COMPARATIVE STUDY ON PHYSICOCHEMICAL PROPERTIES AND MINERAL PROFILING OF HIGH YIELDING RICE VARIETIES (HYVs) IN BANGLADESH

A THESIS

BY

SAMIRON KUMAR SINGH

MASTER OF SCIENCE

IN

BIOCHEMISTRY

DEPARTMENT OF BIOCHEMISTRY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

BANGLADESH

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Approved as to style and content by

……………………………………

Supervisor
MD. NURUDDIN MIAH
Professor
Department of Biochemistry
Sher-e-Bangla Agricultural University

…………………………………..

Co-Supervisor
DR. HABIBUL BARI SHOZIB
Senior Scientific Officer (SSO)
Grain Quality & Nutrition Division (GQN),
Bangladesh Rice Research Institute (BRRI)

……………………………………………….

PROF. DR. KAMAL UDDIN AHMED
Chairman of Examination Committee
Department of Biochemistry
Sher-e-Bangla Agricultural University

DEDICATED TO

MY BELOVED PARENTS

&

All FARMERS

OF BANGLADESH

DEPARTMENT OF BIOCHEMISTRY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh

PABX: +8802944814096
Ext. 186 (Off.)
Fax: +88029112649
E-mail: bioc_sau@ymail.com

Ref: ***Date:***

CERTIFICATE

*This is to certify that the thesis entitled "**COMPARATIVE STUDY ON PHYSICOCHEMICAL PROPERTIES AND MINERAL PROFILING OF HIGH YIELDING RICE VARIETIES (HYVs) IN BANGLADESH"** submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN BIOCHEMISTRY, embodies the result of a piece of bona fide research work carried out by **SAMIRON KUMAR SINGH**, Registration No. **16-07541**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.*

I further certify that any help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

Date: December' 2017
Dhaka,Bangladesh

MD. NURUDDIN MIAH
Professor
Department of Biochemistry
Sher-e-Bangla Agricultural University
Supervisor

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COMPARATIVE STUDY ON PHYSICOCHEMICAL PROPERTIES AND MINERAL PROFILING OF HIGH YIELDING RICE VARIETIES (HYVs) IN BANGLADESH

ABSTRACT

The study was conducted to explore a comparative study on physicochemical properties and mineral profiling of high yielding rice varieties (HYV) in Bangladesh. A total of ten different rice varieties evaluated for various quality aspects in terms of physicochemical, cooking, pasting and mineral characteristics at both unparboiled and parboiled condition. Among the ten rice varieties BRRI dhan62 had the highest broken rice percent and length breadth ratio (L/B). In both conditions, milling outturn (MOT) was found the highest values in BRRI dhan64. Head rice yield (HRY) was below 75% for all tested varieties. Cooking time (CT) varied ranges from 16.2 min to 20.5 min for all tested HYVs. BRRI dhan64 has the highest imbibition ratio (IR) in both conditions. The highest elongation ratio (ER) was observed in BR6 and BRRI dhan64 at unparboiled condition and BR6, BRRI dhan35, BRRI dhan36, BRRI dhan62 and BRRI dhan64 at parboiled condition. BRRI dhan43 and BRRI dhan62 have the highest (25.5%) and the lowest (18.5%) apparent amylose content (AAC) respectively in unparboiled condition. The highest AAC was found for BRRI dhan43 (26.8%) and the lowest for BRRI dhan74 (19.2%) at parboiled condition. Alkaline spreading value (ASV) of the tested HYVs ranges from 3.3 to 7.00. The highest ASV (7.00) and lowest ASV (3.3) were found in BRRI dhan36 and BRRI dhan62 respectively at unparboiled condition. The highest ASV (5.6) was observed in BR6 and BRRI dhan36 and lowest ASV (3.2) was observed BRRI dhan62 at parboiled condition. All tested HYVs showed moisture content ranges from 11.5% - 13.3%. We found that the range of protein content (PC) were 7.1% to 10.4% and the highest PC recorded was for BRRI dhan36 (10.4%) in selected popular BRRI HYVs in Bangladesh. A wide range of variation on the content of phytic acid and minerals like phosphorus, iron, zinc and calcium were found in the tested HYVs of rice at both unparboiled and parboiled condition. Among the tested HYVs, BRRI dhan42 and BRRI dhan43 contain lower content of phytic acid and higher content of minerals, likely zinc, iron, calcium and phosphorus.

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LIST OF ABBREVIATION

AAC	Apparent Amylose Content
ASV	Alkaline Spreading Value
MOT	Milling Outturn
PC	Protein Content
HYR	Head Rice Yield
BKR	Broken Rice
UPR	Unparboiled
PR	Parboiled
IR	Imbibition Ratio
ER	Elongation Ratio
g	Gram
µg	Micro Gram
Kg	Kilogram
L	Liter
ppm	Parts Per Million
FAO	Food and Agriculture Organization
HYVs	High Yielding Varieties
BRRI	Bangladesh Rice Research Institute
GQN	Grain Quality and Nutrition

CHAPTER I

INTRODUCTION

Rice is one of the most important cereal crops, serving the staple food for one third of the world's population. It is the synonym for food in Bangladesh and has been the traditional source of carbohydrates and proteins since the prehistoric days. In Bangladesh around 74% of the total cropped area covered by rice production which produce around 34710 thousands metric ton per year (BBS, 2016). In respect of area and production of rice, Bangladesh ranks fourth following China, India and Indonesia (FAO, 2008). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years but rice production area is decreasing day by day due to high population pressure. A total of eighty six (86) HYVs including both inbreed and hybrids have been released by Bangladesh Rice Research Institute (BRRI) till date. At present, total clean rice production is about 34.8 MT which fulfills the domestic requirement to feed more than 160 million populations with the surplus of 2.06 MT (Kabir, 2015). This is a big challenge for Bangladesh. Considering the vast potential of rice in Bangladesh, it is imperative that rice scientists to develop suitable rice varieties with high nutrient content. Bangladesh is a riverine country with plentiful water resources with hot and humid monsoon climate. Monsoon rain occurs normally between the months of June to September. The condition of Bangladesh is blissful for growing aman paddy. All types of land excepting low lands are brought under rice cultivation where planting of seedlings is possible. It is ecofriendly cultivation as it is purely a tropical monsoon rain dependent crop and helps to reduce ground water depletion as it's not depended on irrigation only or less irrigation. Considering above challenges and advantages, rice scientists should focus on rice season and select right variety which will fill up the upcoming demand.

Quality of rice is determined by the factors such as grain appearance, nutritional value, cooking and eating quality (Juliano, 1990). Consumers base concept of quality on grain appearance, grain size and shape, behavior upon cooking and the taste, tenderness, and flavor of cooked rice. The physical characteristics include grain length, L/B ratio, chalkiness and milling percentage. AAC, Alkali spreading value and protein content are chemical characteristics and cooking characteristics include cooking time, volume expansion and Elongation ratio. Grain quality is a very wide area encompassing diverse characters that are directly or indirectly related to exhibit one quality type (Siddiqui, 2007 and Juliano, 1993). The endosperm possess certain physical and chemical characteristics basically due to AAC (Webb, 1985; Juliano, 1990 and Unnevehr *et al.*, 1992), protein content (Hsieh and Brunner, 1976), gel consistency (Cagampang *et al.*, 1972), gelatinization temperature (Juliano, 1972) and physical properties of cooked rice grain are considered as an important factors (Khatoon and Prakash, 2007).

Malnutrition in Bangladesh is alarmingly high. In Bangladesh, 36.2% children are stunted under 5 years of age are stunted, 15% are wasted and 33% are underweight (Sunanda, 2017). Malnutrition and poverty hinder access to education and the ability to learn. Only 51 percent of those in school will complete primary education. Children of uneducated mothers are significantly affected. This has a bearing of significant impact on the nutritional status of future generations. Wide spread vitamins and minerals deficiencies also exist. One in five preschool/school-aged children suffers from a vitamin A deficiency; 33 percent of preschool children are anemic; folate and vitamin B_{12} deficiency affect 9 percent and 22 percent of women respectively. The national prevalence of zinc deficiency is 44.6 percent amongst preschool age children and 57.3 percent amongst non-pregnant non-lactating women, according to the National Micronutrients Survey 2011-2012 (NMS, 2013). Since we consume rice twice or thrice a day, so it should have some potentiality in meeting our nutritional as well as minerals requirements for some extend. Regarding introducing these selected HYVs it is wise to mention that BR6, BRRI dhan36, BRRI dhan35, BRRI dhan64, BR16, BRRI dhan28, BRRI dhan47, BRRI dhan50 and BRRI dhan74 are usually grown in Boro season from November to May annually on the other hand BR11, BRRI dhan33, BRRI dhan49, BRRI dhan53 and BRRI dhna62 are usually grown in Aman season from July to December annually. Some variety like BR16, BRRI dhan42, BRRI dhan43 and BR6 can also be grown in Aus season from March to July annually (Biswas, 2016). Among these BRRI dhan28 is a single mega variety for Boro season in Bangladesh and its adoption rate was 36.24% in 2015-16. BR16 is popular variety for making puffed rice. BR 11 is the third height adopted rice variety for Aman season having 22.3% adoption rate in 2012-13. To meet up with Zinc deficiency BRRI had released Zn rich BRRI dhan64, BRRI dhan74 for Boro season containing 7.2%, 8.3% protein and 24 mg/kg, 24.2 mg/kg Zinc respectively. Among the insect resistant verities, BRRI dhan35 is one of the most important varieties due to its Grasshopper resistant capability. For BRRI dhan36 seedling is cold tolerant, plant height 90-95 cm, during harvesting period plant remain green, grain in white containing 8.7% protein. BRRI dhan62 is a short duration HYV with 9% protein for Aman season which can easily be adopted in four cropping patterns to increase both crop diversity and soil nutrition along with these lentils, cereals and vegetables in Bangladesh. The development of diabetes mellitus, obesity, cancer and cardiovascular disease (CVD) has been reported to be linked to high GI foods, with regards to the treatment of these diseases (Ludwig, 2002).

Since rice is the staple food of Bangladeshi people and we consume approximately 416 g rice a day per person on an average, so it is high time to focus our scientific attention on rice in term of different aspects of health-related issue especially in case of malnutrition.

A better understanding of the factors that contribute to the overall grain quality of rice (*Oryza sativa*) will lay the foundation for developing new breeding and selection strategies for combining high quality, with high yield and high micronutrient enriched. This is necessary to meet the growing global demand for high quality rice while offering producing countries additional opportunities for generating highest export revenues (Melissa *et al.*, 2009). Humans require at least 49 nutrients for their normal growth and development, and the demands for most nutrients are supplied by cereals, particularly rice due to its staple role (Welch and Graham, 2004). Among these nutrients, mineral elements play numerous beneficial roles due to their direct or indirect effect in both plant and human metabolism and the deficiencies or insufficient intakes of these nutrients leads to several dysfunctions and diseases in humans. Studies have indicated widespread occurrence of deficiencies for mineral elements such as anemia for iron and osteoporosis for calcium in most developing countries as well as developed countries (Welch and Graham, 1999). The numbers indicate that around two billion people suffer from iron deficiency, while prevalence of zinc deficiency is much harder to quantify due to the lack of a reliable and easy clinical assay (FAO, 2004). In addition, these mineral deficiencies such as calcium are also associated with malnutrition and have reached worrying levels with data suggesting that roughly three million people over the age of 50 years suffer from osteoporosis (Van *et al.*, 2001). Recent epidemiological studies found that whole-grain intake (such as brown rice), is linked to disease prevention against cancer, cardiovascular disease, diabetes and obesity (Slavin, 2003). It is noted to be considered that the adequate nutritional intake of Zn actually depends both on the amount of Zn in the diet and on its availability. Among many factors to affect bioavailability of dietary Zn intake, phytate (inositol hexa phosphate) has been known well to decrease Zn bioavailability (Rimbach *et al.*, 1995). Phytate is present at high levels in unrefined cereals, legumes, nuts, and seeds and most of the phosphorus in these foods is present mostly as phytate. Phytate contains negatively charged phosphate ligands which complex with positively charged ions such as Zn^{2+}, Ca^{2+}, Mg^{2+} and Fe^{2+}. Absorption of these metals in the small intestine is therefore inhibited due to their chelation by phytate (Sandstead, 1991 and Graf and Eaton, 1984)

Estimation of molar ratio of Phytate to minerals is very important parameter for understanding bioavailability of minerals. Since Bangladesh is sufficient in rice production at present time, it is high time to focus our grain quality and nutrition research towards grain nutritional properties especially mineral profiling to reveal its aptitude to combat with non-communicable diseases (NCD) especially cancer, cardiovascular disease, diabetes and obesity.

Objectives

In order to fulfill the above mentioned aim, experiments have been undertaken with the following objectives:

- To evaluate physicochemical and cooking properties of selected HYVs in Bangladesh at both parboiled and unparboiled condition.
- To compare mineral profiling such as Fe, Zn, Ca & P of HYVs in Bangladesh.
- Estimation of phytic acid for all tested HYVs at both condition.
- To identify nutritionally enriched HYVs for human consumption especially for malnutrition mitigation.

CHAPTER II

REVIEW OF LITERATURE

2.1 The Origin of rice

Botanists base their evidence of the origin of rice largely on the habitats of the wild species. It is presumed that the cultivated species have developed from certain types of the wild rice (Grist, 1975).

Sharma (1983) reported that the genus *Oryza* comprises twenty - five species distributed through the tropical and subtropical regions of Asia, Africa, central and South America and Australia.

According to Vavilov (1930), the longer a group has been established in an area, the larger will be the number of species to be found there. He concludes that the wealth of forms and varieties of rice found in the south - west Himalayes, which are closely allied to many Chinese varieties, points to this region as the center of origin of rice. It may well be that this and other places in India, South – East Asia, the Philippines and Africa are centers of origin of cultivated forms of rice.

Ting (1949) concludes that in view of the number of wild rice found in southern China, rice cultivation is believed to have started in this region and to have spread north world. Ting (1960) states that rice glumes found in the Yangtse River in red burnt clay, thought to belong to the late Neolithic, have been classified as *O. sativa* F. *spontanea* ssp. Keng and show strong resemblances to the cultivars now grown in eastern China.

Chandraratna (1964) stated that the country of origin of rice is not known, but the weight of evidence points to the conclusion that the center of origin of *Oryza saliva L.* is South - East Asia, particularly India and Indo - China, where the richest diversity of cultivated forms has been recorded.

2.2 The Background of rice

Rice (*Oryza sativa* L.) is one of the leading food crops of the world and is the staple food of over approximately one half of the world's population (Singh *et al.*, 2003).

A better understanding of the factors that contribute to the overall grain quality of rice (*Oryza sativa*) will lay the foundation for developing new breeding and selection strategies for combining high quality, with high yield and high micronutrient enriched. This is necessary to meet the growing global demand for high quality rice while offering producing countries additional opportunities for generating highest export revenues (Melissa *et al.*, 2009).

Rice, the most productive cereal crop has been thought of as a remedy to supplement wheat, Sorghum and millet as food crops. Rice is the second cereal in the world; it is grown in the tropics where rain and sunshine is abundant (Awok, 1995). This wide adaptability of the rice plant is the explanation of its importance as a food crop (Kent, 1980). It is not just a very important source of energy, but also contributes minerals, vitamins and amino acids needed by the body. Since rice is a food of great importance in the human diet, the nutritional assessment of rice provides data relevant to nutritionists. The dietary minerals in rice include Ca, Fe, Mg, P, K, Na, Zn, Cu, Mn and Se (Silva *et al.*, 2013). According to FAO report, rice is regarded as a basic daily food for 17 countries in Asia and the Pacific, nine countries in North and South America and eight countries in Africa (FAA, 2004). The major rice growing areas are found in China, India, Indonesia, Bangladesh, Thailand, Burma, Vietnam, Japan and Philippines (Amissah *et al.*, 2003).

2.3 Importance of rice

Most varieties contain a high amount of carbohydrates and protein. The fiber content varies according to types of rice. For e.g., brown rice has more fiber than white rice and therefore, is a healthy option. It is also rich in minerals like calcium, iron, magnesium, phosphorus, potassium, manganese, selenium, and copper. The vitamins in it include niacin, pantothenic acid, and thiamin. It is a great food for people wanting a gluten-free option and it contains negligible fat.

2.4 Physicochemical Properties

Shakir *et al*. (2017) studied to evaluate the physicochemical characteristics of rice grains of local traditional and high yielding Aman variety. Highest milling outturn 72.5% was found in the BRRI dhan57 and lowest in local variety Sakor (67.4%). The highest milled rice length (6.5 mm) was found in BRRI dhan42 and the highest L/B ratio (3.7) was found in BRRI dhan57 and the lowest was in Sakor (1.9). AAC (apparent amylose content) of these cultivars ranges from 21% (BRRI dhan53) to 28.1 (Subulkua). All the variety contains more than 7.0% protein content. The highest protein content found in traditional variety Betu (9.1%) and the lowest in HYV BRRI dhan51 and BRRI dhan54 (7%). Maximum cooking time required 22.5 min for BRRI dhan33 and lowest in Jabsiri (12.5 min). Elongation ratio (ER) of grain of local and modern aman rice varieties varied 1.2 to 1.6. The highest elongation ratio was BRRI dhan51 (1.6). Imbibition ratio (IR) of grain of local and modern Aman rice varieties varied between BRRI dhan57 (2.4) to Subulkua (4.6). The generated from characterizing these local traditional cultivars will allow breeders to select superior quality rice varieties for parental selection of aman rice breeding program in Bangladesh.

Villota *et al.* (2016) evaluated the cooking qualities and sensory attributes of parboiled rice. Cooking of parboiled milled rice required 1:2.50 – 1:3.00 water ratio using ordinary boiling method with an average cooking time of 27.86 minutes. The physico-chemical properties such as water absorption, volume expansion, and grain elongation ratio of parboiled rice were highest than non-parboiled milled rice. In terms of proximate composition energy and nutrient content, parboiled rice obtained an ash content of 1.002% ± 0.02, crude fiber (0.453% ± 0.01), crude fat (1.57% ± 0.19), crude protein (6.17% ± 0.20), calcium (5.385% ± 0.27), calories (360.55 kcal ± 0.55), thiamine (0.20% ± 0.01) and niacin (1.19% ± 0.13) were highest than the mean values of milled rice.

White milled and parboiled rice samples often lines/varieties were analyzed for nutritional quality parameters. The results clearly showed average increase in mineral contents in terms of ash% increase, dry matter, longer cooked grain length and considerable rise in vitamin B6 contents, highest total milling recovery and head rice recovery in almost all the samples, while crude fiber, crude protein and crude fat decreased non-significantly. Furthermore, quality reducing factors, such as, number of broken grains; bursting and curling percentage of cooked rice were also found reduced significantly in parboiled samples. It may, therefore, be suggested that parboiling offers a better alternative to conserve and increase nutritional, milling and cooking quality values of rice varieties/lines (Akhter *et al*., 2014).

Physicochemical properties of rice flour and rice starch differing in amylose content were evaluated in Setra Ramos and Mentik Susu rice varieties by (Anugrahati *et al.*, 2016). The rice starches of Setra Ramos and Mentik Susu had the highest moisture content than rice flours of Setra Ramos and Mentik Susu whereas the lipid content and protein content of rice starch of

Setra Ramos were lower than its rice flour. The rice flour of Setra Ramos had the higher amylose content (23.69%) than rice flour of Mentik Susu.

The experiment was conducted by Verma *et al*. (2015) to study grain quality characteristics of Azad Basmati and to compare with other prominent Basmati rice varieties. Kernel dimensions of Azad Basmati were satisfactory in respect of breadth (1.60 mm) and Length/Breath (L/B) ratio (3.93). On cooking Azad Basmati exhibited highest kernel elongation ratio (KER) and volume expansion ratio (VER) 2.20 and 4.00, respectively. Azad Basmati variety was high (22.8%) in amylose content (AC) as compared to evolved basmati varieties Basmati-370, Pusa Basmati-1 and Basumathi but found lower than Type-3 and Improve Pusa Basmati-1 and, Azad Basmati was found intermediate except Basumathi.

A study was conducted by Danbaba *et al*. (2011) to evaluate the cooking and eating quality of *Ofada* rice. The result showed that *Ofada* rice had high cooked rice volume with length and breadth increase of 152.54% and 87.85% respectively. Grain elongation (GE) ratio ranged from 1.24-1.75 with *Ofada* 10 having the lowest value and *Ofada* 11 having the highest value. The highest length/breadth ratio of cooked rice (3.68) was recorded by *Ofada* 8, while *Ofada* 3 had the lowest (2.49). Cooking time (CT) and amylose content (AC) of *Ofada* rice samples ranged from 17-24 min, and 19.77-24.13% respectively. There was significant positive correlation between AC and WU ratio, while significant positive association was observed between length/breadth ratio and AC.

A total of six aromatic and two non-aromatic rice accessions grown in India were analyzed for their mineral contents. Among the minerals, the higher Ca (98.75 mg/kg), Zn (17.00 mg/kg) and Fe (31.50 mg/kg) were in Gopal Bhog, whereas the highest Na (68.85 mg/kg) was in Badshah Bhog, the highest K (500.00 mg/kg) was in Swetganga, Khushboo and Sarbati. The identified aromatic rice accessions Gopal Bhog, Govind Bhog and Badshah Bhog and non-aromatic rice accession Sarbati were found nutritionally superior among all eight tested accessions. (Verma and Srivastav, 2017).

Rather *et al*. (2016) evaluated three different rice varieties, namely frome chena (FC), safaid chena (SC), and barkat chena (BC) for various quality aspects in terms of physical, milling, cooking, and pasting characteristics. Among the three rice varieties SC had the highest thousand kernel weight and length breadth ratio (L/B). All the three varieties took similar time to cook and cooking time varied non-significantly between 23.66 and 25.83 min. L/B ratio after cooking was found to be highest for FC followed by BC and SC. Elongation ratio of rice after cooking did not varied significantly between varieties. Elongation ratio after cooking ranged from 1.60 to 1.70.

Efbasher (2001) investigated Five rice grain samples namely long (American (Parboiled rice), A; Pakistan, P and Thailand, T) and short (Egyptian, E and Sudanese, S) types for their physicochemical and cooking quality characteristics. Investigations showed that rice grain of the two types had a length / width (L / w) ratio of 3.24 (A), 4.35 (P), 3.43 (T), 2.06 (E) and 2.07 (S). The investigations showed that rice grains contained 8.6% -10.9% moisture and 6.2% - 8.0% protein. For all types of rice amylose seems to be lower (24.00% - 31.50%) than amylopectin (31.66% -39.57%). Cooking reduced both amylose (13.83% - 18.67%) and amylopectin (26.30% - 34.32%) content; however, it increased the amylopectin content (39.64%) of the Sudanese, S sample. It was observed that cooked parboiled rice is harder and less sticky than cooked raw rice. Texture of cooked rice seems to be improved with increasing amylase content.

Rice grain quality characteristics such as physiological and chemical based on length, L/B ratio, milling percentage and elongation were studied for hybrid and landraces/traditional rice varieties. The maximum seed length was recorded in MEPH 113 and seed breadth was recorded in KPH

466 and MEPH 113. L/B ratio was recorded highest in NDR 97 (3.67) followed by NDR 2064 (3.65) and Pusa RH 42 and minimum was recorded in Sarjoo 52. The milling per cent ranged from 61.65 to 73.07. Maximum milling percentage was recorded in Pusa RH 42 (73.07) followed by MEPH 113 and minimum was recorded in NDR 2064 (Vikram *et al.*, 2018).

Oko *et al*. (2016) assessed the cooking quality and physico-chemical characteristics of 15 selected indigenous and five newly introduced hybrid rice varieties. The grains of “China” had the highest elongation values of 3.2 ± 0.00 mm. “E4197” has the best physical appearance but easily dissolves in water during cooking. Most of the physico-chemical characteristic such as amylose, amylopectin, gel consistency and gelatinization temperature were significantly correlated (positively or negatively) with some of the cooking quality traits (elongation during cooking, solids in cooking water and optimum cooking time), indicating that efforts aimed at selecting rice varieties with improved cooking quality traits would warrant a consideration of the physico-chemical attributes of the rice grain. The overall cooking quality and physico-chemical attributes of some of the indigenous rice varieties were even relatively better than the newly introduced hybrid varieties.

2.5 Phytic acid and minerals

Shozib *et al*. (2017) profiled mineral composition for Zn, Fe, Ca, P and anti-nutrient components such as PA (Phytic acid) and molar ratio of PA to minerals for 68 HYVs including Aus, Aman and Boro seasons in Bangladesh. BRRI dhan43 possess the highest Zn content of 38.4 ppm followed by Fe (17 ppm), Ca (68.1 ppm) and P (2.5 gKg-1) at clean rice condition. We also noticed that it’s molar ratio to Zn (PA/Zn); Fe (PA/Fe); Ca (PA/Ca) and P(PA/P) are lower among all selected high Zn enriched HYVs by 3.56, 6.93,1.24 and 25.69 respectively. Since there is no single HYV reported yet, BRRI dhan43 might be a potential micronutrient enriched

BRRI HYV for Aus season and it could be used as parental source for zinc enriched rice (ZnER) breeding in Bangladesh.

A total of eight BRRI inbreed high yielding rice varieties (HYVs) were subjected to evaluate both physicochemical and biochemical characterization. In terms of bioavailability of micronutrients such as Zn and Fe, molar ratio of Phytic acid (PA) was evaluated to respective minerals. Regarding molar ratio of PA/Fe and PA/Zn, it was found BRRI dhan53 and BRRI dhan62 were suitable for mineral intake of Fe and Zn respectively among other tested HYVs. This information might possibly be helpful for generating breeding materials especially for low GI and micronutrient enriched rice (MER) breeding programs in Bangladesh (Shozib *et al.*, 2017).

Njavara, medicinal rice, was assessed by Deepa *et al*. (2008) for its nutrient composition and physicochemical properties, in order to understand its thisapeutic properties. Dehusked Njavara rice consisted of 73% carbohydrates, 9.5% protein, 2.5% fat and 1.4% ash. Njavara rice had 16.5% higher protein, and contained higher amounts of thiamine (27–32%), riboflavin (4–25%) and niacin (2–36%) compared to non-medicinal rice varieties – Jyothi (red colored) and IR 64 (brown colored). Significantly higher phosphorus, potassium, magnesium, sodium and calcium levels were found in Njavara rice, compared to the other two varieties. The cooking time of dehusked Jyothi and IR 64 varieties were found to be 30 min, while Njavara needed longer time to cook, (38 min).

The present work aims to compare the chemical composition of commercial samples of brown, parboiled brown, parboiled milled and milled rice. Protein (N×5.7) and crude fat contents in all rice forms similar to literature data with some differences in ash contents, mainly between milled samples. Parboiled milled rice showed 18% ash enrichment in comparison with milled rice, and higher contents of K and P. Lower contents of Mn, Ca and Zn were observed, even though contents of other nutritionally important elements were basically similar to milled rice. The brown rice analyzed showed concentrations of P, Mn and Na lower than those reported in literature, indicating the usefulness of selecting nutritionally promising varieties for commercial production (Heinemann *et al*., 2005).

Study was conducted (Noreen *et al*., 2009) to find out variation in chemical composition of rice cultivars subjected to common cooking processes by making different products. Analysis of rice grain showed appreciable amount of sodium (155 mg kg^{-1}), zinc (37.5 mg kg^{-1}), phosphorus (381 mg kg^{-1}), potassium (1908 mg kg^{-1}) and copper (3.29 mg kg^{-1}). Soaking and boiling processes caused significant ($P<0.05$) decrease in phytic acid, sodium and phosphorus contents in all varieties. Cooking process decreased the concentration of phytic acid, potassium and zinc. Among selected minerals, potassium was found to be highest (1908 mg kg^{-1}). Phosphorus, sodium and zinc were also present in appreciable amounts i.e. 381, 155 and 37.5 mg kg^{-1} respectively. Phytic acid was reduced by 26% due to boiling and 21% due to soaking for 30 minutes.

Elemental analysis of the phosphorus- containing product from rice bran indicated that its predominant elements were P (45.1%), Mg (26.8%), K (12.2%), Na (6.3%), Ca (3.9%), Mn (2.3%) and Si (2.1%). The sample was a mixture of phytic acid and its salts predominantly Mg and K. (Makarenko *et al*., 2018).

Garcia-estepa *et al*. (1999) were determined phytic acid in cereal (brans, flours and milled wheat-products) and breads. The phytic acid for oat brans was half that of wheat bran (20 mg/g) and highest value (58 mg/g) than that for rice bran. The milling products (semolinas) from hard wheat exhibited 10 mg/g and soft wheat a mean of 23 mg/g. The breads made with single or mixture cereal flours exhibited ranges between 1.5 and 7.5 mg/g. The loss of phytic acid relative to unprocessed flours was between 20% for oat bread and 50% for white bread.

The influences of the chemical environment on the mineral, protein and phytic acid relationships in rice bran were examined. Adding increasing amounts of Fe (II), Fe (III), Zn (II), or Cu (II) ions as the sulfates to rice bran slurries affected the solubility's of the endogenous minerals, protiens and phytates. (Champagne *et al*., 1985).

Norhaizan and Nor (2009) was determined the inhibitory effect of phytate on the bioavailability of iron, zinc and calcium by measuring their molar ratios. A total of 29 food samples consisting of 12 rice and rice products, 5 wheat and wheat products, 5 grains and cereal based products and 7 different popular varieties of cooked rice and rice products were selected. Cooked products have lower content of phytate and minerals as compared to raw products. This could be due to the influence of the cooking method on phytate and mineral content in the food. Of the 29 food samples, 25 food samples had a phytate/iron molar ratio > 1, 5 food samples had a phytate/zinc molar ratio > 15 and 23 food samples had a phytate/ calcium molar ratio of 0.24. These results show that although many of the food samples analyzed had high mineral content, the high phytate content may impair the bioavailability of the mineral in the body.

Reduced phytic acid content was observed in cooked seeds of peanut (47 %), soybean (52 %), sunflower (56.5 %), pigeon pea (49.5 %) and rice (47.9 %). However, soybean and rice zinc contents and peanut, pigeon pea and rice iron contents were increased in cooked seeds. The mean nutrient availability in cooked and non- cooked seeds was statistically non-significant ($p < 0.05$). The cooking treatment significantly ($p < 0.05$) reduced the inherent phytic acid content in seeds besides soaking and germination treatments, although the phytic acid break down did not show increased nutrients content as expected in all food crops (Mahesh *et al*., 2015).

The content of phytic acid and minerals of thirty two rice genotypes were determined by Hossain *et al*. (2006) from both high and low yielding varieties in Bangladesh. A wide range of variation on the content of phytic acid and minerals like iron, zinc were found in the tested genotypes. Among the high yielding varieties, BR11 (Mukta), BRRI dhan29, BR8 (Asha) and BRRI dhan28 contain low content of phytic acid and high content of minerals, especially iron and zinc. These varieties were selected as suitable for human consumption. From the low yielding varieties, Chinigura, Kalijira, Sazoni and Basmoti were also suitable for human consumption as they have low phytic acid and high minerals content.

Bio fortification and reducing the phytic acid (PA) content of rice have arisen as new strategies for increasing micronutrient bioavailability in rice. Several genes involved in PA biosynthesis have been identified and characterized in rice. Manipulating the micronutrient distribution in rice grain, enhancing micronutrient levels and reducing the PA content in endosperm are possible strategies for increasing mineral bioavailability (Perera *et al*., 2018).

Rosero *et al.* (2013) investigated the relations between phytic acid P content and phytase activities of varieties quinoa Nariño-Colombia (QC), quinoa Anapqui's-Bolivia (QBA), quinoa - IICA 020 Oruro-Bolivia (QB) and quinoa Huancavelica-Peru (QP). They found significant differences in the proportions of protein, fat, fiber, and ash among the four varieties. The analysis of essential amino acids showed that these varieties were rich in arginine, leucine, phenylalanine, lysine and valine, and tyrosine a semi essential amino acids. The varieties were rich in phosphorus and calcium. The phytic acid P proportion in total P, in the QC (19,64%) was significantly lower than in other three varieties. In the variety QC (1052 FTU/kg) we found high concentration of phytase. A significant negative correlation (r=-0.89) was found between the concentration of phytase activity and phytic acid P among the four varieties.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out at the Biochemistry Laboratory under the Department of Biochemistry, Sher-e-Bangla Agricultural University (SAU), Dhaka and at the Laboratory of Grain Quality and Nutrition Division, Bangladesh Rice Research Institute (BRRI), Gazipur during the period of June 2016 to June 2018.

3.2 Materials

Ten released verities of rice grain namely BRRI Dhan42, BRRI Dhan43, BRRI Dhan62, BRRI Dhan64, BRRI Dhan72, BRRI Dhan74, BRRI Dhan35, BRRI Dhan36, BR6 and BR11 were selected for the study. Rice grains were collected from Gene Bank of BRRI (GRSD) than processed milling at parboiled and un-parboiled condition for physicochemical, cooking properties, mineral profiling and phytic acid analysis. Grains were cleaned, sun dried and stored into plastic container in a cool place until used for the chemical analysis.


Unparboiled
Brown Rice
BR6

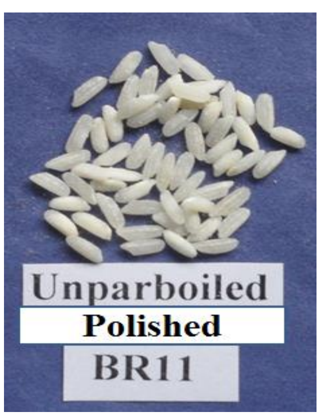

Parboiled
Brown Rice
BR6


Unparboiled
Polished
BR6

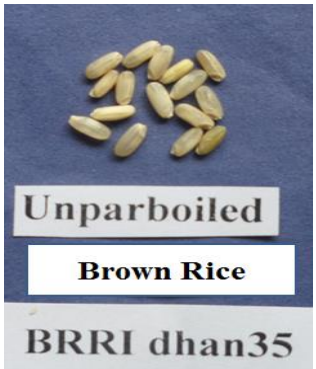

Parboiled
Polished
BR6


Unparboiled
Brown Rice
BR11


Parboiled
Brown Rice
BR11


Unparboiled
Polished
BR11


Parboiled
Polished
BR11


Unparboiled
Brown Rice
BRRI dhan35

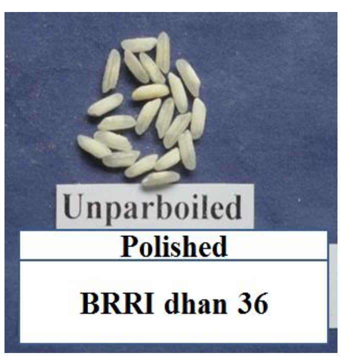

Parboiled
Brown Rice
BRRI dhan35


Unparboiled
Polished
BRRI dhan35


Parboiled
Polished
BRRI dhan35


Unparboiled
Brown Rice
BRRI dhan 36


Parboiled
Brown Rice
BRRI dhan 36


Unparboiled
Polished
BRRI dhan 36


Parboiled
Polished
BRRI dhan 36


Unparboiled
Brown Rice
BRRI dhan42


Parboiled
Brown Rice
BRRI dhan42


Unparboiled
Polished
BRRI dhan42


Parboiled
Polished
BRRI dhan42


Unparboiled
Brown Rice
BRRI dhan43


Parboiled
Brown Rice
BRRI dhan43


Unparboiled
Polished
BRRI dhan43


Parboiled
Polished
BRRI dhan43


Unparboiled
Brown Rice
BRRI dhan62

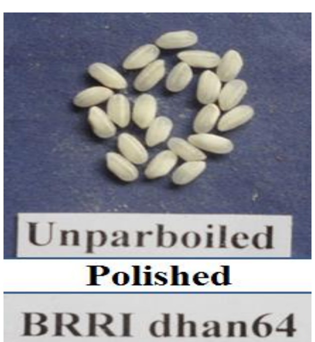

Parboiled
Brown Rice
BRRI dhan62


Unparboiled
Polished
BRRI dhan62


Parboiled
Polished
BRRI dhan62


Unparboiled
Brown Rice
BRRI dhan64


Parboiled
Brown Rice
BRRI dhan64


Unparboiled
Polished
BRRI dhan64


Parboiled
Polished
BRRI dhan64

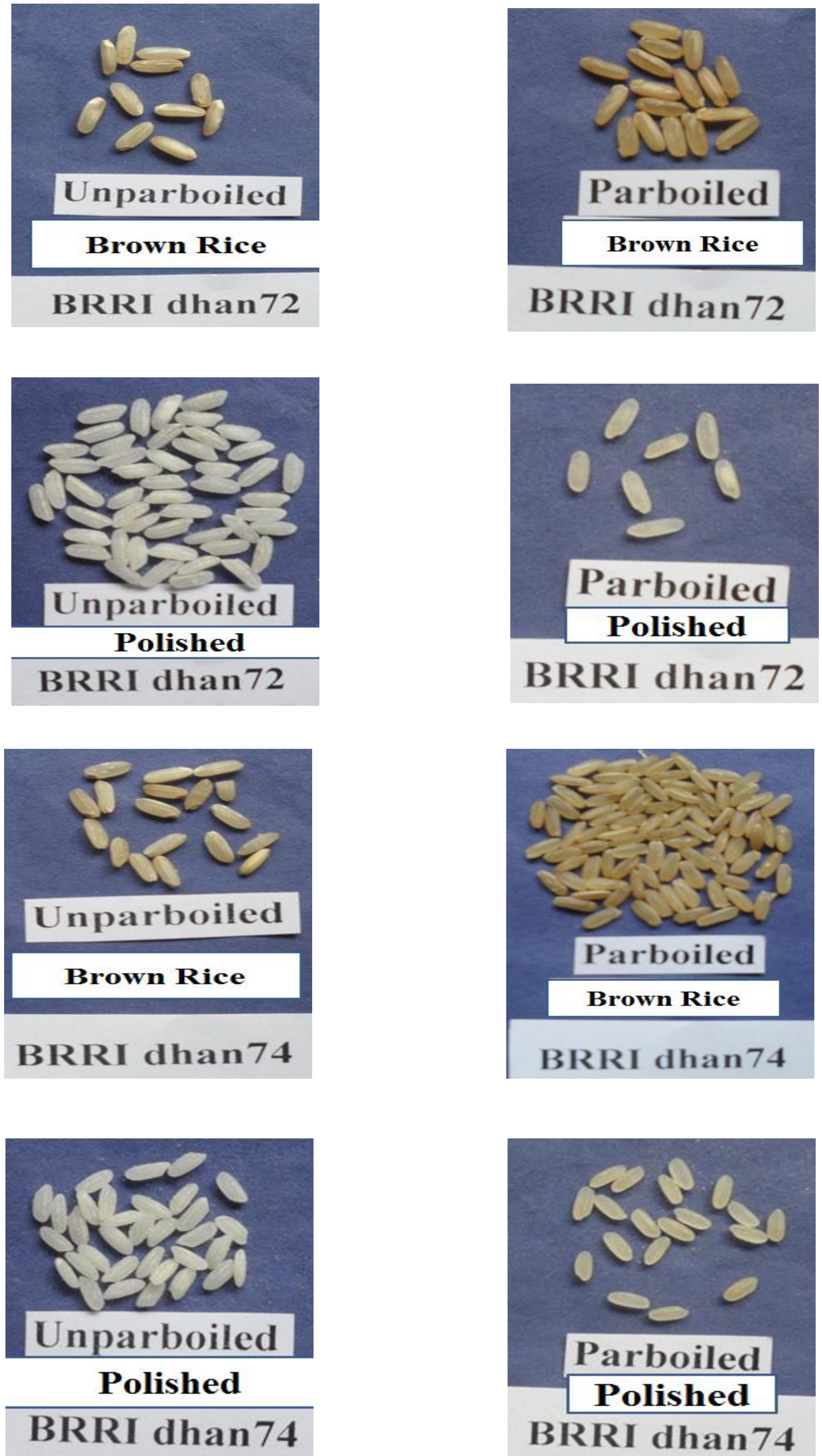


Figure 1: Photographs showing variation in samples color, size and shape of some selected released Rice varieties.

3.3 Physical Parameters

3.3.1 Milling Quality

Milling yield is one of the most important criteria of rice quality, especially from a marketing standpoint. A variety should possess a high turnout of wholegrain (head) rice and total milled rice (Webb, 1985). Milling yield of rough rice is the estimate of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as a percentage (Khush *et al.,* 1979). Thus, the milling quality of rice may be defined as the ability of rice grain to stand milling and polishing without undue breakage so as to yield the greatest amount of total recovery and the highest proportion of head rice to broken. The milling process generally consists of five fundamental operations:

1. Cleaning the rough rice to remove leaves, rice stems, and other foreign matter.
2. Shelling or de hulling the cleaned rice to remove the hulls.
3. Cleaning the brown rice to remove the hulls not totally removed by dehulling.
4. Milling or polishing the brown rice.
5. Separating whole grains from broken kernels.

3.3.2 Milling Yield Determination

Duplicate 200-g rough rice samples were used for milling determinations. Moisture content for these samples was in the range of 11-14%. A Foss moisture meter was used for determining the moisture content.

Rough rice samples are dehulled with a Satake laboratory sheller. The sample was poured into the hopper. Samples with many partially filled grains of reduced thickness usually require two passes. The resulting brown rice was weighed to obtain the percentage of hulls.

The brown rice was milled in satake rice grain Testing Mill TM-05 (Adair, 1952) for 30 seconds with the prescribed added weight (680 g) on the pressure cover, followed by a second milling for another 30 seconds without the weight. The fraction removed was considered bran in the first milling and that after the second milling polish. The milled rice sample was collected in a jar or thick paper bag and sealed immediately. The rice was allowed to cool before weighing. This procedure minimizes grain cracking during cooling. The weight of the total milled rice was recorded.

Whole grains (head rice) were separated from the total milled rice with a rice-sizing device. The indentation size of the device depends on the grain size. Two plates of the same size were used for each run. The resulting head rice was weighed. Samples were at least 3 to 4 months old after harvest to obtain reliable head-rice yields.

Calculations

The percentage of hulls of rough rice is calculated as follows:

$$\text{Brown Rice (\%)} = \frac{\text{Weight of Brown Rice}}{\text{Weight of Rough Rice}} \times 100$$

$$\text{Hull (\%)} = \frac{\text{Weight of Hulls}}{\text{Weight of Rough Rice}} \times 100$$

$$\text{Total Milled Rice (\%)} = \frac{\text{Weight of Total Milled Rice}}{\text{Weight of Rough Rice}} \times 100$$

$$\text{Head Rice (\%)} = \frac{\text{Weight of Head Rice}}{\text{Weight of Rough Rice}} \times 100$$

$$\text{Degree of Milling (\%)} = \frac{\text{Weight of Total Milled Rice}}{\text{Weight of Brown Rice}} \times 100$$

The proportions of the various components vary according to the method of milling used and the variety of rice. Generally, the hulls form 20% to 22% of the rough rice, although variation of 18% to 26% has been recorded. Bran and embryos constitute another 8% to 10%. Thus, from a given sample of rough rice, about 70% milled rice was obtained. The proportion of whole grains was known as head rice recovery and was expressed as percentage of rough rice. Thus, if from a sample of 100 g of rough rice, 70 g of milled rice is obtained and 20 g of this is broken, head rice recovery is 50%. The head-rice recovery may vary from as low as 25% to as high as 65% (Khush *et al.*, 1979).

3.3.3 Length and Breadth

All physical parameters were measured following IRRI evaluation standard (SES, 2015). Slide Calipers was used for the measurement of grain length and breadth. Preferences for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some prefer medium long grains, and others highly prize long slender grains. In general, long grains are preferred in the Indian subcontinent, but, in Southeast Asia, the demand is for medium to medium-long rice. In temperate areas, short-grain varieties are prevalent. There is a strong demand for long-grain rice on the international market.

Grain appearance depends upon the size and shape of the kernel and translucency and chalkiness of the grain. The physical dimensions of rice kernels are of vital interest to those engaged in the many facets of the rice industry. Rice varieties may be objectively classified into grain-type categories based upon two physical parameters: length and shape. Length is a measure of the rice kernel in its greatest dimension. While grain size and shape can be visually classified, more exact measurements are needed for a more critical comparison of varieties.

Standards for evaluating grain length and shape of breeding materials vary among countries and marketing areas. Below is a useful classification for a routine breeding evaluation.

Size classification:

Scale	Size Category	Length in mm
1	Very long	More than 7.50
3	Long	6.61 to 7.50
5	Medium or intermediate	5.51 to 6.60
7	Short	Less than 5.50

Shape classification:

Scale	Shape	Length/width ratio
1	Slender	More than 3.00
5	Medium	2.10 to 3.00
9	Bold	2.00 Or less than 2.00

3.3.4 Chalkiness

Grain appearance was also determined by endosperm opacity, the amount of chalkiness on the dorsal side of the grain (white belly), on the ventral side (white back), or in the center (white center), and the condition of the "eye." In some varieties, the grain tends to break more frequently at the "eye" or pit left by the embryo when it was milled. Rice samples with damaged eyes have a poor appearance and low market value. Similarly, the greater the chalkiness, the lower the market acceptability. The starch granules in the chalky areas were less densely packed vis-à-vis translucent areas. Therefore, the chalky areas were not as hard as the translucent areas and the grains with chalkiness were more prone to breakage during milling.

Milled grains were visually scored for the presence or absence of white belly, white back, white center, degree of translucency, and breakage at the basal-ventral end of the grain referred to as the condition of the eye. The above determinations are scored on a 0 to 9 scale according to increasing intensity.

The following scale is used for classifying endosperm chalkiness of milled rice:

Scale	% area with chalkiness
0	None
1	Less than 10%
5	10% to 20%
9	More than 20%

3.4 Chemical Parameters

3.4.1 Determination of Gelatinization Temperature (GT)

A duplicate set of six whole-milled kernels without cracks was selected and placed in a plastic box (5 × 5 × 2.5 cm). Half kernels were used in the absence of whole kernels. 10 mL of 1.7% (0.3035 M) potassium hydroxide (KOH) solution is added. The samples are arranged to provide enough space between kernels to allow for spreading. The boxes are covered and incubated for 24 h in a 30 °C oven. Samples were placed outside in the absence of an oven if the ambient temperature was almost the same as what was required. Starchy endosperm was rated visually based on a 7-point numerical spreading scale. Standard check varieties of high, intermediate, and low gelatinization types of rice are included for every test.

3.4.2 Cooking Time

This was determined by boiling 2.0 g of whole rice kernels from each treatment in 20 ml distilled water, removing a few kernels at different time intervals during cooking and pressing them between two glass plates until no white core was left. Optimum cooking time was taken as the established cooking time plus two (2) additional minutes (Oko, 2012).

3.4.3 Grain Elongation During Cooking

This was determined by first measuring the initial grain length (L_0) before cooking. The final length (L_1) after cooking was then measured. The grain elongation during cooking was then calculated as: $L_1 - L_0$, where L_0 = initial grain length before cooking, L_1 = final length after cooking (Oko, 2012).

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 90% of cooked rice totally gelatinized (Shozib *et al*., 2017).

3.4.4 Estimation of Iron, Zinc and Calcium

Sample were digested and estimated by the method of the Association of Official Agricultural Chemists (AOAC, 1995).

Reagents

i. Nitric Acid
ii. Perchloric Acid

Procedure

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°C 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. 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, for zinc 0.05, 0.10 0.20, 0.40, 0.80, 1.00 µg mL^{-1} at 213.8 nm and for calcium 1.0, 2.0, 4.0, 8.0, 12.0 µg mL^{-1} at 422.7 nm were taken respectively.

3.4.5 Estimation of Phosphorus

Estimation of phosphorus was carried out by measuring calorimetrically the blue color formed when the ash solution was treated with ammonium molybdate and the phosphomolybdate thus formed was reduced (Yoshida *et al.*, 1976).

Reagents

i. Nitric Acid
ii. Perchloric Acid
iii. Molybdatevanadate Solution

Procedure

About 0.2 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 samples were heated at 350°C for digestion until the color became clear. Then the digested sample was cooled and filtered through a Whatman filter paper No. 1 and the volume was made up to 50 mL with de-ionized distilled water. One mL of extracted sample was taken into a test tube and 2 mL HNO3 (2N), 4 mL de-ionized water was added. Then 1 mL molybdatevanadate solution and 2 mL de-ionized water was added to make the volume 10 mL. Mixed the solution with vortex mixture and the absorbance were taken at 420 nm after 15 minutes. For the preparation of standard curve for phosphorus, absorbance of 0.0, 0.5, 1.0, 2.0, 4.0 μg mL^{-1} P solutions were used.

3.4.6 Estimation of Amylose

Amylose in starch was released by treatment with dilute alkali. By the addition of Tri-iodide ion, amylose produces blue color. Then the absorbance of blue color produced in aqueous solution was measured (Juliano, 1971).

Reagents

i. Acetic Acid (1 N)
ii. NaOH (1 N)
iii. Ethanol (95%)
iv. Stock iodine solution (0.2%) in (2.0%) KI
v. Amylose, purified (NBC, Stein Hall, Sigma).

Procedure

100 mg of rice powder was accurately taken into a 100 mL volumetric flask and 1 mL (95%) ethanol and 9 mL NaOH (1N) were added carefully. Then the flask was incubated overnight at room temperature to gelatinize the starch and then made the volume up to the mark with distilled water. About 5 mL portion of the starch solution was pipette into another 100 mL volumetric flask and 1 mL (1N) glacial acetic acid; 2 mL of iodine solution were added and made the volume up to the mark with distilled water. Shake the mixture and after waiting 20 minutes, absorbance was measured at 620 nm in a spectrophotometer (Spectronic 20).

Calculation

$$\text{Amylose (\%)} = \frac{\text{Absorbance} \times \text{Slope} \times \text{Dilution Factor} \times 100}{\text{Weight of sample (mg)}}$$

3.4.7 Estimation of Phytic Acid

Phytic acid present in rice samples was determined calorimetrically by Wheeler and Ferral method (Wheeler and Ferral, 1971).

Reagents

i. Trichloroacetic acid (5%)
ii. Potassium thiocyanate (29%)
iii. Ferric chloride solution (0.025%)

Procedure

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 vortexes the mixture. The mixture was incubated at 60^{o}C 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 digester at 95^{o}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. 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.

3.5 Preparation of Standard Graph

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 digester at 95^{o}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 ($Fe_4P_6C_6H_6O_{24}$) (Anderson, 1963). Calculation was done on the basis of dry weight of the sample.

Calculation

$$\text{Fe (\%)} = \frac{\text{Absorbance} \times \text{Slope} \times \text{Dilution Factor} \times 100}{\text{Weight of sample (g)}}$$

$$\text{Zn (\%)} = \frac{\text{Absorbance} \times \text{Slope} \times \text{Dilution Factor} \times 100}{\text{Weight of sample (g)}}$$

$$\text{Ca (\%)} = \frac{\text{Absorbance} \times \text{Slope} \times \text{Dilution Factor} \times 100}{\text{Weight of sample (g)}}$$

$$\text{Phytic acid (mg g}^{-1}\text{)} = \frac{\text{MW of Phytic Acid} \times \text{Fe (\%)}}{4 \times \text{Atomic Weight of Fe/Zn/Ca/Mg}}$$

3.6 Statistical Analysis

Statistical analysis was done by using Microsoft Excel and SPSS version 20.

CHAPTER IV

RESULT AND DISCUSSION

4.1 Estimation of Physicochemical Properties

4.1.1 Milling Outturn

Milling outturn (MOT %) is one of the key parameters of the rice grain quality as it increases the shell life and provides the consumer with more whiteness that they desire. In physical properties analysis ten tested rice varieties contained satisfactory milling outturn in both parboiled and unparboiled condition. Milling outturn is the total quantity of head rice and broken rice recovered from unit quantity of rough rice. In general milling outturn more than 50% is desirable as the more the value the less the rough rice is discarded as bran. Among the tested varieties highest milling outturn 80.9% was found in BRRI dhan64 and lowest milling outturn 75.0% found in BRRI Dhan74 under unparboiled condition. In case of parboiled condition, lowest milling outturn were found in BRRI dhan74 (74.7%), BRRI dhan43 (78.6%) and highest milling outturn were found in BRRI dhan64 (82.2%) and BRRI dhan36 (81.2%) respectively. Ten rice varieties showed the milling outturn more than 70%. Husk percentage was higher in BRRI dhan74 both unparboiled (25.0%) and parboiled BRRI dhan74 (25.3%). Husk/Grain ranges between 0.2 and 0.3 almost all the varieties in unparboiled and parboiled situation. In unparboiled condition, the maximum head rice yield was found 68.4% in BRRI dhan 64 and lower was 39.8% in BRRI dhan74. In parboiled condition, the maximum head rice yield was found 73.7% in BRRI dhan 64 and lower was 66.4% in BRRI dhan74 (Table 1).

Rice varieties with highest length are more susceptible to cracking and breakage during milling (Wiset, Srzednicki, Driscoll, Nimmuntavin, & Siwapornrak, 2001). According to Dipti, Hossain, Bari, and Kabir (2002), good quality rice will have a head rice yield of at least 70%, therefore, it can be claimed that these three (BRRI dhan35, BRRI dhan36 & BRRI dhan64) rice varieties have an intermediate quality in terms of head rice yield percentage.

4.1.2 Length

The length of the various samples, under study, was found to be 4.9 mm to 6.6 mm (Table 1). For unparboiled condition, the highest length was recorded 6.6 mm in BRRI dhan36 and BRRI dhan62 and the lowest length was recorded 4.9 mm in BRRI dhan35. Under parboiled condition, the highest length was recorded 6.5 mm in BRRI dhan62 and the lowest length was recorded 5.1 mm in BRRI dhan35 and unparboiled condition, the highest length was recorded 6.6 mm in BRRI dhan36 and BRRI dhan62 and the lowest length was recorded 4.9 mm in BRRI dhan 35. The results are in conformity with the range of 6.6-7.7 for long type and 5.5mm for short type reported by Leonard and Martin (1963).

4.1.3 L/B Ratio

The highest length/ breath ratio (L/B) was 3.4 and 3.5 in unparboiled and parboiled condition, respectively found in BRRI dhan62. BRRI dhan64 showed the lowest L/B ratio in unparboiled (1.8) and parboiled (2.1) condition (Table 1).

Table 1. Physical properties of BRRI HYVs

HYV	MOT%		Husk%		Husk/Grain		HYR%		BKR%		Length (mm)		L/B		Moisture%	
	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR
BR6	79.7de	79.9bcde	20.3bc	20.2de	0.3b	0.3a	61.6c	71.4de	11.1a	8.4bc	6.5de	6.4c	3df	3cd	12.4b	11.1a
BR11	79.8de	80.3de	20.2bc	19.7cd	0.3b	0.2a	61.8c	71.9e	11.4a	8.4bc	5.7bc	5.5ab	2.8d	2.8bc	12.8bcd	11.4a
BRRI dhan35	80def	80.1cde	20.1bc	19.9cd	0.3b	0.2a	67.5ef	71.8e	11.5a	8.2bc	4.9a	5.1a	2.3b	2.4ab	12.6bc	11.5a
BRRI dhan36	80.5ef	81.2ef	19.5bc	18.8b	0.2a	0.2a	67.2e	72.1e	11.2a	9.1d	6.6e	6.2c	3.2fg	3.1cd	12.4b	11.2a
BRRI dhan42	78.2c	78.7bc	21.8d	21.3f	0.3b	0.3a	64.4d	70.3bc	11.5a	8.5c	6cd	6.4c	3df	3.4df	12.8bcd	11.5a
BRRI dhan43	76.6b	78.6b	23.4f	21.5f	0.3b	0.3a	59.2b	70.6cd	11.4a	7.9a	5.7bc	6.1bc	2.7cd	3.1cd	13.3d	11.4a
BRRI dhan62	79.1cd	80.4de	20.9c	19.6c	0.3b	0.2a	39.9a	69.6b	11.6a	10.8f	6.6e	6.5c	3.4g	3.5f	13.3d	11.6a
BRRI dhan64	80.9f	82.2f	19.1a	17.8a	0.2a	0.2a	68.4f	73.7f	11.4a	8.5c	5.1a	5.1a	1.8a	2.1a	13cd	11.4a
BRRI dhan72	80.8ef	79.4bc	19.2a	20.6e	0.2a	0.3a	61.3c	69.7b	11.5a	9.7e	6.4de	6.3c	2.9df	2.8bc	11.5a	11.5a
BRRI dhan74	75a	74.7a	25g	25.3g	0.3b	0.3a	39.8a	66.4a	11.4a	8.3bc	5.4ab	5.2a	2.4bc	2.6bc	12.6bc	11.4a
SE	0.61	0.64	0.61	0.64	0.02	0.02	3.35	0.17	0.05	0.28	0.2	0.18	0.15	0.14	0.17	0.05
CV%	0.02	0.03	0.09	0.1	0.18	0.21	0.18	0.04	0.01	0.1	0.11	0.1	0.17	0.15	0.04	0.01

MOT: Milling Outturn; HYR: Head Rice Yield; BKR: Broken Rice; L/B: Length Breadth Ratio; SE: Standard Error; CV: Coefficient of Variation.

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).

4.1.4 Cooking Time

The cooking properties of rice are important as it is consumed almost immediately after cooking. Rice being a major staple food in most of the developing countries, reduced cooking time can be beneficial, especially when fuel consumption is of concern. Cooking time of a rice grain is usually ascertained when 90% starch of grain no longer shows an opaque center (Dipti *et al.*, 2003).

The cooking characteristics (cooking time, imbibition ratio, and elongation ratio) of nine rice varieties are shown in Table 2. Cooking time varied between 16.2 min and 20.5 min. Variation in cooking time can be attributed to the presence or absence of bran layer on grains. Higher cooking time is required for rice varieties having fibrous bran layer attached (Juliano & Bechtel, 1985).Cooking time of the unparboiled ranges from 16.2 to 20.0 minute, while parboiled ranges from 18.5 to 20.5 minute. Highest cooking time for unparboiled group was recorded 20.0 min in BRRI dhan64 and BRRI dhan72 and lowest was 16.2 min in BRRI dhan74. Highest cooking time for parboiled group was recorded 20.5 min in BRRI dhan42, BRRI dhan64, BRRI dhan72 and lowest was 18.5 min in BR11 and 18.0 mint in BRRI dhan36, respectively.

4.1.5 IR, ER and Apparent Amylose Content (AAC)

IR ratio of all tested varieties under unparboiled and parboiled condition were ranged from 2.9 to 4.4 and 2.6 to 4.5, respectively .BRRI dhan64 has the highest IR ratio and BRRI dhan36 has the lowest IR ratio in both groups. This means BRRI dhan64 expand more in size than others upon cooking. Lengthwise expansion without an increase in girth is considered a highly desirable trait in some high-quality rice (Singh, 2000). Elongation ratio in unparboiled cultivars varies from 1.3 to 1.6 and parboiled varieties from 1.1 to 1.6. Highest elongation ratio (ER) was observed in variety BR6 and BRRI dhan64 under unparboiled condition and in BR6, BRRI dhan35, BRRI dhan36, BRRI dhan62 and BRRI dhan64 under parboiled condition (Table 2).

Among tested HYVs, BRRI dhan43 and BRRI dhan62 have the highest (25.5%) and the lowest (18.5%) Apparent Amylose Content, respectively in unparboiled varieties. BRRI dhan43 and BRRI dhan43 have the highest (26.8%) and BRRI dhan74 have the lowest (19.2%) AAC, respectively in parboiled varieties. Intermediate amylose containing rice gradually popularizes in Bangladeshi population in recent days especially for formulation of baby foods and consuming by senior citizens of Bangladesh. Amylose content of rice determines the hardness and stickiness of cooked rice. AAC content higher than 25% gives non sticky soft or hard cooked rice. Among the varieties, BR11, BRRI dhan36 and BRRI dhan43 had higher AAC. Rice having 20-25%

AAC gives soft and relatively sticky cooked rice. Intermediate level of AAC content (20% - <25%) were found in rest of the variety under both condition except BRRI dhan62 and BRRI dhan74 (Table 2). A positive correlation was found between AAC and IR. It resembles that higher AAC containing rice will absorb higher amount of water while cooking and it will eventually increase cooked rice volume accordingly.

4.1.6 Alkaline Spreading Value (ASV), Moisture and Protein Content:

ASV of the tested varieties ranges from 3.3 to 7.00. The highest ASV (7.00) and lowest ASV(3.3) was found in BRRI dhan36 and BRRI dhan62, respectively in case of unparboiled group (Table 2). The highest ASV (5.6) was observed in BR6 and BRRI dhan36 and lowest ASV (3.2) was observed BRRI dhan62 in case of parboiled group Majority of the varieties have intermediate ASV. The ASV was lower in parboiled condition than unparboiled one.

Protein content of rice is important from nutritional point of view. Several factors such as variety, environmental and cultural practices may influence the protein content of the grain. Rice provides a significant portion of protein. In both group, BRRI dhan36 has the highest and BR6 has the lowest protein content among tested HYVs (Table 2). Protein content of the tested varieties ranges from 7.1% to 10.4%.

Highest moisture content was found in BRRI dhan43 and BRRI dhan62 under unparboiled condition and in BRRI dhan62 under parboiled condition. Lowest moisture content was found in BRRI dhan72 under n unparboiled condition and in BR6 under parboiled condition.

The positive correlation of amylose content with moisture content and alkali spreading value indicates that high amylose rice variety will absorb more water and will produce a greater volume of cooked materials.

Kernel elongation ratio was found to be not related with either Amylose content or alkali spreading value. (Table 2).

Table 2. Cooking and Chemical properties of BRRI rice varieties

HYV	Cooking Time(mint)		IR		ER		Protein%		AAC%		ASV	
	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR	UPR	PR
BR6	18.2b	19a	3.4ab	3.1b	1.6a	1.3ab	7.1a	7.8a	22.1c	23.2e	6.7e	5.6c
BR11	18.5bc	18.5a	3a	3.3bc	1.3a	1.2a	8.4bc	8.8bc	24.3d	25.7g	5.7d	4.5b
BRRI dhan35	19cd	19.5a	3.4ab	3.1b	1.4a	1.3ab	8.1b	8.9c	23.6d	24.8e	5.8d	4.5b
BRRI dhan36	18b	18.5a	2.9a	2.6a	1.4a	1.3ab	10.1d	10.4d	23.7d	25.2f	7e	5.6c
BRRI dhan42	19cd	20.5a	3.4ab	4.3c	1.5a	1.1a	8.4bc	8.6bc	22.2c	22.9cd	4b	3.5a
BRRI dhan43	19.3d	20a	4.1cd	3.3bc	1.5a	1.2a	8.3bc	8.6bc	25.5e	26.8h	3.6bc	3.4a
BRRI dhan62	19.3d	19.5a	3.9bc	4.5c	1.3a	1.3ab	7.9b	8.4b	18.5a	19.9b	3.3a	3.2a
BRRI dhan64	20e	20.5a	4.4d	4.5c	1.6a	1.3ab	7.2a	7.8a	21.7bc	22.6c	4.8c	4.3b
BRRI dhan72	20e	20.5a	3.4ab	3.7cd	1.3a	1.2a	8.7c	8.8bc	21.1b	22.9cd	7e	5.3c
BRRI dhan74	16.2a	20a	3.7bc	4de	1.4a	1.6c	8.1b	8.6bc	18.6a	19.2a	5c	4.6b
SE	0.35	0.25	0.15	0.21	0.04	0.04	0.26	0.23	0.73	0.77	0.44	0.28
CV%	0.06	0.04	0.13	0.18	0.08	0.1	0.1	0.08	0.1	0.1	0.26	0.2

IR: Imbibition Ratio; ER: Elongation Ratio AAC: Apparent Amylose Content; ASV: Alkaline Spreading Value; SE: Standard Error; CV: Coefficient of Variation.

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).

4.1.7 Estimation of P, Zn, Fe, Ca and Phytic Acid at both Unparboiled and Parboiled Condition

Mineral profiling including P, Zn, Fe, Ca and Phytic acid (PA) content of all tested HYVs of rice both parboiled and unparbioled condition were summarized in Table 3. All of the varieties were found to be containing more minerals in unparboiled condition than parboiled one.

Mineral contents in HYVs were estimated. Significant variations were shown in the different varieties of rice. Among the HYVs at unperbioled condition, BR6 and BRRI dhan42 have high P content of 5.9 mgg^{-1} followed by BRRI dhan72 (5.5 mgg^{-1}) and BRRI dhan43 (5.4 mgg^{-1}), respectively and BRRI dhan35 have low P content of 3.7 mgg^{-1}. Regarding Zn content, BRRI dhan42 and BRRI dhan43 showed higher concentration of 27.6 and 26.4 $mgkg^{-1}$, respectively. Regarding Fe content, BRRI dhan62 and BR11 showed higher concentration of 10.5 and 9.5 $mgkg^{-1}$, respectively. Lower Fe concentration was recorded 2.0 $mgkg^{-1}$ in BRRI dhan42. Regarding Ca content, BRRI dhan42 and BRRI dhan43 showed higher concentration of 85.0 and 68.1 $mgkg^{-1}$, respectively. The lower concentration of Ca was found in BRRI dhan72 (11.5$mgkg^{-1}$). BRRI dhan62 and BRRI dhan36 had showed the highest content of phytic acid at 15.3 and 15.0 mgg^{-1} respectively. BR11 had shown the lowest content of phytic acid at 5.4 mgg^{-1}.

Under parboiled condition, among the high yielding varieties, the highest P content was determined in BRRI dhan42 (5.0 mgg^{-1}) and BRRI dhan62 (4.9 mgg^{-1}) respectively. Lowest content was found in BRRI dhan35 (2.8 mgg^{-1}) variety. On the other hand highest Zn content was found in BRRI dhan42 (27.4 $mgkg^{-1}$) followed by BRRI dhan43 (25.9 $mgkg^{-1}$). Whereas the lowest content of Zn was estimated in BR11 (17.7 $mgkg^{-1}$). The highest Fe content was recorded 9.0 $mgkg^{-1}$ in BR11 and 8.5 mgkg-1 in BRRI dhan62. The lowest Fe content was recorded 1.8 $mgkg^{-1}$ in BRRI dhan42. BRRI dhan42 and BRRI dhan43 showed higher Ca concentration of 69.5 and 56.4 $mgkg^{-1}$, respectively. The lower concentration of Ca was found in BRRI dhan72

(10.2 $mgkg^{-1}$). Among the HYVs, the phytic acid content in parboiled condition varied from 12.5 to 5.4 mg per gram. The highest amount of phytic acid was found in BRRI dhan62 (15.3 mgg^{-1}) followed by BRRI dhan36 (15.0 mgg^{-1}). BR11 contained the lowest amount of phytic acid (5.4 mgg^{-1}).

Chiej (1984) reported the phytic acid contents of rough/brown/hull rice, milled rice and rice bran were 0.98 mg, 0.25 mg and 7.81 mg per 100g, respectively at 14% moisture. Juliano (1985) reported the iron and zinc content ranges of rough rice and brown rice were 1.4-6.0 mg, 1.7-3.4 mg and 0.2-5.2 mg and 0.6-2.8 mg per 100g of rice respectively. On the other hand N I IR (2003) revealed the iron content of brown and white rice was 1.8mg, 0.9mg respectively. The zinc content of brown and white rice was 1.6mg and 1.4mg at dry weight basis respectively the present findings were little varied from the cited value. It might be due to different analytical method and different genotypes.

Among the high yielding varieties, BRRI dhan42 and BRRI dhan43 contained the higher amount of phosphorus, zinc and calcium and lower amount of iron both parboiled and unparboiled condition. BR11 contained lower amount of zinc and phytic acid content and contained more amount of iron. BRRI dhan42 and BRRI dhan43 is very good and suitable for Zn deficit human consumption. Although the highest amount of iron was found in BRRI dhan62 variety, but the phytic acid content of this variety was very high and consequently was not suitable for dietary purpose. Likewise, in BRRI dhan72 contained high amount of calcium, at the same time, the phytic acid concentration was also high and was not suitable for consumption. So BRRI dhan42 and BRRI dhan43 can be considered as the nutritionally suitable variety for human consumption to mitigate malnutrition.

Mameesh and Tomar (1993) reported phytate contents in different varieties of uncooked rice ranged between 0.05- 0.22%. When rice was cooked after steeping in excess water and then excess water discarded, 82% decrease is observed in phytic acid content in rice. Toma and Tabekhia (1979) studied the effect of cooking on rice in both domestic tape water and distilled deionized water. The phytic acid in raw rice variety Terso, M-5 and S-6 containing (191.8, 139.6 and 137.1 mg/100g) phytic acid respectively after cooking in distilled deionized water decreased to 187.9, 134.5 and 134.6 mg/100g respectively. Cooking in tape water decreased phytic acid content by approximately 2/3rd in all these varieties (53.7, 44.8 and 41.8 mg/100g) respectively. The result of this experimemts also supported the findings of (Mameesh and Tomar, 1993) and (Toma and Tabekhia, 1979).

Table 3: Mineral profiling of BRRI HYVs at both unparboiled and parboiled rice processing condition

HYV	**P (mgg^{-1})**		**Zn($mgKg^{-1}$)**		**Fe ($mgKg^{-1}$)**		**Ca ($mgKg^{-1}$)**		**PA (mgg^{-1})**	
	UPR	**PR**	**UPR**	**PR**	**UPR**	**PR**	**UPR**	**PR**	**UPR**	**PR**
BR6	5.9a	4.2abc	21.3d	20.9c	4.8cd	4.5cd	34.2c	30.0e	11.6b	10.2bcd
BR11	4.6abc	3.4cde	18.3e	17.7e	9.5a	9.0a	34.0c	29.3e	9.1a	5.4a
BRRI dhan35	3.7c	2.8de	18.9e	18.0de	7.3b	6.8b	26.8c	25.4e	11.2b	10.3bc
BRRI dhan36	4.9abc	3.6bcde	22.8bc	22.4b	4.8d	4.2d	35.1c	32.0e	15.0c	11.4bc
BRRI dhan42	5.9a	5.0a	27.6a	27.4a	2.0e	1.8e	85.0a	69.5f	11.7b	10.7bc
BRRI dhan43	5.4ab	4.3abc	26.4a	25.9b	8.5a	8.4a	68.1b	56.4f	11.4b	10.9bc
BRRI dhan62	5.0abc	4.9ab	19.0e	18.8de	10.5a	8.5a	14.0d	13.2c	15.3c	12.5f
BRRI dhan64	5.2abc	4.1abcd	24.0b	23.4b	5.6cd	4.9cd	18.7d	16.3d	14.4c	11.3cd
BRRI dhan72	5.5ab	4.2a	21.6cd	19.9cd	4.5d	4.1d	11.5d	10.2a	14.2c	10.7bcd
BRRI dhan74	4.0bc	3.6e	23.4b	22.6b	6.1bc	5.8bc	13.8d	12.2b	12.3b	9.9b
SE	0.23	0.21	1.00	1.03	0.82	0.74	7.72	6.20	0.64	0.60
CV%	0.15	0.17	0.14	0.15	0.41	0.40	0.72	0.67	0.16	0.18

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) using SPSS V-20.,UPR: Unparboiled rice, PR; Parboiled rice; CV: Coefficient of Variation; SE: Standard Error

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Laboratory of Biochemistry, Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka and the Laboratory of Grain Quality and Nutrition Division of Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur during the period from June 2016 to June 2018 for comparative study on physiochemical properties and mineral profiling of high yielding rice verities (HYV) with phytic acid in Bangladesh. Ten released HYVs namely BRRI Dhan42, BRRI Dhan43, BRRI Dhan62, BRRI Dhan64, BRRI Dhan72, BRRI Dhan74, BRRI Dhan35, BRRI Dhan36, BR6 and BR11 were selected for the study. Rice grains were collected from Gene Bank of BRRI (GRSD) than processed milling at parboiled and un-parboiled condition for physicochemical, cooking properties, mineral profiling and phytic acid analysis. Among the tested varieties highest milling outturn 80.9% was found in BRRI dhan64 and lowest milling outturn 75.0% found in BRRI Dhan74 under unparboiled condition. In case of parboiled condition, lowest milling outturn were found in BRRI dhan74 (74.7%), BRRI dhan43 (78.6%) and highest milling outturn were found in BRRI dhan64 (82.2%) and BRRI dhan36 (81.2%) respectively. BRRI Dhan74 showed the highest husk percentage. In both case, BRRI Dhan64 has the highest head rice yield; 64.4% in unparboiled condition and 73.3% in parboiled condition. BRRI Dhan74 has the lowest head rice yield; 39.8% in unparboiled condition and 66.4% in parboiled condition. The length of the various samples, under study, was found to be 4.9 mm to 6.6 mm. The highest length/breath ratio was found in BRRI dhan62 in unparboiled (3.4) and parboiled (3.5) condition. BRRI dhan64 showed the lowest L/B ratio in unparboiled (1.8) and parboiled (2.1) condition. Highest cooking time for unparboiled condition was recorded 20.0 min in BRRI dhan64 and BRRI dhan72 and lowest was 16.2 min in BRRI dhan74. Highest cooking time for parboiled condition was recorded 20.5 min in BRRI dhan42, 64 72 and lowest was 18.5 min in BR11 and 18.0 min in BRRI dhan36. IR ratios of all tested varieties under unparboiled and parboiled condition were ranged from 2.9 to 4.4 and 2.6 to 4.5, respectively. Highest elongation ratio (ER) was observed in BR6 and BRRI dhan64 at unparboiled condition and BR6, BRRI dhan35, BRRI dhan36, BRRI dhan62 and BRRI dhan64 at parboiled condition. BRRI dhan43 and BRRI dhan62 have the highest (25.5%) and the lowest (18.5%) AAC, respectively at unparboiled condition. BRRI dhan43 and BRRI dhan74 have the highest (26.8%) and the lowest (19.2%) AAC, respectively at parboiled condition.

Majority of the HYVs have intermediate ASV. The ASV was lower at parboiled condition than unparboiled one. Protein content of the tested varieties ranges from 7.1% to 10.4%. Highest moisture content was found in BRRI dhan62 under both conditions. Lowest moisture content was found in BRRI dhan72 at unparboiled condition and in BR6 at parboiled condition.

Mineral contents of HYVs were estimated and significant variations were found at different HYVs. Among the HYVs at unperbioled condition, BR6 and BRRI dhan42 have high P content of 5.9 mgg^{-1}. , BRRI dhan42 and BRRI dhan43 showed higher concentration of zinc 27.6 and 26.4 $mgkg^{-1}$, respectively. Regarding Fe content, BRRI dhan62 showed higher concentration of 10.5 $mgkg^{-1}$. Higher concentration of Ca was recorded in BRRI dhan42. BRRI dhan62 and BRRI dhan 36 had showed the highest content of phytic acid at 15.3 and 15.0 mgg^{-1} respectively. On the other hand BRRI dhan42 and BRRI dhan43 shows lower phytic acid 11.7mgg^{-1}, 10.7 mgg^{-1} and 11.4 mgg^{-1}, 10.9mgg^{-1} both in unparboiled and parboiled condition respectively. Though BR11 had shown the lowest content of phytic acid at 5.4 mgg^{-1}, its mineral content is lower enough to recommend as nutritionally valuable. Here BRRI dhan42 and BRRI dhan43 contained lower phytic acid and higher content of minerals, especially Zn, P and Ca. So availability of minerals is higher in BRRI dhan42 and BRRI dhan43. These varieties may be selected as most suitable for human consumption due to their nutritional values to mitigate malnutrition.

CHAPTER VI

RECOMMENDATION

- BRRI dhan42 and BRRI dhan43 are nutritionally enriched and mostly bioavailable HYVs that is why recommended for human consumption to mitigate malnutrition.
- Less (<9%) polishing of brown rice is recommended for retaining maximum minerals and proteins.
- Parboiled rice is comparatively more suitable in terms of higher mineral and less phytic acid availability.
- Recommended Dietary Allowance of minerals and proteins can be met up through consumption of these two rice varieties.

CHAPTER VII

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