NUTRIENT CONTENT OF TRADITIONAL AND HIGH-YIELDING VARIETIES OF RICE GROWN IN BANGLADESH

Siddiquee, Muhammad Ali[1], **Buffo,** Roberto A.[2], **Chowdhury,** Nurul H[1], **Kabir,** Yearul[3]

[1]Grain Quality and Nutrition Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
[2]Food Science and Technology Program,Universidad de San Pablo-T, Tucumán, Argentina
[3]Department of Biochemistry and Molecular Biology, University of Dhaka, Dhaka -1000, Bangladesh
E-mail address: ykabir@yahoo.com

Abstract
Nine traditional and eight high-yielding varieties of rice grown in Bangladesh were compared for nutritional value. All samples underwent parboiling and then milling to differentiate between brown and milled rice. Traditional and high-yielding varieties did not differ in moisture content, protein, crude fiber and most minerals. High-yielding varieties contained more amylose than traditional ones. Although the difference was small in absolute terms, it has remarkable importance from a functional viewpoint. Traditional varieties yielded more ash and contained more potassium and less amylose than high-yielding varieties, but in general, milling was more influential in determining nutrient content than rice type. Traditional and high-yielding varieties did not differ on their protein content, but brown rice contains more protein than the milled rice samples. Milled samples retained 80 to 94.2% of protein in brown samples. Brown rice samples also contained more crude fiber, ash and minerals than milled samples. Bran removal on milling meant a percentage increment of amylose on milled over brown rice. On a percentage basis, there was more amylose in milled than brown samples. The ash content was higher for brown samples over milled ones. Traditional and high-yielding varieties did not show major nutritional differences. Thus, the preference of the latter over the former because of their higher yields per unit area is justified from a nutritional viewpoint.

Key words: Rice, nutrient content, parboiling, traditional and high-yielding varieties, Bangladesh.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely cultivated cereal crop and it serves as staple food for the vast majority of the world's population (GRiSP, 2013). Its production and consumer's demands for better quality are continuously increasing throughout the world (McGuire et al. 2015). In Bangladesh, rice occupies the largest farming area compared to any other crop and is the most important staple in the diet of the population, with a production of nearly 32 million metric tons per year (Bangladesh Bureau of Statistics, 2010).
Rice parboiling is a common practice in Bangladesh as well as India and other countries in South Asia (Singh et al., 1999). In fact, more than 90% of the rice consumed in Bangladesh is parboiled and milled whereas brown rice is rarely consumed. Milled rice is the principal energy source in the Bangladeshi diet, accounting for about 80% of total energy intake (Jahan and Hossain, 1998). Rice is parboiled by soaking rough rice in water, draining and steaming, then drying (Bhattacharya, 1985). Parboiled rice is prized for its longer shelf-life because of enzyme inactivation. It also results in a less insect-infested product and causes hardening of the grains, which makes them more resistant to breakage during milling. This translates into an increased yield, giving an economic advantage to the process. Nutritionally speaking, parboiling allows retention of minerals and water-soluble vitamins; at least theoretically, this effect has been attributed to nutrient solubilization and migration to the center of the grain and their setting during the starch gelatinization process (Amato et al., 2002; Juliano, 1985; Sajwan et al., 1990).
Independently from parboiling, rice is commercially milled by polishing the grain to various grades, sometimes to the extent of 15% to obtain white rice. Milling removes husk, bran and germ from the grain and may result in considerable nutrient loss according to the degree of polishing (Esmay et al., 1979).

However, in recent years an increased demand for brown rice (i.e., rice without milling) has been observed because of their reputation for nutritional excellence and health claims (Heinemann et al., 2005).
In Bangladesh during the last few decades a large number of new varieties of rice have been developed by the Bangladesh Rice Research Institute (BRRI) on the basis of their suitability for growth and higher yields under the agroclimatic conditions of the country, though little attention has been paid to the quality and yield of nutrients per unit area of those varieties. The nutrient content of traditional and high-yielding varieties of rice grown in Bangladesh has not been investigated systematically to date. As considerable differences in nutrient composition have been found between cultivars of the same crops (Kennedy and Burlingame, 2003; Kennedy et al., 2005), the consumption of different cultivars within a species may have an impact on nutritional status of people.
The aim of this study was to investigate differences in chemical composition and nutritional quality of traditional and high yielding varieties of rice (brown and milled) grown in Bangladesh, as well as to compare newly developed high yielding varieties to existing traditional ones from nutritional viewpoint.

MATERIALS AND METHODS

Rice varieties

Nine traditional cultivars (namely Agunsail, Ghungshe, Kajalsail, Kumragior, Lonakhuchory, Monteshor, Moulata, Rajasail and Sadamota) and eight high yielding varieties (namely BR10, BR11, BR22, BR23, BRRIdhan31, BRRIdhan32, BRRIdhan40 and BRRIdhan41) were studied. Samples were collected from the farmer's fields through Adaptative Research Division of BBRI (Gazipur, Bangladesh).

Rice treatment

All rough rice samples were cleaned thoroughly, soaked in excess water for 24 hours at room temperature (25-30°C), and then steamed till the opening of the hull at palea lemma. After sun drying, the resulting parboiled rice was dehulled using the Satake Rice THU-type husker (Satake Eng. Co., Japan) and the resulting brown rice milled in a Satake TM-50 grain testing mill (Satake Eng. Co., Japan) to have about 10% weight removal, calculated as the percent weight losses observed after milling 100g samples of brown rice. Milling to the extent of 10% required 75 s to 80 s. Samples of both brown and milled rice were ground using an Udy cyclone to pass through a 60-mesh net (Udy Analyzer Co., Boulder, CO, USA).

Analytical methods

Moisture, crude fiber and ash were determined by standard AOAC methods (AOAC, 1995). Amylose was determined by the Simple Amylose Assay Procedure using potato amylose as standard (Juliano, 1971). The micro-Kjeldahl method (AOAC, 1995) was used to determined nitrogen. Kjeldahl nitrogen was converted to crude protein by multiplying by a factor of 5.95. Minerals were determined by means of Atomic Absorption Spectrometry (Hitachi Spectrometer, Model 170-10, Japan) after acid extraction with a 5:2 mixture of nitric acid and perchloric acid, respectively. All samples were analyzed in triplicate for each nutrient and mean values were taken for statistical analysis.

Statistical analysis

Moisture values of traditional and high yielding varieties were compared by a two-tailed t-student test. Mean, standard deviation and coefficient of variation were computed for each nutrient under each combination of a 2 x 2 factorial design: *type* (traditional rice varieties vs. high yielding rice varieties) and *treatment* (parboiled brown rice vs. parboiled milled rice). All analysis, namely t-test, and analysis of variance (ANOVA) were performed using the software MACANOVA (Oehlert and Bingham, 1997). The level of significance was set at $p<0.05$ for all statistical tests performed in the study.

RESULTS AND DISCUSSION

Proximate composition and mineral content of traditional and high-yielding varieties discriminated according to treatment (parboiled brown vs. parboiled milled) are presented in Tables 1 and 2, respectively. Table 3 gives descriptive statistic parameters (i.e., mean ± standard deviation - coefficient of variation), discriminated according to *type* and *treatment*, and Table 4 also presents the corresponding ANOVA for each nutrient under the 2 x 2 factorial designs.

All samples showed very similar moisture contents around 12% (Table 1), which is the recommended value for long-term storage to avoid insect infestation and microorganism development (Cogburn, 1985). There were no differences in moisture content between traditional and high-yielding varieties.

Nitrogen-to-protein conversion factors for protein content in rice are not standardized in the literature, varying from 5.7 to 6.25. The 5.95 value is the conversion factor recommended for rice by AOAC (AOAC, 1995). Protein content showed moderate variability for all four combinations resulting from the factorial design (Table 1). As indicated by the corresponding coefficients of variation, this variability was slightly higher for traditional vs. high-yielding varieties and for milled vs. brown samples (Table 3). ANOVA gave an extremely high statistical significance (p<0.001) to *treatment* and no significance to *type* (Table 4). Therefore, traditional and high-yielding varieties did not differ on their protein content, but brown rice contains more protein than the milled rice samples. Milled samples retained 80 to 94.2% of protein in brown samples. This effect is related to the protein distribution pattern on the grain, with some varieties having protein evenly distributed between bran and endosperm and others unevenly distributed with more protein in bran than endosperm. For those samples with a significant amount of protein evenly distributed within the endosperm, protein retention after milling is evidently higher (Juliano and Bechtel, 1985). In any case, the polishing operation needed for bran removal meant a significant protein loss in our study as a whole (Table 3).

Data variability for amylose content was evidently higher for traditional over high-yielding varieties (Table 1). Effectively, *type* was extremely highly significant (p<0.001) in ANOVA and only moderately significant for treatment (p<0.05). High-yielding varieties contained more amylose than traditional ones (Table 3). Although the difference was small in absolute terms, it has remarkable importance from a functional viewpoint. An amylose content of more than 25% (as it was the case for mean values of high-yielding varieties) gives harder and non-sticky cooked rice, whereas an amylase content in the 20-25% range (as it was the case for mean values of traditional varieties, both brown and milled) gives soft and slightly sticky cooked rice. The majority of the population prefers the former over the latter (Biswas et al., 1992; Juliano, 1972). On a percentage basis, there was more amylose in milled than brown samples (Table 3). As bran is removed in milled samples and considering that amylose is an essential constituent of the endosperm, there is an enrichment of amylose in milled samples with respect to other components.

Crude fiber values showed much higher variability than protein and amylose in traditional varieties and the highest variability of all components in high-yielding varieties due to four samples containing about twice the fiber of the other four (Table 1). There were no statistical differences on *type* but *treatment* was associated with an extremely significant value (p<0.001) (Table 3). For all samples, bran removal meant fiber loss of about 50%. Juliano and Bechtel (1985) have signaled fiber as a potent inhibitor for the intestinal absorption of other nutrients; thus, at least from a nutritional perspective, their removal on milled rice seems beneficial.

Data variability on ash content was consistently higher for traditional over high-yielding varieties and for brown samples over milled ones (Table 1). Effectively, ANOVA showed extremely high statistical significance (p<0.001) for both *type* and *treatment* (Table

4). Bran removal caused an ash decrease of about 50% of original content. Considering that the same degree of polishing was applied to all samples, variability on ash content among milled samples resulted from different degrees of hardening. Bhattacharya (1985) has reported a higher resistance to milling on parboiled rice due to grain hardening, a factor that could have certainly contributed to the data variability observed in addition to native differences in grain hardening. In fact, a similar effect could have placed a role on the high data variability observed for crude fiber content on traditional varieties as well. The much higher variability shown on crude fiber data within high-yielding varieties could have been a combination of this effect plus the aforementioned high dissimilarities on initial fiber content within the group.

Potassium is the overwhelming most abundant mineral on rice (Table 2), as had been reported previously by Heinemann et al. (2005). Sodium and calcium are also significant macronutrients whereas iron and zinc predominated among trace elements. For all minerals, ranges found in this study agree with those reported in previous studies (Heinemann et al. 2005; Juliano and Bechtel, 1985; Wolnik et al., 1985).

Potassium content was remarkably consistent across variety types and treatments, comparable in fact with major constituents (protein and amylase). ANOVA showed extremely high significance ($p<0.001$) for both *type* and *treatment*, with higher contents for traditional varieties and brown samples, respectively (Table 3 & 4). Data variability for other minerals was much higher. All milled samples showed higher variability than their corresponding brown counterparts (Table 2). ANOVA for all other minerals indicated extremely high significance ($p<0.001$) for treatment, always showing higher contents for brown over milled samples (Table 4). Chinnaswamy and Bhattacharya (1983) have indicated that mineral retention in rice is the result of a number of factors, namely mineral location in the grain, solubility during soaking, migration ratios and milling resistance of the parboiled grain. Loss of minerals due to bran removal on milling was quantitatively lower in macronutrients than in trace elements, but evidently signaled a migration phenomenon towards outer layers of the grain during parboiling and subsequent removal during milling. Similar effects have been previously reported (Heinemann et al., 2005).

CONCLUSION

Differences on nutrient contents were essentially due to milling rather than rice *type*. Bran removal meant significant losses of protein, fiber and minerals. There were no interaction effects between *type* and *treatment* for any nutrient. For practical purposes, this study found no major nutritional differences between traditional and high-yielding varieties grown in Bangladesh. The rationale behind preferring newly developed varieties over traditional ones due to their higher yields per unit area is justified from a nutritional viewpoint. Nevertheless, traditional varieties should be conserved for future breeding programs as their mineral content is consistently higher than that of new varieties.

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Table 1: Proximal Composition of Traditional and High Yielding Varieties of Rice Grown in Bangladesh

	Moisture (%)	Protein (%)		Amylose (%)		Crude Fiber (%)		Ash (%)	
		Brown	Milled	Brown	Milled	Brown	Milled	Brown	Milled
Traditional									
Agunsail	12.28	8.53	7.21	24.52	25.76	1.65	0.42	1.56	0.79
Ghungshe	12.23	9.00	7.75	22.60	23.05	1.21	0.36	1.36	0.40
Kajalsail	12.81	9.18	8.32	24.41	25.65	1.15	0.49	1.28	0.54
Kumragoir	12.12	10.18	8.14	23.73	25.99	1.48	0.71	1.64	0.80
Lonakhuchory	12.45	9.54	8.17	19.08	21.40	1.49	0.72	1.68	0.80
Monteshor	12.28	9.74	8.29	20.94	22.33	1.62	0.65	1.68	0.73
Moulata	12.27	9.23	8.57	24.42	25.34	1.48	0.73	1.70	0.81
Rajasail	12.23	7.83	6.77	26.16	26.97	1.42	0.67	1.58	0.74
Sadamota	12.12	9.38	8.30	23.68	25.56	1.59	0.82	1.77	0.94
High Yielding									
BR10	12.23	9.91	8.73	24.35	25.16	2.01	1.28	1.61	0.84
BR11	12.35	9.74	8.70	25.70	26.51	2.07	1.47	1.21	0.35
BR22	12.42	9.13	8.56	25.16	26.24	1.00	0.44	1.36	0.48
BR23	12.12	8.76	7.50	25.47	27.86	1.98	0.52	1.58	0.63
BRdhan31	12.20	8.85	8.34	26.22	26.97	1.89	0.59	1.39	0.56
BRdhan32	12.21	8.78	7.91	26.37	27.57	1.07	0.48	1.23	0.53
BRdhan40	11.99	9.11	8.19	25.62	26.67	1.08	0.41	1.20	0.46
BRdhan41	12.45	8.77	7.32	26.07	27.12	0.95	0.44	1.02	0.49

Each entry is the mean of three replicates.

Table 2: Mineral Content (mg/100g) of Traditional and High Yielding Varieties of Rice Grown in Bangladesh

	Sodium		Potassium		Calcium		Iron		Zinc		Copper	
	Brown	**Milled**	**Brown**	**Milled**	**Brown**	**Milled**	**Brown**	**Milled**	**Brown**	**Milled**	**Brown**	**Milled**
Traditional												
Agunsail	20.37	18.37140		113	16.83	7.47	1.87	0.89	1.63	1.30	0.21	0.10
Ghungshe	12.83	10.03	153	120	13.47	7.13	1.38	0.72	1.40	0.93	0.14	0.10
Kajalsail	14.73	11.40	137	97	13.87	7.53	1.95	1.13	1.63	1.30	0.14	0.10
Kumragoir	16.60	12.67	153	117	12.87	7.53	1.87	1.24	1.77	1.47	0.17	0.10
Lonakhuchory	15.70	12.67	147	110	11.20	7.20	1.79	1.29	1.63	0.93	0.24	0.10
Monteshor	12.83	10.03	153	110	12.20	4.83	1.54	0.89	1.83	1.13	0.24	0.14
Moulata	16.67	15.67	157	107	14.53	8.20	1.46	1.13	2.00	1.23	0.28	0.10
Rajasail	17.60	16.63	147	117	12.20	7.17	1.46	0.89	1.23	0.50	0.21	0.10
Sadamota	17.60	16.67	153	113	13.83	7.87	1.36	1.03	1.07	0.50	0.17	0.10
High Yielding												
BR10	18.53	16.67	153	100	14.87	8.53	1.37	0.97	1.13	1.07	0.21	0.10
BR11	16.63	15.70	127	90	10.83	3.87	1.38	1.05	1.63	0.70	0.17	0.10
BR22	13.83	12.83	140	90	12.53	5.20	2.11	1.46	1.57	0.93	0.17	0.14
BR23	12.83	11.93	123	93	13.50	5.83	1.95	0.80	1.30	0.70	0.14	0.10
BRdhan31	14.70	11.90	140	90	17.20	5.20	1.71	0.89	1.93	1.00	0.28	0.10
BRdhan32	12.87	11.90	137	100	12.87	6.83	1.30	0.97	2.00	1.13	0.28	0.14
BRdhan40	14.70	13.80	130	83	12.17	6.53	1.30	1.05	2.10	0.97	0.21	0.17
BRdhan41	19.47	13.77	123	77	15.87	6.83	1.71	1.54	1.77	0.70	0.17	0.14

Each entry is the mean of three replicates.

Table 3: Statistical Summary of Nutrient Analysis*

	Traditional (n = 9)		High Yielding (n = 8)	
	Brown	**Milled**	**Brown**	**Milled**
Moisture (%)	12.31 ± 0.21 - 1.70	--------	12.25 ± 0.15 - 1.72	---------
[b]Protein (%)	9.18 ± 0.68 - 7.41	7.95 ± 0.59 - 7.42	9.13 ± 0.45 - 4.93	8.16 ± 0.54 - 6.61
[ab]Amylose (%)	23.28 ± 2.13 - 9.15	24.67 ± 1.91 - 7.74	25.62 ± 0.65 - 2.53	26.76 ± 0.84 - 3.14
[b]Crude Fiber (%)	1.45 ± 0.17 - 12.05	0.62 ± 0.16 - 25.80	1.51 ± 0.52 - 34.44	0.70 ± 0.42 - 60.00
[ab]Ash (%)	1.58 ± 0.16 - 10.12	0.73 ± 0.16 - 21.92	1.32 ± 0.20 - 15.15	0.54 ± 0.14 - 25.92
[b]Sodium (mg/100g)	16.10 ± 2.42 - 15.03	13.79 ± 3.11 - 22.55	15.44 ± 2.52 - 16.32	13.56 ± 1.81 - 13.35
[ab]Potassium (mg/100g)	148.9 ± 6.7 - 4.50	111.6 ± 6.8 - 6.09	134.1 ± 10.3 - 7.68	90.4 ± 7.8 - 8.62
[b]Calcium (mg/100g)	13.44 ± 1.64 - 12.20	7.21 ± 0.96 - 13.31	13.73 ± 2.10 - 15.29	6.10 ± 1.40 - 22.95
[b]Iron (mg/100g)	1.63 ± 0.23 - 14.11	1.02 ± 0.19 - 18.63	1.60 ± 0.31 - 19.37	1.09 ± 0.27 - 24.77
[b]Zinc (mg/100g)	1.58 ± 0.29 - 18.35	1.03 ± 0.35 - 33.98	1.11 ± 0.26 - 23.42	0.90 ± 0.18 - 20.00
[b]Copper (mg/100g)	0.20 ± 0.05 - 25.00	0.10 ± 0.01 - 10.00	0.20 ± 0.05 - 25.00	0.13 ± 0.02 - 15.38

*Mean ± Standard Deviation - Coefficient of Variation (%).
[a]Significant difference between type ($p < 0.05$). [b]Significant difference between treatment ($p < 0.05$).

Table 4: Analysis of Variance (ANOVA) for Nutrients (*p*-values) (2 x 2 Factorial Design: Type [Traditional vs. High Yielding] – Treatment [Brown vs. Milled])

	Type	Treatment	Type. Treatment[a]	Bonferroni Comparisons	
Protein	0.687	4.131×10^{-6}**	0.523	Brown, Milled	0.552, -0.552
Amylose	2.764×10^{-4}**	0.024*	0.819	Traditional, High Yielding Brown, Milled	-1.110, 1.110 -0.633, 0.633
Crude Fiber	0.568	1.046×10^{-7}**	0.890	Brown, Milled	0.410, -0.410
Ash	6.050×10^{-4}**	$<1.000 \times 10^{-8}$**	0.533	Traditional, High Yielding Brown, Milled	0.111, -0.111 0.410, -0.410
Potassium	2.955×10^{-7}**	$<1.000 \times 10^{-8}$**	0.251	Traditional, High Yielding Brown, Milled	8.990, -8.990 20.3, -20.3
Sodium	0.612	0.021*	0.807	Brown, Milled	1.050, -1.050
Calcium	0.449	$<1.000 \times 10^{-8}$**	0.204	Brown, Milled	3.460, -3.460
Iron	0.817	3.502 x 10-7**	0.587	Brown, Milled	0.280, -0.280
Zinc	0.835	4.596 x 10-7**	0.284	Brown, Milled	0.328, -0.328
Copper	0.295	3.195 x 10-7**	0.441	Brown, Milled	0.043, -0.043

[a] Linear Interaction; Significant difference at *$p < 0.05$), **$p < 0.001$.