluble vitamins specially thiamin, protein, apparent amylose content, cooking time, elongation ratio, imbibition's ratio, mineral contents such as Zn, Fe, PA and molar ratio of PA to minerals into account, BRRI dhan43 followed by BRRI dhan42 found suitable to treat as nutriceutically enriched HYV rice in Bangladesh among all tested HYVs. Consuming both BRRI dhan43 and BRRI dhan42 as nutraceutically enriched rice alternately, might impact on nutritionally challenged vulnerable portion of Bangladeshi population specially women and children under five years of age.

Keywords: Thiamin; Riboflavin; Degree of milling; Polishing time

Introduction

Rice is consumed as the whole kernel of the white rice which is obtained after milling of the rough rice. The principle of rice milling is the removal of the husk (husking) followed by the rice bran (polishing), which gives us the edible portion (endosperm) of rice grain [1]. Rice bran layer is rich in minerals, vitamins, fat and dietary fibers [2,3], while proteins and fats are concentrated in the germ of the rice caryopsis [4]. Certain nutrients like fats, vitamins, proteins and minerals are found in good concentration in germ and outer layers of endosperm i.e. bran portion of kernels [5]. A study by Lamberts et al. showed that about 84.2% of kernel proteins are concentrated in outer endosperm and upon milling further the concentration of proteins decrease [6]. The researchers also found that 61% of most of the minerals are present in bran fraction of the kernels whereas the core of endosperm fraction mainly consists of starch (84.6%) in the kernels. Milling is a phenomenon of wear which involves removing material from solid surface either by mechanical action or by combinations of various actions such as rolling, impact or sliding [7,8]. Commercial milling is a process consisting of various stages where firstly paddy or rough rice go through dehusking process and then the outer brown bran layer is removed during whitening process. In the final step, adhering bran is completely removed from grain surface and is known as polishing. Quality of milled rice is depicted by two important parameters i.e., whiteness of the kernel and yield of head rice (HRY). Rice can be milled by two methods i.e., abrasion milling and friction milling. When the rice grain is made to revolve inside a milling chamber, then the grain which get in touch with the emery surface experience abrasion type of milling while grain which rub against each other experience adhesive type of wear. In rice polishing, generally a combination of both the types of wear is used as no pure form of milling has yet been discovered [9]. Rubber rolls were determined to be most suitable for laboratory scale milling operations as these increased the dehusking percentage but decreased breakage of rice kernels [10]. During milling operations, these nutrients are removed thus reducing the nutritive value of starch. The degree of milling (DOM) has an effect on the concentration of nutrients. The proximate composition depends upon the degree to which bran has been removed from kernel surface. The rice subjected to lower DOM could lead to more nutrition which can assure better health of the consumers. Minerals are generally concentrated in bran layers of rice kernels which are lost during milling process [11]. It was observed that rice husking parameters are dependent on size and shape of rice kernels and the speed of the impeller cannot be taken as a sole criterion for optimization of impeller husker performance [12]. This could be judged by low husked ratio even if the impeller speed was at its optimum. The quality of rice milling is affected by moisture content of paddy as well as rotor speed of the whitener [13]. Various experiments were performed using different cultivars and different types of milling material such as plywood, iron sheet, rubber, glass and

fiberglass. Milling against rubber was found to be most effective for paddy but least for milled rice. In another study by Firouzi et al. [14] performance of perforated screen size and blade rotor clearance for whitening of rice grain was evaluated. During milling process, the losses of minerals reached up to 84.7% [15]. In a study by Fukai et al. different brown rice cultivar was milled and loss in iron content was measured. It was observed that due to milling processes, 25-84% of iron content was lost from different cultivars [16]. Like other nutrients, selenium was also lost during milling. This observation was based on milling and analysis of 10 different rice cultivars by Liu et al. [15] People take thiamin VitB$_1$ for conditions related to low levels of thiamin (thiamin deficiency syndromes), including beriberi, inflammation of the nerves (neuritis) associated with pellagra or pregnancy. Thiamin is also used for digestive problems including poor appetite, ulcerative colitis, diabetic pain, heart disease, alcoholism, aging, vision problems such as cataracts, glaucoma, motion sickness, improving athletic performance, preventing cervical cancer and progression of kidney disease in patients with type 2 diabetes, AIDS and boosting the immune system. Thiamin functions as a coenzyme in the metabolism of carbohydrates and branched-chain amino acids. Recommended Dietary Allowance (RDA) for adults is 1.2 mgday^{-1} for men and 1.1 mgday-1 for women. Riboflavin functions as a coenzyme in numerous redox reactions. The RDA for riboflavin for adults is 1.3 mgday-1 for men and 1.1 mgday-1 for women. The redox reactions in which flavocoenzymes participate include flavoprotein-catalyzed dehydrogenations that are both pyridine nucleotide (niacin) dependent and independent, reactions with sulfur-containing compounds, hydroxylations, oxidative decarboxylations (involving thiamin as its pyrophosphate), dioxygenations, and reduction of oxygen to hydrogen peroxide. There are obligatory roles of flavocoenzymes in the formation of some vitamins and their coenzymes. For example, the biosynthesis of two niacin-containing coenzymes from tryptophan occurs via FAD-dependent kynurenine hydroxylase, an FMN-dependent oxidase catalyzes the conversion of the 5'-phosphates of vitamin B$_6$ to coenzymic pyridoxal 5'-phosphate, and an FAD-dependent dehydrogenase reduces 5,10-methylene-tetrahydrofolate to the 5'-methyl product that interfaces with the B$_{12}$-dependent formation of methionine from homocysteine and thus with sulfur amino acid metabolism [17]. Since rice is a good source of water soluble vitamins such as Thiamin VitB$_1$ but poor source of Riboflavin VitB$_2$ and we do not have any prior reports on vitamin profiling of HYVs in Bangladesh till date, so in this experiment we were aimed to explore VitB$_1$ and VitB$_2$ contents for our 35 BRRI HYVs in Bangladesh including their physicochemical and mineral profiling for superior selected BRRI HYVs. In addition, we also tried to explain how the variation of degree of milling (DOM) might possibly affect the mineral contents of rice.

Materials and Methods

A total of thirty five (35) BRRI HYVs such as BR3, BR5, BR6, BR7, BR10, BR11, BR14, BR16, BR17, BR18, BR19, BR21, BR22, BR23, BR25, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan31, BRRI dhan34, BRRI dhan36, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan42, BRRI dhan43, BRRI dhan46, BRRI dhan47, BRRI dhan48, BRRI dhan49, BRRI dhan58, BRRI dhan61 and BRRI dhan64 were selected in this study to evaluate their mineral profiling including zinc, iron, phytic acid and molar ratio of phytate to respective minerals (PA/Zn and PA/Fe). Rice grain were collected from Genetic Resources and Seed (GRS) Division bank of Bangladesh Rice Research Institute (BRRI) and processed milling at

cleaned rice (by 80 sec. polishing time) condition for vitamin analysis. Rice samples were dehusked by Satake Rice mill, followed by 80, 100, 120, 140, 160 and 180 second polishing in a Grainman rice polisher (USA) to get 8.5%, 9.0%, 9.5%, 9.9%, 10.3% and 10.6% polished rice (Clean rice) respectively as an average scale for 5 HYVs such as BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 in mineral analysis. All physical parameters were measured following IRRI evaluation standard SES [18]. AAC was determined by the procedure of Juliano [19] and Protein contents were calculated from nitrogen (multiplied by 5.95 factor) and was determined by Micro Kjeldahl method. Volumes of cooked and milled rice were measured by water displacement method. Five grams of milled rice was placed in a graduated cylinder containing 50 mL of water and the change in volume was noted. For cooked rice volume 5 g of milled rice was cooked and the cooked rice was placed in the same cylinder and the change in volume was measured. Cooking time was measured when 100% of cooked rice totally gelatinized. Duncan's multiple range test (DMRT) was applied on DOM% and Zn content of five selected HYVs which varied over 80 seconds to 180 seconds of polishing for statistical analysis using SPSS, version 20.0.

Determination of thiamin and riboflavin

These water-soluble vitamins are extracted from the rice powder by acid hydrolysis followed by enzymatic hydrolysis. The aqueous extract is injected onto a reverse phase HPLC column. The fluorescence of riboflavin is measured, and thiamin is determined after post column derivatisation with alkaline potassium ferricyanide that converts the thiamin to thiochrome [20-24]. The method is described for the determination of thiamin and riboflavin in rice by HPLC in ASEAN Manual of Food Analysis [25].

Estimation of iron and zinc: Sample were digested and estimated by the method of the Association of Official Agricultural Chemists [26]. About 0.5 g rice powder was taken into a 25 mL conical flask and then for extraction of minerals, 5 mL mixture of nitric acid: perchloric acid (5:2) was added to the flask. The sample were heated at 350℃ for digestion until the color became clear. Then the digested sample were cooled and filtered through a Whatman filter paper No. 1 and the volume was made up to 25 mL with de-ionized distilled water (Branstad, USA). Iron, zinc and calcium were determined by the atomic absorption spectrometry (Shimadzu Atomic Absorption Spectrophotometer AA-6800) using a different standard curve for each. For the preparation of standard curve for iron, absorbance of 0.0, 1.0, 2.0, 4.0, 8.0 µg mL^{-1} iron solutions at 348.3 nm and for zinc 0.05, 0.10 0.20, 0.40, 0.80, 1.00 µg mL^{-1} at 213.8 nm were taken respectively.

Estimation of Phytic Acid (PA): Phytic acid present in rice samples were determined colorimetrically by Wheeler and Ferral method [27]. About 200 mg rice powder was weighed and transferred into a 15 mL centrifuge tube. Then 7.5 mL TCA (5%) solution was added and vortexed the mixture. The mixture was incubated at 60℃ for 10 minutes and then centrifuged at 5000 rpm for 10 minutes. The supernatant was transferred into a 25 mL volumetric flask. The extraction was repeated for 2 more times and transferred the supernatant into the volumetric flask and the volume was made up to 25 mL. Twenty mL extracted sample was taken into a 75 mL Technicon tube and then 5 mL ferric chloride solution was added. The tubes were then heated in a block digestor at 95℃ for 45 minutes. After cooling the tube, it was made up to 75 mL with deionized water and filtered through Whatman filter paper No. 42. Pipetted out 2.5 mL filtrates and then 2 mL potassium thiocyanate (29%) and 5 mL de-ionized water

was added in each of the tube for making total volume 9 mL. Then after mixing, the absorbance of the mixture was measured at 485 nm against water as blank. Pipetted out 5 mL of ferric chloride solution into a tube, and then 20 mL de-ionized water and 2 mL TCA (5%) was added. The flask was heated in a block digestor at 95°C for 45 minutes. After cooling the tube, it was made up to 75 mL with de-ionized water and filtered through Whatman filter paper No. 42. Then filtrates were pipetted from 0.5 to 2.5 mL in different tubes. The volume was made up to 7.5 mL with de-ionized water and 2 mL of potassium thiocynate (29%) was added in each tube. After mixing, the absorbance of the solution was measured at 485 nm. A standard graph of ferric ion was plotted. From the graph, the slope was determined and then values for phytic acid was calculated on the assumption that four ferric ions combine with one molecule of phytic acid ($Fe_4P_6C_6H_6O_{24}$). Calculation was done on the basis of dry weight of the sample.

Molar ratio of phytic acid (PA) to Zn and Fe: The molar ratio of PA/Zn and PA/Fe were calculated as follows; the molar intake of phytate (molecular weight, 660) was divided by the molar intake of Zn (molecular weight, 65) and molar intake of Fe (molecular weight, 56) respectively.

Results and Discussion

In this study protein content of BRRI HYVs were found averagely at 8.1 ± 1.0% along with a range from 6.4%-10.4%. According to HIES BBS, 2016 data of Bangladesh, per capita rice consumption is 367 (g capita^{-1}day^{-1}). Considering the amount in to account, we are getting approximately 29.73 g (8.1*367/100 g) of protein from rice daily where RDA of protein is 56 g for an average 70 Kg (Recommended amount is 0.8 g protein intake kg^{-1} body weight day^{-1}) weighted individual of Bangladeshi population. BRRI dhan34, BRRI dhan36 and BRRI dhan37 possess more than 10% of protein at brown rice condition. Apparent amylose content (AAC) is very important characteristic for varietal characterization and development. Since Bangladeshi population usually prefers non-sticky rice over sticky rice. Even through, there is no single trait responsible for significant correlation between AAC and stickiness of rice but others such as alpha amylase inhibitor, degree of milling etc. BRRI usually prefers to release advance lines whose AAC is preferably higher than 25% and it found at a range from 20-27% of ACC (Table 1). BRRI dhan43 and BRRI dhan42 has relatively high AAC value of 26.7 and 26.1% respectively.

Variety	Protein	AAC	Cooking Time	ER	IR
BRRI HYV rice	(%)	(%)	(Min.)	Ratio	Ratio
BR3	8.1	26.2	17	1.4	3.4
BR5	9.0	26.0	14	1.6	3.4
BR6	7.1	26.0	17	1.4	3.6
BR7	8.1	22.3	16	1.3	3.5
BR10	8.3	26.0	16	1.3	3.7
BR11	8.2	26.0	17	1.4	3.6
BR14	7.5	27.1	18	1.4	3.6
BR16	7.4	27.0	18	1.4	3.5
BR17	7.0	27.0	20	1.4	3.7
BR18	8.2	27.0	21.0	1.3	3.7
BR19	7.5	26.2	18.0	1.3	3.6
BR21	8.8	25.1	15.0	1.4	3.4
BR22	7.3	26.0	18.0	1.5	3.8
BR23	7.8	27.2	17.0	1.4	3.4
BR25	9.1	25.9	19.0	1.4	4
BR26	8.4	22.6	19.5	1.3	4.1
BRRI dhan28	8.7	26.5	17.5	1.5	4.3
BRRI dhan29	7.0	27.0	18.5	1.4	4.4
BRRI dhan31	8.9	26.5	20.5	1.4	4
BRRI dhan34	10.2	23.0	13.0	1.4	4
BRRI dhan36	10.1	25.4	19.0	1.3	3.7
BRRI dhan37	10.4	23.8	20.0	1.2	3.7
BRRI dhan38	8.8	22.6	19.0	1.3	3.7
BRRI dhan39	8.4	26.6	19.5	1.3	3.7
BRRI dhan40	7.6	25.7	19.0	1.4	4
BRRI dhan41	6.4	24.6	17.5	1.4	4
BRRI dhan42	8.4	26.1	18.5	1.4	4.3
BRRI dhan43	7.5	26.7	15.5	1.4	4.4
BRRI dhan46	8.2	24.7	16.3	1.4	3.3
BRRI dhan47	6.6	26.1	22.0	1.4	3.6
BRRI dhan48	8.0	26.8	18.3	1.4	3.4
BRRI dhan49	8.7	24.8	20.0	1.4	3.6
BRRI dhan58	7.2	26.0	15.4	1.3	3
BRRI dhan61	7.1	20.0	16.0	1.3	3.5
BRRI dhan64	7.4	23.0	22.0	1.4	3.1
Mean ± STD	8.1 ± 1.0	25.4 ± 1.7	17.9 ± 2.1	1.4 ± 0.1	3.7 ± 0.3
Range	6.4-10.4	20.0-27.0	13.0-22.0	1.2-1.6	3.0-4.4

Table 1: Chemical and cooking properties of 35 BRRI HYVs.

BRRI HYV rice	Thiamin mg100^{-1}g	Riboflavin mg100^{-1}g
BR 3	0.46	0.056
BR 5	0.8	0.071
BR 6	0.56	0.019
BR 7	0.4	0.008
BR 10	0.55	0.069
BR 11	0.51	0.042
BR 14	0.59	0.095

BR 16	1.05	0.075
BR 17	0.45	0.039
BR 18	0.67	0.06
BR 19	0.62	0.045
BR 21	0.45	0.011
BR 22	0.82	0.032
BR 23	0.83	0.014
BR25	0.93	0.08
BR 26	0.53	0.002
BRRI dhan28	1.09	0.045
BRRI dhan29	1.14	0.047
BRRI dhan31	0.84	0.044
BRRI dhan34	0.79	0.038
BRRI dhan36	1.15	0.019
BRRI dhan37	0.83	0.057
BRRI dhan38	0.93	0.08
BRRI dhan39	0.58	0.017
BRRI dhan40	0.83	0.058
BRRI dhan41	0.78	0.048
BRRI dhan42	0.85	0.03
BRRI dhan43	1.08	0.064
BRRI dhan46	0.75	0.016
BRRI dhan47	0.73	0.03
BRRI dhan48	1.12	0.023
BRRI dhan49	0.84	0.025
BRRI dhan58	1.09	0.046
BRRI dhan61	0.82	0.026
BRRI dhan64	0.89	0.045
Mean ± STD	0.78 ± 0.22	0.042 ± 0.023
Ranges	0.41-1.15	0.002-0.095

Table 2: Water soluble vitamins (Thiamin and Riboflavin) profiling of 35 BRRI HYVs.

If we consider average thiamin content of 0.78 ± 0.22 mg100^{-1}g into account, then we will get 2.87 mg (0.781*367/100 mg) of thiamin daily from rice intake only (Table 2). The median intake of thiamin from food in the United States is approximately 2 mgday^{-1}, and the ninety-fifth percentile of intake from both food and supplements was approximately 6.1 mgday^{-1}. Since thiamin is a water soluble vitamin so tolerable upper intake level **UL** for thiamin is not fixed yet [27] but deficiency is scared. Our BRRI HYVs rice are found very good source of thiamin. Regarding riboflavin, BRRI HYVs possess riboflavin at average 0.042 ± 0.023 mg100^{-1}g with a range from 0.002-0.095 mg100^{-1}g at ($8.0 \pm 0.50\%$ polished) milled rice. We can get approximately 0.15 mg (0.042*367/100 mg) of thiamin from rice daily where RDA of riboflavin for adults is 1.3 mgday^{-1} for men and 1.1 mgday^{-1} for women [28]. So, it seems rice is not a good source of riboflavin but BR14 showed the highest amount of riboflavin content (0.095 mg100^{-1}g). It could serve maximum of 0.35 mg (0.095*367/100 mg) riboflavin daily (Table 2).

Selective mineral profiling of BRRI HYVs were analyzed and the selection criteria was set at the level of Thiamin VitB$_1$ is ≥ 0.85 mg100^{-1}g (Tables 2 and 3). Phytic Acid (PA) and molar ratio of PA to minerals (Zn and Fe) were also selectively analyzed and the selection criteria was set at the level of Zn is ≥ 20 ppm. In this regard, a total of 10 BRRI HYVs were subjected analyzed for mineral profiling such as Zn and Fe content and among them only 5 BRRI HYVs were also subjected to further analyzed for PA and molar ratio of PA to minerals (Zn and Fe). All mineral data are assembled in a tabular form in table 3 where DOM was approximately ($10.2 \pm 0.22\%$).

Variety		Zn	Fe	PA	PA/Zn	PA/Fe
BRRI HYV rice	DOM%	(ppm)	(ppm)	(mg/g)	(Ratio)	(Ratio)
BR 16	10.2	16.49	5.16	ND	ND	ND
BR25	10.12	21.3	4.54	19	9	43
BRRI dhan28	10.43	15.21	8.17	ND	ND	ND
BRRI dhan29	10.3	16.02	7.78	ND	ND	ND
BRRI dhan36	10.38	20.43	10.12	15	6	13
BRRI dhan38	10.11	10.19	20.32	ND	ND	ND
BRRI dhan42	10.46	27.12	4.13	14	5	23
BRRI dhan43	10.43	27.17	10.09	14	3	4
BRRI dhan48	9.56	11.3	9.11	ND	ND	ND
BRRI dhan64	10.15	20.1	11.21	24	10	18

Mineral profiling of selected BRRI HYVs which Thiamin (VitB1) level is ≥ 0.85 mg100^{-1}g. Phytic Acid (PA) and molar ratio PA to minerals (Zn and Fe) were analyzed for BRRI HYVs which Zn level ≥ 20 ppm. ND=Not Done.

Table 3: Mineral profiling of 10 selected BRRI HYVs (DOM at $10.20 \pm 0.22\%$).

Zn content of both BRRI dhan43 (27.17 ppm) followed by BRRI dhan42 (27.12 ppm) were found higher in this study even at (10.20 ± 0.22) % DOM. Earlier in 2017, Shozib et al. [29] reported mineral profiling of 68 BRRI HYVs in Bangladesh but Zn content varied for these reported varieties because of variation of DOM percentage. Eighty (80 Seconds) of polishing by Gainman polisher was applied for all tested varieties which gave around 8.5% of DOM as an average. Grain size and shape also has a role in DOM, so we tried to explore the explanation of zinc content variation over increasing DOM. Our data

reveals that mineral content specially Zn content varied over increasing DOM and polishing time (Figure 1 and Table 4).
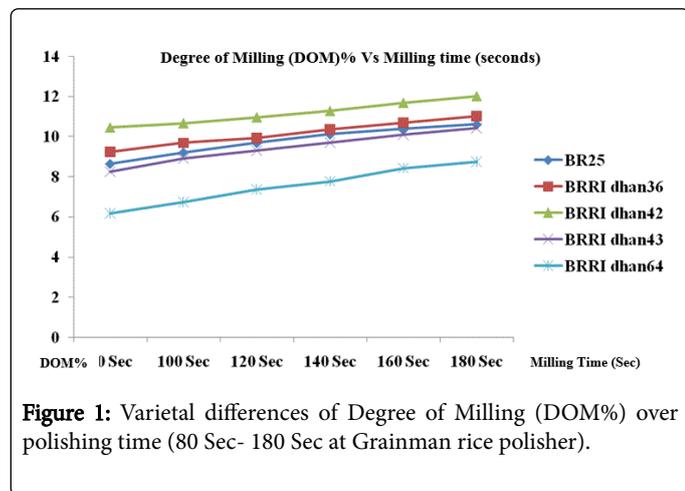

Figure 1: Varietal differences of Degree of Milling (DOM%) over polishing time (80 Sec- 180 Sec at Grainman rice polisher).

HYVs	L (mm)	L/B ratio	S&S	DOM% at 80 Sec	DOM% at 140 Sec	DOM% at 180 Sec
BR25	4.7	2.6	SB	8.65[a]	10.12[a]	10.62[a]
BRRI dhan 36	6.1	3.2	LS	9.24[b]	10.38[b]	11.04[b]
BRRI dhan42	6.5	3.1	LS	10.46[c]	11.28[c]	12.02[c]
BRRI dhan43	5.8	2.4	MB	8.25[d]	9.30[d]	10.43[d]
BRRI dhan64	5.3	2.1	MB	6.19[e]	7.78[e]	10.15[e]

L: Length; L/B ratio: Length /Breadth ration of polish rice; S&S: Size and Shape; SM; Small and Medium; LS; Long and Slender; MB; Medium and Bold; DOM: Degree of milling; ppm: mgkg^{-1}. Any two-means having common letter (s) are not statistically different at a P<0.05, as measured by the Duncan Multiple Range Test (DMRT).

Table 4: Variation of DOM% of 5 HYVs at different time points (80 sec, 140 secs and 180 sec).

HYVs	BR25	BRRI dhan36	BRRI dhan42	BRRI dhan43	BRRI dhan64
Polishing time at 80 Sec	24.70[a]	23.6[a]	27.12[a]	38.40[a]	24.46[a]
Polishing time at 140 Sec	21.30[b]	20.43[b]	24.21[b]	32.90[b]	22.10[b]
Polishing time at 180 Sec	18.21[c]	17.34[c]	20.43[c]	27.17[c]	20.10[c]

ppm: mgKg^{-1}. Any two-means having common letter (s) are not statistically different at a P<0.05, as measured by the Duncan Multiple Range Test (DMRT).

Table 5: Variation of Zn content (ppm or mgKg^{-1}) of 5 HYVs at different time points (80, 140, and 180 sec).

Lamberts et al. in 2007 [30] reported that the mineral content is the highest in bran (61.0%), followed by outer endosperm (23.7%), core endosperm (11.6%), and the lowest in the middle endosperm (3.7%). Proteins, minerals and starch were not uniformly distributed in the brown rice kernel. Bran (0%<DOM<9%) contained most of the minerals (61.0%). In our experiment we found variation in Zn content with increasing polishing time from 80 seconds to 180 seconds and DOM (Table 4). At 80 seconds of polishing, DOM varied ranges from 6.19 to 10.46% for five selected HYVs whose grain size and shape are also varied from small and medium grain, long and slender grain, medium and bold grain etc. Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 24.70 ppm, 23.60 ppm, 27.12 ppm, 38.40 ppm and 24.46 ppm at 80 seconds of polishing. Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 21.30 ppm, 20.43 ppm, 24.21 ppm, 32.90 ppm and 22.10 ppm at 140 seconds of polishing where DOM varied ranges from 7.78 to 11.28%. Finally, Zn content of BR25, BRRI dhan36, BRRI dhan42, BRRI dhan43 and BRRI dhan64 were 18.21 ppm, 17.34 ppm, 20.43 ppm, 27.17 ppm and 20.10 ppm at 180 seconds of polishing where DOM varied ranges from 10.15 to 12.02% (Tables 4 and 5). We have clearly demonstrated how Zn content and DOM% of 5 different BRRI HYVs significantly varied at different polishing time ranges from 80 seconds to 180 seconds (Tables 4 and 5) considering grain size and shape into account.

Indica type Bangladeshi HYVs are seems very rich in vitamins, minerals, protein and starch content. In this study we were aiming to identify few nutraceutically enriched HYVs which may be rich in vitamins, minerals along with superior physicochemical and cooking properties. Considering all nutritional values such as water-soluble vitamins specially thiamin, protein, apparent amylose content, cooking time, elongation ratio, imbibition's ratio, mineral contents such as Zn, Fe, PA and molar ratio of PA to minerals into account, we found few BRRI HYVs which are appropriate to treat as nutriceutically enriched HYV rice in Bangladesh. In addition, higher content of minerals in rice can only be attained at lower degree of polishing (<10% DOM) and grain size and shape can equally be important trait in considering DOM of individual rice genotypes. Naturally selected these nutraceutically enriched HYVs can possibly play a pivotal role in attaining better nutrition through widely consume rice at 367 (g capita^{-1}day^{-1}) in Bangladesh at present fashion.

Conclusion

In conclusion, we would like to emphasis some promising HYVs such as BRRI dhan43 and BRRI dhan42 since these HYVs have relatively higher concentration of thiamin (≥ 0.85 mg100^{-1}), zinc (≥ 27.0 ppm), apparent amylose content (≥ 27%), imbibitions ratio (≥ 4.3) and lower content of phytic acid (≤ 14 mgg^{-1}) and molar ratio of PA to minerals among all tested BRRI HYVs in Bangladesh. Since, lower degree of milling is associated with higher mineral content, so it is further recommended to consume lower degree of polished rice (<10% DOM) rather over polishing (≥ 10%). Rice grain size and shape has been found significant impact on degree of milling (DOM) and mineral content trends to be decreased significantly over increasing the polishing time. This acquainted information might be very useful in rice and rice-based food industries in Bangladesh. Further research activities should be conducted in an attempt to assess bioavailability of

both micronutrients and vitamins of nutraceutically enriched BRRI HYVs specially BRRI dhan43 and BRRI dhan42 in human trail.

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