

Grain Quality Research of Rice for Ensuring Nutritional Food Security

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ABSTRACT

Per capita rice consumption in Bangladesh is in a decreasing trend. Considering the constant loss of per capita daily dietary energy @ 0.028% year⁻¹, nutrition-based prediction of daily dietary energy intake (kcal) may be reduced to 2201 and 2188 kcal for our population by 2030 and 2050, respectively. We are optimistic that consuming per capita rice consumption of 365 g and 363 g (dry wt. basis) in 2030 and 2050, respectively will help to attain the current trends of 59.0% of Calorie intake from rice only. Appropriate amount of rice intake including incorporating rice-based products in our daily diet, we will be able to attain daily required dietary allowance and combination of both may ensure nutritional security along with food security in Bangladesh in a way to effective utilization of the rice grain. Rice is nutraceutically enriched because of the presence of phenolic compounds, flavonoids and antioxidants. Research thrust of BRRI is to focus on releasing nutraceutically enriched HYVs such as high zinc, high iron, beta carotene (A Vit A precursor) enriched antioxidant rice etc. Gluten free rice-based bakery products have potential to get popularize in Bangladeshi population with ensuring high nutritional value and effective management of controlling non-communicable diseases since lesser amount of rice carbohydrates are being utilized in formulating products such as rice biscuit, rice cake etc. BRRI has formulated gluten free rice-based energy dense product specially rice biscuit (ED 5.15) could be extended as a potential nutritionally balanced dry food application in malnutrition mitigation programme, school feeding nutritional programme and humanitarian relief operation replacing current wheat-based products.

Key words: Nutraceutical, malnutrition mitigation, gluten free rice-based bakery products. energy dense rice biscuit.

INTRODUCTION

The nutrient content of rice varies depending on rice soil, and the conditions they grow. A better understanding of the intrinsic factors that contribute to the overall rice grain quality will set the foundation for developing new breeding and selection strategies for combining high grain quality, with higher yield and nutritional value. Rice producing countries have the potential to generate higher export revenues by meeting the ever-increasing global demand for high-quality rice specially nutraceutical enriched premium quality rice. Bangladesh can not be an exception in this regard.

The malnutrition scenario of the Bangladeshi population

Humans need at least 49 different types of nutrients for their regular development and the

majority of the required nutrients are supplied by cereals, particularly rice due to its staple role (Welch, 2004). Minerals play numerous beneficial roles due to the effect on both plant and human metabolism. The deficiencies or an insufficient intake of nutrients lead to several dysfunctions and diseases in humans, such as anemia for iron, stunting for zinc, and osteoporosis for calcium which are most prevalent in developing countries (Welch *et al.*, 1999). Malnutrition in Bangladesh is alarmingly high since approximately 36.2% children of under five years of age are stunted, 15% are wasted and 33% are underweight (Sunanda and Jahida, 2017). Both malnutrition and poverty hamper access to education especially the ability to learn. One in every five preschool or school-aged children suffers from vitamin A deficiency in Bangladesh. Also, 33% of preschool children

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are anemic, 9% of women have folate deficiency and 22% of women are suffering from Vit-B₁₂ deficiency in our population. According to the National Micronutrients Survey 2011-2012, Bangladesh has a frequency of zinc deficiency is about 44.6% amongst preschool-age children and 57.3% amongst non-pregnant non-lactating women.

Nutrient loss negatively correlates with the degree of milling

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. 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. In 2007, Lamberts *et al.*, showed that about 84.2% of kernel proteins are concentrated in outer endosperm, and upon milling further the concentration of proteins decreases. They found that 61% of most of the minerals are present in the bran fraction of the kernels whereas the core of the endosperm fraction mainly consists of starch (84.6%) in the kernels. Milling is a phenomenon of wear that involves removing material from a solid surface either by mechanical action or by combinations of various actions such as rolling, impacting, or sliding. Commercial milling is a process consisting of various stages where firstly paddy or rough rice goes through the dehusking process and then the outer brown bran layer is removed during the whitening process. In the final step, the adhering bran is completely removed from the grain surface and is known as polishing. The quality of milled rice is depicted by two important parameters i.e., the 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 gets in touch with the emery surface experiences abrasion type of milling

while grain which rubs against each other experiences adhesive type of wear. In rice polishing, generally, a combination of both types of wear is used, as, no pure form of milling has yet been discovered. Rubber rolls were determined to be most suitable for laboratory scale milling operations as these increased the dehusking percentage but decreased the breakage of rice kernels. During milling operations, these nutrients are removed thus reducing the nutritive value of starch. The degree of milling (DOM) affects the concentration of nutrients. The proximate composition depends upon the degree to which the bran has been removed from the kernel surface. The rice subjected to lower DOM could lead to more nutrition which can assure better health of the consumers (Puri, 2014). The speed of the impeller cannot be taken as a sole criterion for optimization of impeller husker performance, as it depends on the size and shape of rice kernels also (Puri, 2014). This could be judged by a low husked ratio even if the impeller speed was at its optimum. The quality of rice milling is affected by the moisture content of paddy as well as the rotor speed of the whitener. Various experiments were performed using different cultivars and different types of milling material such as plywood, iron sheet, rubber, glass, and fiberglass. Milling in rubber roll huller was found to be the most effective for paddy but least for milled rice. In 2010, Firouzi *et al.*, evaluated the performance of perforated screen size and blade rotor clearance for whitening of rice grain. During the milling process, the losses of minerals reached up to 84.7%. Fukai and Godwin, (2007) milled brown rice cultivars and measured loss in iron content. The iron content of 25-84% was lost during the milling process.

Functional properties of rice

Rice is an important source of energy, hypoallergenic, easily digested, providing protein with higher nutritional quality, and

has versatile functional nutraceutical properties. Rice has an important role in the relation between diet and health. Several compounds with antioxidant activity have been identified in rice, including phenolic compounds, tocopherols, tocotrienols, and γ -oryzanol (Iqbal *et al.*, 2005). The phenolic compounds are mainly associated with the pericarp in rice; hence, the milling process reduces the concentration of these compounds in the grain. Besides, grains with darker pericarp colour, such as red and black rice, contain higher amounts of polyphenols (Tian *et al.*, 2004; Zhou *et al.*, 2004). The concentration of total phenolics in the grain has been positively associated with the antioxidant activity (Itani *et al.*, 2002; Zhang *et al.*, 2006). Therefore, it reduces oxidative stress (Ling *et al.*, 2001), cancer (Hudson *et al.*, 2000; Hu *et al.*, 2003), blood lipids and related diseases, and hence prevents cardiovascular problems (Ling *et al.*, 2001), and diabetes complications (Morimitsu *et al.*, 2002; Yawadio *et al.*, 2007).

Water soluble vitamins in rice

People intake thiamin Vit-B₁ 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 and 1.1 mg day⁻¹ for men and women, respectively. Riboflavin functions as a co-enzyme in numerous redox reactions. The RDA for riboflavin for adults is 1.3 and 1.1 mg

day⁻¹ for men and women (Institute of Medicine, 1998), respectively.

Gluten-free rice-based bakery food products

Food intolerance became an important public health concern, and the identification of effective strategies for prevention is obligatory. There is an increasing incidence of coeliac disease or other allergic reactions/intolerances to gluten. This intolerance can be at any age, from early childhood to the elderly. Since rice does not have gluten protein naturally, it has advantages to prepare rice-based bakery products over wheat-based products. Bangladesh Rice Research Institute (BRRI) has formulated several gluten-free rice-based products such as rice biscuit, cake, bread and bun, and gluten-free rice-based processed food items have the potential scope in Bangladesh specially for malnutrition mitigation approach, school feeding nutrition programme, disaster management programme, etc. In this regard, BRRI has formulated energy-dense nutraceutically enriched rice-based bakery food formulation especially biscuits having energy density ranges from ED 5.0-5.5 per 100 g serving. Rice-based balanced and nutritious food intake might reduce rice consumption from the current rate of 367 g capita⁻¹ day⁻¹ to 363 g capita⁻¹ day⁻¹ or lesser for the Bangladeshi population. Since floating urban street children are classified as the most vulnerable group in Bangladeshi population so, nutraceutically enriched rice-based bakery food products might play a role in shifting malnutrition status in this regard. In addition, in quest to attain the required daily dietary allowance on scale of average of 2000 kcal, rice-based energy-dense food might assist as a supplementary diet and it will be helpful to attain the SDG goal for hunger-free and sustain food security in Bangladesh in a way to properly and effectively utilizing the rice grain. Kabir *et al.*, (2020) has also emphasized the established value of production for ensuring the rice productivity double.

In Bangladesh, rice is synonymous to food and has been the customary source of carbohydrates and proteins since the ancient days. BRRI has developed 106 HYVs including both inbred and hybrid. At present, total clean rice production is about 34.9 MT which fulfills the domestic requirement to feed more than 168 million populations. So, it is high time to focus our grain quality and nutrition research towards grain nutraceutical properties especially mineral profiling, phytate estimation, antioxidant profiling, volatile compounds including aroma quantization, low glycemic content, water, fat-soluble vitamin profiling, etc. to reveal its ability to combat with non-communicable diseases (NCD) especially cancer, cardiovascular disease, diabetes, and obesity.

With the above background, this article undertook three specific objectives in relation to rice grain quality in Bangladesh: (i) presentation of dietary energy changing status, (ii) highlighting the scenarios of nutraceutical rice research activities at BRRI, and (iii) developing and mapping the action plan for three decades on improving nutraceutically enriched rice grain quality.

METHODOLOGY

A total of 72 high yielding varieties (HYV) including 68 inbred and four hybrid rice were surveyed for Glycemic Index (GI) screening in vivo experiment (Shozib *et al.*, 2017a) rat model and GI value was measured by AUC (Area under the curve) method (Haffner, 1986; slightly modified by both Psyrogiannis, 2003 and Keh, 2004). Sixty-eight BRRI HYVs were analyzed for mineral profiling of Zn, Fe, Ca, and P elements by standard AOAC methods (AOAC, 1995) for AAS (Atomic absorption spectrophotometer), and 35 BRRI developed HYVs were analyzed for water-soluble vitamins such as thiamine and riboflavin (Shozib *et al.*, 2017b; Shozib *et al.*, 2018a) by HPLC methods mentioned in ASEAN Manual of Food Analysis (Prapasri *et al.*, 2011).

Physicochemical parameters were measured following IRRI evaluation standard SES (IRRI, 2013). Antioxidant properties such as Total Phenolic Content (TPC, mg GAE g⁻¹ dry weight), Total antioxidant activity (TAC, AAE g⁻¹ dry weight Assay, Ferric ion reducing antioxidant power assay (FRAP, AAE g⁻¹ dry weight) and DPPH radical scavenging activity of rice were measured by Singleton *et al.*, (1999), phospho-molybdenum assay by Prieto (1999) and Oyaizu (1986) by 1, 1-dipheyl-2-picryl-hydrazyl (DPPH) using the method described by Oktay *et al.*, (2003) respectively. The water-soluble vitamins are extracted from the rice powder by acid hydrolysis followed by enzymatic hydrolysis. Thiamin and riboflavin in rice were measured by HPLC method (ASEAN Manual of Food Analysis).

In the baseline survey (Saima *et al.*, 2020) on dietary intake of street children our target population was both boys and girls of 4-12 years old street children. We have interviewed 384 street children from above mentioned 20 hot spots in the capital city of Dhaka. Using Cochran Equation, we found the sample size 384.

$$\text{Sample size} = \frac{Z^2 P (1 - P)}{E^2}$$

The value of Z is found in statistical tables which contains the area under the normal curve. Z = 1.96 for 95% level of confidence. P is the estimated proportion of an attribute that is present in the population.

E² is the desired level of precision.

$$\text{Sample size} = \frac{Z^2 P (1 - P)}{E^2} = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 384.16 \approx 384$$

Rice-based bakery products were formulated according to the general guideline of Biscuit and cake of BSTI, Bangladesh. Gluten-free energy-dense rice biscuit (EDRB) and energy-dense rice cake (EDRC) were also formulated.

Per capita rice consumption (kcal) projection was made using continuous exponential

growth model $y = a(1 + r)^x$. Here y = per capita rice consumption in kcal, r = growth rate, a = initial value and x = time interval. Per capita rice consumption data of BBS-HIES 2016 was selected for the initial value. Observed kcal data of BBS were used as 2244, 2240, 2238, 2318, and 2210 for 1995, 2000, 2005, 2010, and 2016 respectively to calculate the growth rate. We have predicted the daily dietary energy intake projection for 2050 considering all the food components contribution into account.

RESULTS AND DISCUSSION

Daily dietary energy intake projection

Since rice is the major dietary energy source among the cereal crops for our population, so rice should be nutraceutically enriched in terms of antioxidants, minerals, having low glycemic and higher protein, etc. In order to attain SDG goals on safe and nutritional food, newly released HYVs will have to be aligned with special nutraceutical properties such as antioxidants enriched and high content of minerals especially zinc (>27.50 ppm), iron (>10.00 ppm), and vitamin A (>8.64 ppm) etc. Reviewing the per capita per day Calorie (kcal) data from the year 1995 to 2016, we observed that these years had declining trends of 0.028% year⁻¹. Considering the constant loss of per capita daily dietary energy @ 0.028% year⁻¹,

nutrition-based prediction of daily dietary energy intake (kcal) might be reduced to 2201 and 2188 kcal for our population by 2030 and 2050, respectively (Table 1 and Fig. 1). We are hopeful that consuming per capita rice consumption of 365 g and 363 g (dry wt. basis) in 2030 and 2050, respectively will help to attain the current trends of 59.0% of Calorie (kcal) intake from rice only.

Energy plays a vital role in our daily activities. Fruits and vegetables are treated as an energy booster and provide a diversified, flavoured, colourful, tasty, low caloric, and protective, micronutrient rich diet. A healthy diet contains fruits, vegetables, legumes (e.g. lentils, beans), nuts, and whole grains (WHO, 2020). The total per capita food intake (g) of the Bangladeshi population decreased from 2010 to 2016 by 2.5%. Per capita rice and wheat (g) intakes decreased by 11.77% and 62.32% from 2010 to 2016 but simultaneously per capita pulses, vegetables, fish, meat, and egg intake (g) increased by 9.09, 0.73, 26.65, 29.99, and 87.31%, respectively for the same period of time (HIES, 2016). The overall calorie intake per capita per day has decreased to 2210 kcal in 2016 from 2308 kcal in 2010 (a decrease of 4.23%). This is may be due to a substantial decrease in rice consumption in 2016 compared to 2010 (HIES, 2016).

Table 1. Prediction of per capita rice consumption in Bangladesh.

Year	Source	Energy intake (kcal person ⁻¹ day ⁻¹)	Rice intake (g person ⁻¹ day ⁻¹)	Energy from rice (kcal)	Calorie (%)	Rice intake (kg person ⁻¹ year ⁻¹)
2016	HIES, BBS	2210	367	1307	59	134
2020	Projected*	2207	366	1302	59	134
2025	Projected*	2204	365	1300	59	133
2030	Projected*	2201	365	1299	59	133
2035	Projected*	2198	364	1297	59	133
2040	Projected*	2195	364	1295	59	133
2045	Projected*	2192	363	1293	59	133
2050	Projected*	2188	363	1291	59	132

*Projection was made by considering the constant loss of per capita daily dietary energy @ 0.028% year⁻¹ using a continuous exponential growth model and 100 g serving of raw rice generates approximately 356 kcal of energy. HIES and BBS denotes Household Income and Expenditure Survey and Bangladesh Bureau of Statistics.

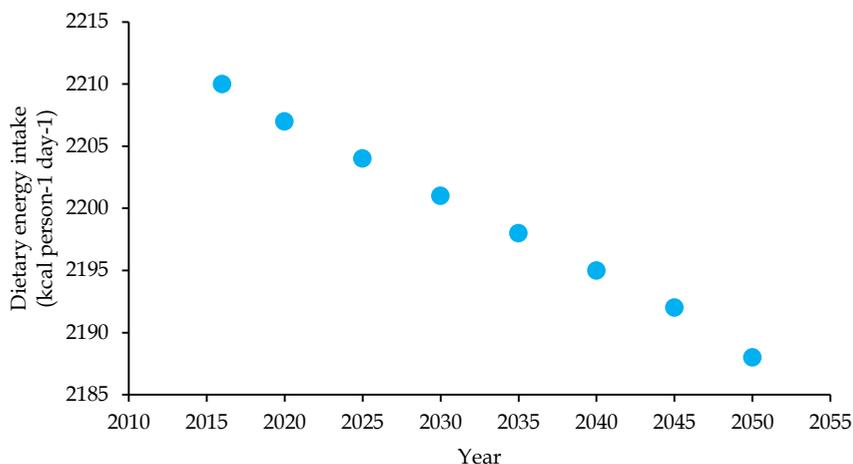


Fig. 1. Predicted per capita dietary energy intake (kcal) by 2050 in Bangladesh.

Daily protein intake from rice

The DRI (Dietary Reference Intake) is 0.8 grams protein per kilogram body weight (Gabrielle *et al.*, 2008). For the average sedentary women (57.5 kg) and men (70 kg), 46 and 56 grams of protein intake per day is required respectively. Approximately 45.87% of the daily recommended protein comes from the current rate of rice consumption (367 g provides 28.9 g of protein) and it will further be continuing to get 28.6 g protein from 363 g per capita rice intake in 2050 as projected (Table 2). Currently, we are getting an average of 7.90% rice protein from our well adopted BRRi HYVs and expected to increase rice protein up to 9.0 and 10.0% through our newly

released HYVs, which will enable to increase 12.22% and 26.58% more protein supplementation from rice only in our food table by 2030 and 2050 respectively (Table 2).

Desire characteristics of future HYV

New HYVs should also be considered for specific physicochemical traits such as high apparent amylose content (>25% AAC) with soft gel consistency (Soft GC, >61-100 mm), translucent (Tr) and long slender to medium slender size and shape grain, etc. Based on the consumer's preference for non-sticky soft rice, these types of rice may be popular in our population in the coming days. The specific grain quality characteristics such as whiteness, broken rice, shape, apparent amylose content

Table 2. Per capita protein intake per day from plant source (Rice).

Year	Source	Per capita rice consumption (g person ⁻¹ day ⁻¹)	Protein (g) from plant source (HYVs having ~7.9% protein)	Protein (g) plant source (HYVs having 9% protein)	Protein (g) plant source (HYVs having 10% protein)	Increased (%)
2016	HIES, BBS	367	28.993	-	-	-
2030	Projected	365	28.835	32.85	-	12.22
2050	Projected	363	28.677	-	36.3	26.58

Average 70 kg body wt. human requires 56 g protein (including both vegetable and animal sources) per day (0.8 g kg⁻¹ body wt.). HYV denotes high yielding variety.

(AAC%), aroma, cooking quality such as gel consistency (GC), and chalkiness influenced the consumers' and producers' preference. Nutraceutically enriched black rice, antioxidant, low GI, Zn, Fe, and Vitamin A enriched advance breeding materials should be screened to get the above mentioned desired grain quality and nutritional characteristics for newly superior HYVs. Estimation of the molar ratio of Phytate (PA) to minerals is a very important parameter for understanding the bioavailability of minerals since low phytate containing rice is desirable for plant breeders (Shozib *et al.*, 2017b).

Nutraceutical rice varieties in Bangladesh

BIRRI has identified a number of nutraceutical enriched HYVs such as three low glycemic index rice namely BR16 (GI 52.4), BIRRI dhan46 (GI 53.1), BIRRI dhan69 (GI 54.9), eight Zn enriched HYVs namely BIRRI dhan42 (27.12 ppm), BIRRI dhan43 (27.17 ppm) for Aus season, BIRRI dhan62 (19.0 ppm), BIRRI dhan72 (22.0 ppm) for Aman season, BIRRI dhan64 (24.0 ppm), BIRRI dhan74 (24.40 ppm), BIRRI dhan84 (27.60 ppm), BIRRI dhan100 (25.7 ppm) for Boro season, two thiamin (Vit-B₁) and riboflavin (VitB₂) enriched BIRRI dhan42, BIRRI dhan43, four antioxidant-enriched HYVs namely BIRRI dhan84 (TPC 37.74 mg GAE), BR5 (TPC 25.30 mg GAE), BIRRI dhan88 (TPC 23.07 mg GAE) and one GABA (gamma aminobutyric acid) enriched pre-germinated brown rice namely BIRRI dhan31 (Shozib *et al.*, 2017a; Shozib *et al.*, 2017b; Shozib *et al.*, 2018a; Siddiquee *et al.*, 2017). For BIRRI dhan29 containing the GR2E Golden Rice trait, concentrations of the b-carotene equivalents (BCEs) are approximately 12.0 $\mu\text{g g}^{-1}$ (ppm) (Donald, 2018). Besides these 17 nutraceuticals enriched HYVs, BIRRI is conducting diversified research activities with anthocyanin enriched black rice in both animal and human cell lines to combat non-communicable diseases such as cancer, diabetes, and hypertension.

Over polishing ($\geq 10\%$) effect on nutritional loss

In 2007, Lamberts *et al.*, reported that the mineral content is the highest in the 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 (DOM < 9%) contained most of the minerals (61.0%). Shozib *et al.*, (2018a) found variation in Zn content with increasing polishing time from 80 seconds to 180 seconds at DOM on a laboratory scale. 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 or milled rice) respectively as an average scale for 5 HYVs such as BR25, BIRRI dhan36, BIRRI dhan42, BIRRI dhan43 and BIRRI dhan64 in the mineral analysis. 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, BIRRI dhan36, BIRRI dhan42, BIRRI dhan43, and BIRRI dhan64 were 24.70, 23.60, 27.12, 27.17, and 24.46 ppm respectively at 80 seconds of polishing. Zn content of BR25, BIRRI dhan36, BIRRI dhan42, BIRRI dhan43, and BIRRI dhan64 was 21.30, 20.43, 24.21, 23.90, and 22.10 ppm respectively at 140 seconds of polishing where DOM varied ranges from 7.78 to 11.28%. Finally, Zn content of BR25, BIRRI dhan36, BIRRI dhan42, BIRRI dhan43, and BIRRI dhan64 were 18.21, 17.34, 20.43, 27.17, and 20.10 ppm respectively at 180 seconds of polishing where DOM varied ranges from 10.15 to 12.02%. Authors have demonstrated how Zn content and DOM of five different BIRRI HYVs significantly varied at different polishing time ranges from 80 seconds to 180 seconds considering grain size and shape into account. For citation, in the commercial milling

process a nutraceutically enriched BRRIdhan42 can lose a maximum up to 24.7% of Zn at 18.4% degree of milling (DOM). The more we will increase the degree of milling the more nutrient we will lose. In this regard, 1st pass which means 7.4%, DOM is enough to get 27.1 ppm of Zn from BRRIdhan42. On the other hand, 11% extra milling will produce whitening starch compounds only but fewer or trace amounts of fiber, ash, and fat which will cause health hazard directly.

Since over-polishing (>10%) of rice does not possess much nutrients, fiber, vitamins, and minerals so, it will not be able to bring any health benefit rather it is a threat of some non-communicable diseases. We have to fix rice milling $\leq 10\%$ DOM through any interventions either from the government and NGOs or both so that we will be able to get the maximum benefit of nutraceutical properties of rice indeed. Escaping an extra 10% DOM loss will help to achieve productivity double in quantity. Consuming a lesser degree of milling rice will not only assist in the productivity doubling process but it will qualitatively improve our nutritional status as well. Recently released BRRIdhan42's grain types are recorded as long slender, long bold or medium slender such as BRRIdhan80, BRRIdhan81, BRRIdhan84, BRRIdhan85, BRRIdhan86, BRRIdhan87, BRRIdhan88, BRRIdhan89. So, these HYVs need not to be over-polished.

Table 3. Loss percentage of Zn content in BRRIdhan42 during commercial milling (unpublished data of GQN Division, BRRIdhan42, 2019).

Pass	DOM (%)	Zn (ppm)	Zn loss (%)
1 st	7.4	27.1	-
2 nd	10.9	25.3	6.9
3 rd	13.9	22.6	16.9
4 th	16.4	21.8	19.6
5 th	18.4	20.4	24.7

Note: DOM denote degree of milling; ppm indicate parts per million

Aspects of rice-based bakery products in Bangladesh

BRRIdhan42 scientists have formulated nutraceutically enriched rice-based popular bakery food products such as rice biscuits, rice cakes, rice bread, etc. These rice-based bakery products are gluten-free and consist of high protein, minerals (Zn, Fe, Ca, and P), antioxidants, vitamins such as thiamin and riboflavin, etc. Scientists also formulated energy-dense rice cookies or biscuits (Energy Density; ED 5.15, 100 g serving provides 515 kcal, high protein >10% and high-fat content of 25%) which are low cost, safe, and nutritionally balanced (Shozib, 2018b). Rice-based products require lesser amount of carbohydrates than we have usually taken as cooked rice for a single meal. For example, 100 g serving rice-based food items required 50 g carbohydrate to generate 500 kcal and on the other hand 125 g raw rice required to generate the same quantity of energy by consuming cooked rice for a single meal (1.0 g carbohydrate generate 4.0 kcal energy).

Rice-based products are supposed to be formulated in an ideal proportion of carbohydrate, fat, protein ratio as 50:30:20. So there is a huge scope in increasing the average income of small-scale food producers especially learned farmers and local bakery owners in adopting nutraceutically enriched rice production.

Rice-based bakery products can potentially be used to minimize malnutrition of the most vulnerable portion of our population especially street children. Since street children are the most vulnerable group of population coming to fight to gild the streets for their habitual abode and livelihood drifted into a nomadic life. These children are generally malnourished due to their deprivation of health care and improved nutrition. In 2021, Saima *et al.*, conducted a baseline survey on street children of the capital city, Dhaka on both boys and girls of 4-12

years. A total of 384 street children were subjected to study a baseline survey. The sample size was fixed by addressing Cochran equation. Among the respondents 63% were male and 37% were female from street children population of 384. Survey took place at 20 different hot spots covering both parts of Dhaka city north and south. We have observed the recommended dietary intake per day from 4 years to 12 years old male boys and found 27 to 59% deficiency in our male population samples of 243. Similarly, we also observed the recommended dietary intake per day from four years to 12 years old female girls and found 28 to 56% deficiency in our female population samples of 141. Since our energy dense rice cake (EDRC) has a potential of providing 500 kcal energy per 100 g serving so, we could predict that incorporating our improved rice-based product once a day along with their daily regular intake, it will be able to mitigate nutritional gap by 64 to 100% for street boys and noticeably 70 to 100% for girls. We have prepared energy dense rice biscuit (EDRB, 3.6% moisture, 515 kcal per 100 g of serving) and energy dense rice cake (EDRC, 5.0% moisture, 500 kcal per 100 g of serving).

EDRC was found prepared than EDRB in impact study when the respondents were given choice of rice-based bakery items intake for four months long period. Finally, a total of 32 respondents took part in a four months period impact study on EDRC from street children population. All anthropometric and biochemical data such as CBC (Complete Blood Count), Hemoglobin, CRP, Prealbumin etc. were collected at both the starting (Day 0) and the end time (Day 120) of the impact survey of selected 32 respondents. Respondents were given 100g serving of EDRC every day (Rice cake) to 32 street children samples for 4 months period along with their normal food intake. Our data revealed that malnutrition related parameters specially CRP (decreased) and Prealbumin (Increased) are significantly improved during four months supplementary intake of extra 500 kcal per 100 g serving of EDRC in tested street children's samples which resemble the possible impact of EDRC on street children. Rice-based bakery products specially EDRB and EDRC can potentially be used in school feeding nutritional programme and disaster management in Bangladesh.

Table 4. Baseline survey on daily dietary intake of street children (age 4-12) for boys.

Male N=243	Age	RDI In kcal	Observed data in kcal	Observed data ranges	RDI % intake	Gap in kcal	Gap % of RDI	EDRB kcal per 100 g serving	EDRB provide RDI %	Gap % of RDI % Remain	Predicted gap minimization of RDI %
	4 (n=13)	1303	955	600-1100	73	348	27	515	40	-13	100
	5 (n=11)	1362	865	630-1210	63	497	37	515	38	-1	100
	6 (n=14)	1403	852	670-1180	61	551	39	515	37	3	97
	7 (n=21)	1507	994	720-1187	66	513	34	515	34	0	100
	8 (n=20)	1624	919	620-1170	57	705	43	515	32	12	88
	9 (n=35)	1750	865	620-1250	49	885	51	515	29	21	79
	10 (n=32)	1890	877	670-1300	46	1013	54	515	27	26	74
	11 (n=40)	2038	866	620-1400	42	1172	58	515	25	32	68
	12 (n=57)	2200	893	650-1280	41	1307	59	515	23	36	64

EDRB: Energy dense rice biscuit; ED: Energy Density; RDI: Recommended dietary intake.

Table 5. Baseline survey on daily dietary intake of street children (age 4-12) for girls.

Female N=141	Age	RDI In kcal	Observed data in kcal	Observed data ranges	RDI % intake	Gap in kcal	Gap % of RDI	EDRB kcal per 100 g serving	EDRB provide RDI %	Gap % of RDI % Remain	Predicted gap minimization of RDI %
	4 (n=12)	1244	898	625-1110	72	346	28	515	41	-14	100
	5 (n=19)	1202	850	700-1300	71	352	29	515	43	-14	100
	6 (n=11)	1300	769	658-1020	59	531	41	515	40	1	99
	7 (n=28)	1403	884	620-1180	63	519	37	515	37	0	100
	8 (n=11)	1502	1002	820-1210	67	500	33	515	34	-1	100
	9 (n=13)	1638	767	672- 970	47	871	53	515	31	22	78
	10 (n=15)	1777	931	670-1170	52	846	48	515	29	19	81
	11 (n=21)	1942	863	650-1025	44	1079	56	515	27	29	71
	12 (n=11)	2070	930	850-1270	45	1140	55	515	25	30	70

EDRB: Energy dense rice biscuit; ED: Energy Density; RDI: Recommended dietary intake

ACTION Plan (2021-2050)

To fulfill the SDG goal on nutritional security, Grain Quality and Nutrition (GQN) Division of BIRRI should follow the proposed action plan (Table 6) through 10 year period of interval (Table 7) from 2020 to 2050. A total of 10,500 (estimated) genebank entities of BIRRI including advanced breeding lines, BIRRI released HYVs and local germplasms will be evaluated for physicochemical, nutraceutical properties during these three decades from 2021-2050. The action mapping plan is divided into two separate themes such as research and development, and dissemination. Themes are divided into three phases such as primary, secondary, and tertiary phases. Further, it is segmented in several progresses such as characterization, baseline survey, product formulation, sensory evaluation, training, and dissemination.

In the progress of characterization of a primary phase several activities will be taken to fully characterize germplasm such as physicochemical (Physical and Chemical

properties), nutraceutical (Nutrition and Medicinal properties), minerals profiling (Macro and Micronutrients), heavy metal profiling (As, Cd, Pb, Ni, Cr), aroma profiling, fatty acid profiling (Rice bran, Rice Bran Oil), amino acid profiling, prebiotics production (Rice straw and Rice Bran), vitamin profiling (Water- and fat-soluble vitamins), antioxidant profiling, and proximate analysis.

The baseline survey will be followed by rice grain characterization and it will come in the second phase including several activities such as a baseline survey on rice grain preferences of farmers, millers, and consumers and baseline survey on rice-based products of manufacturers and consumers. Few superior rice cultivars or HYVs will be selected for three following decades based on consumers' preference through the above mentioned activities (Table 6).

Product formulation will come to 3rd progress in tertiary phase with several actions such as product profiling of quality rice grain,

rice-based nutrient dense products formulation (Value added rice-based products), multiple rice-based food products for disease management, the residual effect of herbicides and pesticides of rice grain and rice-based products, proximate analysis of rice-based products, energy estimation and quality analysis of rice-based food products. The sensory evaluation will be followed by product formulation in tertiary phases which

includes several activities such as quality rice grain selection and rice-based nutrient dense products formulation (Value added rice-based products). Dissemination will be adopted at the tertiary phase including two stages such as training and demonstration with several actions such as training for food manufacturer, rice miller and RBO miller and demonstration in bakery and food industries (Table 7).

Table 6. Action plan for ensuring safe rice consumption with superior grain quality and nutrition.

Action title	Ensuring safe rice consumption with superior grain quality and nutrition		
Theme	Phase	Progress	Activities
Research and Development	Primary	Characterization	<ol style="list-style-type: none"> 1. Physicochemical (Physical and Chemical properties) 2. Nutraceutical (Nutrition and Medicinal properties) 3. Minerals profiling (Macro and Micronutrients) 4. Heavy metal profiling (As, Cd, Pb, Ni, Cr). 5. Aroma profiling 6. Fatty acid profiling (Rice bran, Rice bran oil) 7. Amino acid profiling 8. Prebiotics (Rice straw and Rice bran) 9. Vitamin Profiling (Water- and fat soluble vitamins) 10. Antioxidant profiling 11. Proximate analysis
	Secondary	Baseline survey	<ol style="list-style-type: none"> 1. Baseline survey on rice grain preferences of farmers, millers and consumers 2. Baseline survey on rice-based products of manufacturers and consumers
	Tertiary	Product formulation	<ol style="list-style-type: none"> 1. Product profiling of quality rice grain 2. Rice-based nutrient dense products formulation (Value added rice-based products) 3. Multiple rice-based food products for disease management 4. Residual effect of herbicides and pesticides of rice grain and rice-based products 5. Proximate analysis of rice-based products 6. Energy estimation 7. Quality analysis of rice-based food products
Dissemination	Tertiary	Sensory evaluation	<ol style="list-style-type: none"> 1. Quality rice grain selection 2. Rice-based nutrient dense products formulation (Value added rice-based products)
		Training	<ol style="list-style-type: none"> 1. Training for food manufacturer, rice miller and RBO miller
		Demonstration	<ol style="list-style-type: none"> 1. Demonstration in bakery and food industries

Table 7. Timeline for implementing the action plan of rice and rice-based products in three decades from 2021-2030, 2031-2040 and 2041-2050

Research Objects	Period 2021-2030				Period 2031-2040				Period 2041-2050				
	Research & Development Phase			Dissemination	Research & Development Phase			Dissemination	Research & Development Phase			Dissemination	
	Primary	Secondary	Tertiary	Tertiary	Primary	Secondary	Tertiary	Tertiary	Primary	Secondary	Tertiary	Tertiary	
	Germplasm in quantity	CH	BS	PF	SE	TR	DS	CH	BS	PF	SE	TR	DS
Rice grain characterization	3500				x	x	x			x	x	x	x
RBO production	100			x	x	x	x			x		x	x
Puffed rice Production	100			x		x	x			x		x	x
Pooped rice Production	100			x		x	x			x		x	x
Flattened rice production	100			x		x	x			x		x	x
Rice cake Formulation	100												
Rice biscuit Formulation	100												

CH: Characterization, BS: Baseline survey, PF: Product formulation, SE: Sensory evaluation, TR: Training, DS: Demonstration

CONCLUSION

Rice is the most valued cereal crop to combat non-communicable diseases (NCDs) with its versatile nutraceutical properties embedded in it. We predicted per capita rice consumption of 365 g and 363 g (dry wt. basis) in 2030 and 2050, respectively will help to attain the current trends of 59.0% of calorie intake from rice only. We expect to increase rice protein from 7.9% to 9% and 10% through our newly released BRRI HYVs which will enable us to increase 12.22% and 26.58% more protein supplementation from rice only in our food table by 2030 and 2050, respectively. Nutraceutically enriched rice-based food items have the potential to be popular among Bangladeshi people. This will play a vital role to gradually reduce overall rice consumption and preferably help sustain food security in Bangladesh in a way to properly utilizing the rice keeping the required dietary allowance intake. Rice-based energy dense dry bakery products can be utilized in the disaster management programme and school feeding nutritional programme for mitigation of malnutrition. Besides, nutraceutical rice-based food formulation requires a lesser amount of carbohydrate so its glycemic load is usually low and these products will help in non-communicable disease management especially diabetics in Bangladesh.

RECOMMENDATIONS

- Nutraceutical enriched rice should be consumed periodically (thrice a week) or should intake a little portion mixed with white rice daily.
- Over polished (>10%) milled rice should not be eaten to avoid bowel related diseases.
- Gluten-free energy-dense rice biscuit (EDRB) has the potential to be utilized for malnutrition minimization approaches including school feeding nutritional programmes and disaster management programme in Bangladesh.

- Nutraceutical enriched such as antioxidant-enriched, micronutrient enriched, anthocyanin enriched rice varieties can be used for rice-based bakery products with a special interest in combating NCDs disease such as cancer, diabetic, and heart disease for the Bangladeshi population.
- Intergovernmental initiatives between the Ministry of Agriculture and Ministry of Disaster Management and Relief can upscale EDRB biscuits as dry food for emergency relief operation and disaster management.

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AUTHORS' CONTRIBUTION

HBS generated idea; MUS, MARS and MAAM coordinated the research; HBS developed methodology; HBS, MAS and NMFR provided scientific insights; HBS, NMFR and MAAM gathered data, carried out analysis and synthesis. HBS did writings for all versions of the manuscript; MUS, MARS, SMHAR and MSK performed critical review and editing; All authors read and approved the final manuscript.

DECLARATION OF INTERESTS

A version of the paper was published in a book 'Doubling Rice Productivity in Bangladesh' in 2020 by the Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh to commemorate BRRI's 50th anniversary. The Bangladesh Rice Journal has prior knowledge of the book publication and does not see any conflict of interest.

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