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Screening for Nutritionally Rich and Low Glycemic Index Bangladeshi Rice Varieties

By

Md Zakir Hossain Howlader, *Principal Investigator*
Department of Biochemistry and Molecular Biology
University of Dhaka
and
Shunil Kumar Biswas, *Co-Investigator*
Grain Quality and Nutrition Laboratory
Bangladesh Rice Research Institute

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TABLE OF CONTENTS

Abbreviations

BRRI- Bangladesh Rice Research Institute

CI- Co-Investigator

DM- Diabetes Mellitus

FAO- Food and Agriculture Organization of the United Nations

GI- Glycemic Index

L/B ratio- Length and Breadth ratio

NFPCSP- National Food Policy Capacity Strengthening Programme

P.B.- Parboiled

PI- Principal Investigator

TAT- Technical Assistance Team

U.P.B.- Unparboiled

WHO- World Health Organization

SUMMARY

Rice grain is the staple food for more than half of the world's population. It grows in more than 100 countries and, for this reason, deserves a high level of investigation. In this study, an attempt was undertaken to highlight some of the nutritional parameters of some popular rice varieties of Bangladesh. These parameters include carbohydrate, protein, fat, moisture, ash, dietary fiber, amylose contents, gelatinization temperature, phytic acid, mineral and vitamin contents and the Glycemic Index (GI). In vitro digestibility of protein and starch was also investigated. Also the content of rapidly digestible starch (RDS) was measured to explain the value of GI. For this purpose, ten rice (Oryza sativa) varieties were collected and categorized as parboiled and unparboiled and thus the effect of parboiling was also studied.

Results showed a considerable intervarietal difference for these parameters mentioned above. Carbohydrate content showed an intervarietal range from 78.03 ± 0.69 % (BR-26) to 81.18 ± 0.88 % (BRRI-Dhan-29) in parbolied varieties and from 78.93 ± 0.79 (BR-11) to 80.93 ± 0.77 (BR-26) in unparboiled varieties. Protein content ranged from 5.8 ± 0.13 (BRRI-Dhan-29) to 8.8 ± 0.18% (BR-26) for parboiled rice and from 5.5 ± 0.09 (BRRI-Dhan-29) to 7.5 ± 0.10 % (BR-3) for unparboiled rice. Amylose content was found to range between 22.8 ±1.0 % (BR-26) and 28.9 ±0.95 % (BR-16) for parboiled rice and between 21.3 ±0.82 % (Chinigura) and 29.1 ± 0.92 % (BRRI-Dhan-29) for unparboiled rice. The mean value of phytic acid content for parboiled and unparboiled rice was found to range between 4.25 ± 0.05 (BRRI-Dhan-28) to 6.65 ± 0.27 (BR-3) mg/g and 4.05 ± 0.05 (BRRI-Dhan-28 & Chinigura) to 6.35 ± 0.15 (BR-3) mg/g, respectively.

The range for starch digestibility was determined to be between 74.13 ± 3.07 (BR-26) to 86.56 ± 2.9 % (BRRI-Dhan-40) for parboiled rice and between 70.2 ± 2.7 (BRRI-Dhan-28) to 86.4 ± 2.8 % (BR-11) for unparboiled rice. Digestibility of protein ranged from 89.31± 2.8% (BRRI-Dhan-30) to 98.4 ± 1.8 % (BR-3) for parboiled rice and from 88.34 ± 3.0 % (BRRI-Dhan-40) to 98.4 ±1.7 % (BR-3) for unparboiled rice.

For measuring GI value of the selected rice varieties 15 healthy male volunteers were recruited by matching their age (25-32 years) and BMI (20.5-23.5 kg/m^2). Glycemic Index (GI), the blood glucose response of dietary carbohydrate was ranged from 49.87 ± 9.8 (BR-16) to 74.2 ± 12.9 (BRRI-Dhan-29) in parboiled varieties and from 52.3 ± 6.9 (BR-16) to 76.3± 10.3 (BRRI-Dhan-

29) in unparboiled varieties. Only two varieties (BR-16 and Pajam) are in the low GI group (55 and below). Most of the varieties are within medium GI group (56-69). High GI value (70 and above) varieties are BRRI Dhan-29 and Chinigura. BR-26 and BRRI Dhan-28 also have near high GI values. The effect of parboiling was found to have no significant effect ($P>0.05$) on these nutritional parameter. Pajam showed the lowest RDS content of 4.23%, whereas BRRI Dhan-29 had the highest RDS content of 11.21±0.54 % followed by BRRI Dhan-30 (11.1±0.23%) in the parboiled group. On the other hand, BR-26 showed the highest RDS content of 12.8% followed by Chinigura (12.36 ±0.61%) and BRRI-Dhan-30 (12.1 ±0.27%), whereas BR-3 had the lowest RDS content of 7.6% in the unparboiled group. A significant correlation ($r=0.62$, $p = 0.004$) was found between GI values and RDS content.

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INTRODUCTION

Rice grain is the staple food for more than half of the world population and grows in more than 100 countries. China, India, Indonesia, Bangladesh, Thailand, and Vietnam produce about 80 percent of the world rice production. Among the leading rice growing countries of the world, Bangladesh ranked fourth of in both rice area and production. But the position of Bangladesh is more critical due to its highest population density in a situation where majority of rice growing areas are rain fed and flood prone. Rice accounts for 95 percent of the food grain production in Bangladesh. Rice production in Bangladesh was less than 10 million tons in 1970 and then exceeded 20 million tons in 1999.

The health problems associated with consumption of carbohydrate rich food is a mater of great concern. It is the most widely consumed nutrient all over the world, but if it consumed in excessive amount it can have undesirable effect on health. The adverse effect of carbohydrate is due to its ability to increase blood glucose beyond the normal limit. It is for this reason that there is need to know the glucose level increasing capability of carbohydrate foods. The ranking of carbohydrate food according to blood glucose level is provided by the glycemic index value of that food.

The Glycemic index (also glycaemic index) or GI is a measure of the effects of carbohydrates on blood glucose levels.The concept of glycaemic index (GI) was introduced by Jenkins and Wolever in 1981 as a quantitative indicator of the ability of carbohydrates to raise blood glucose. The GI is defined as the incremental area under the glucose response curve following the intake of 50 g carbohydrate from a test food compared with the glucose area induced by the same amount of carbohydrate from a standard carbohydrate source, usually white bread or glucose (Jenkins et al. 1981).

$$\text{Glycemic index} = \frac{\text{incremental area under 2 h plasma glucose curve for meal} \times 100}{\text{incremental area under 2 h plasma glucose curve for 50 g glucose}}$$

The glycemic index consists of a scale from 1 to 100, indicating the rate at which 50 grams of carbohydrate in a particular food is absorbed into the bloodstream as blood-sugar. Glucose itself is used as the main reference point and is rated 100.

The glycemic index separates CHO-containing foods into three general categories:

(1) High Glycemic Index Foods (GI 70+), that cause a rapid rise in blood-glucose levels.

(2) Intermediate Glycemic Index Foods (GI 56-69) that cause a medium rise in blood- glucose.

(3) Low Glycemic Index Foods (GI 55 or less), that cause a slower rise in blood-glucose.

The study will help to identify or classify popular rice varieties for glycemic indices. Low glycemic index variety will be beneficiary for carbohydrate and lipid metabolism It will reduce the blood glucose in diabetic patients and it will become popular among the diabetic patients. Since obesity is another serious problem in developed countries and obesity is strongly associated with high glycemic index food.

It will also have a great impact on the productivity of our people. Low glycemic index rice with good nutritional composition may encourage farmers as well as consumers for their high demand and economic benefit. Successful completion of this work may have a significant contribution to the food security.

Objectives of the study:

The study was done

- (i) to determine the grain quality of selected rice varieties
- (ii) to standardize screening technique to measure the glycemic index of rice varieties
- (iii) to identify low glycemic index varieties from popular modern and local improved varieties
- (iv) to determine the nutritional quality factors such as minerals (Ca, Zn, Fe, Se),Vitamin B1, vitamin B2, Niacin, Protein and Starch content and in vitro digestibility.

MATERIALS AND METHODS

Collection and preparation of samples

Ten varieties of paddy were collected in different occasions from the Bangladesh Rice Research Institute (BRRI), stations from different parts of the country and also from BRRI, Gazipur. A portion of collected every variety of paddy was run through a process of parboiling. The collected varieties were divided into two groups- parboiled (PB) and unparboiled (UPB), except Chinigura rice for which only the unparboiled sample was used. The husk of the paddy was removed by using a blender and the paddy was converted to rice. These rice grains were used as raw sample for different biochemical analysis.

Physical analysis

Determination of Milling Yield (Khan and Wikramanayake, 1971)

200g of brown rice was milled with a satake grain testing mill using the 36 mesh abrasive cylinder for 1 minute at 800 rpm to obtain 10% milling. A timer accurate to 1 second was used for more precise milling and 1000 rpm speed was used for parboiled sample.

Determination of L/B ratio

Length and breadth was measured using a slide calipers and L/B ratio was determined by dividing length with breadth.

Scale:

Size Category	Length	Shape	L/B ratio
Long	>6 mm	Slender	>3
Medium	5-6 mm	Bold	2-3
Short	< 5 mm	Round	< 2

Biochemical analysis

Estimation of Protein Content (Microkjeldahl Method): The nitrogen present in the sample is converted to ammonium sulphate by digestion at 380 ^{0}C with sulphuric acid in presence of a catalyst, potassium sulphate and mercuric oxide. Ammonia liberated by distilling the digest with NaOH solution is absorbed by boric acid and is titrated for quantitative estimation. (Anonymous, 1984).

Estimation of Fat Content (Choudhury and Juliano, 1980): Dried powdered rice sample was taken in a round joint flask and extracted with chloroform: methanol (2:1).
Estimation of dietary fiber content of rice: Crude fiber is defined as the organic fraction (residue) of plant food after sequential extraction with solutions of 1.25 % H_2SO_4 and 1.25 % NaOH. (Anonymous, 1984, p 160-161)

Estimation of carbohydrate content: The carbohydrate content of a sample is calculated from the percentage of other components of that sample by subtracting the additive value of moisture, ash, fat, protein and fiber from 100.
Percentage of carbohydrate = 100 – (moisture +ash+ fat + protein +fiber).

Determination of amylose content of rice: Amylose in rice is released by treatment with dilute alkali. By the addition of Tri-iodide ion, amylose produces blue color. The absorbance of blue color produced in aqueous solution is measured spectrophotometrically at 600nm as described by William et al (1958).

Estimation of minerals: Extreme caution was taken to avoid the contamination of glassware and reagent used for mineral analysis. All apparatus were soaked overnight in 2% nitric acid followed by washing with deionized water and oven dry. Deionized water was used for mineral analysis throughout the procedure (Minami et al., 2004).
Sample was digested using 25 ml acid mixture of H_2SO_4, $HClO_4$ and HNO_3 (0.5:1.0:0.5) by volume. The digestion continued in an electrothermal resistant high neck volumetric flask at approximately 200 ºC until the solution was not clear (slightly greenish). This solution was then cooled and transferred to a test tube. After dilution, the concentration of Fe^{++}, Ca^{++}, Zn^{++} and Se were determined by the use of Chemito atomic absorption spectrophotometer, 201. The wavelength used for Fe^{++}, Ca^{++}, Zn^{++} and Se were 248.3, 422.7, 213.9 and 196 nm respectively. The samples were analyzed against a calibration curve prepared by standard solution of each element.

Estimation of phytic acid content of rice: The phytic acid and phytic acid chelates react with ferric chloride and form ferric phytate. The available ferric ion after reaction is determined by developing blood-red color with potassium thiocyanate (Wheeler and Ferral, 1971).
Determination of Gelatinization Temperature of Starch Granules (alkaline spreading method):
Gelatinization temperature of starch granule was determined by the procedure described by Little

et al (1958). Six kernels of whole milled rice were placed in duplicate in plastic boxes containing 10 ml 1.7% KOH arranged so that the kernels do not touch each other. The boxes were covered and incubated for 23 hours at 30ºC. The appearance and disintegration of the endosperm were rated visually on the basis of an international standard scale.

A rating of 1 to 3 is classified as high gelatinization temperature (greater than 74ºC); a rating of 4 to 5 is classified as inter mediate gelatinization temperature (70-74ºC); and a rating of 6 to 7 corresponds to gelatinization temperature below 70ºC.

In vitro *digestibility of starch and protein: In vitro* digestibility of starch from rice sample were determined using the α-amylase following the method describe by Singh et al. (1982). The digestibility of rice protein was determined by the method of Akeson and Stahmann (1964). In this method protein is digested by pepsin, followed by pancreatin.

Estimation of vitamin content (Juliano et al. 1972): Thiamine, Riboflavin, and Niacin were estimated in the selected rice samples. 5 gm rice powder was taken in a 100 ml vol. flask & 50 ml 0.1N H_2SO_4 was added and autoclaved for 30 min. After cooling the contents, pH was adjusted to 4.5 with 2M sodium acetate. 5 ml of Takadiastase (1M) and a 5 ml of papain 10% was added to each flask. The contents were incubated overnight at 35 ^{0}C. The samples were diluted to 100ml with deionized water and filtered through ash free filter paper. The filtrate was analyzed using HPLC against respective standard.

Determination of Glycemic Index (GI), (Jenkins et al. 1988)

To determine the GI of selected rice varieties, we have recruited 15 healthy volunteers (healthy, male subjects) aged from 25 to 32 years (BMI= 20.5-23.5kg/m^2). Total 19 samples (including parboiled and unparboiled) were fed to each volunteer. Rice of 50 g carbohydrate equivalent was fed after overnight fasting and blood was collected (both venous blood and fingerpick) at fasting, 30, 60 and 120 minutes after eating of rice (as test food) and glucose (as standard). Blood glucose was measured immediately. Glucose was fed to each volunteer at least two times in the study period. GI was calculated by estimating the increment of area under the curve in different time point.

Estimation of Rapidly Digestible Starch (RDS)

Free glucose is liberated by the treatment of the mixture of enzymes (α-amylase and amyloglucosidase) which is then measured by the Glucose oxidase reagent kit. It produces light pink color and the absorbance is measured at 510 nm

Statistical analysis

Data obtained by different procedure were subject to statistical analysis using SPSS statistical software.

RESULTS AND DISCUSSION

Rice (Oryza sativa L.) is one of the leading food crops of the world and is a staple food of over approximately one-half of the world population and grows in more than 100 countries. The rice is grown under a variety of climatic conditions. The crop is produced at sea level on coastal plains and in delta regions and is also to a height of 2600 m on the slopes of Nepal's Himalayan. China, India, Indonesia, Bangladesh, Thailand, and Vietnam are the world's largest rice producers, accounting for about 79% world productions in 1993 (IRRI 1993). Among the leading rice growing countries, China ranked topmost followed by India, Indonesia, and Bangladesh (IRRI 1993). The position of Bangladesh is most critical due to highest population density in a situation where majority of rice growing areas are rain fed and flood pron. In Bangladesh, rice accounts for 95% of the food grain production. Rice occupies over 75% of the total cropped area of the country. Thus a nutritional study on Bangladeshi rice varieties is very important and carries significance.

The data presented in this study provided unique information on carbohydrate content, protein content, fat content, ash content, moisture content, fiber content, amylose content, gelatinization temperature, phytic acid content and mineral content (Fe, Zn, Ca and Se), vitamin content of ten Bangladeshi varieties- eight BRRI varieties (BR-3, BR-11, BR-16, BR-26, BRRI Dhan-28, BRRI Dhan-29, BRRI Dhan-30, and BRRI Dhan-40) and two traditional varieties (Pajam and Chinigura), collected from the farm of Bangladesh Rice Research Institute (BRRI). Glycemic Index (GI) of these varieties was also estimated. The samples are studied by dividing into two groups on the basis of parboiling and the effect of parboiling was also investigated.

In this study, BRRI varieties were investigated because most of the varieties developed by BRRI are being extensively cultivated that produce high yields (3.0-6.5 ton/hector) as well as meet farmers need for cattle feed and roofing materials. They have short growth duration and fine grain. All the BRRI varieties are suitable for cultivation under favorable rice growing ecosystems in Bangladesh.

Grain quality characteristics are presented in Table 1. Grain size, shape and appearance, and higher milling recovery determine the grain quality in rice. Grain quality includes grain 6-7 mm long 1.5-2.0 mm breadth, cooking rice elongation 1.5-2.0 times and 20-24% amylose content. The length of collected varieties ranges from 3.93 mm to 6.70 mm whereas breadth varies from 1.82 mm to 2.42 mm.

Table 1: Grain quality characteristics of selected rice varieties:

Varieties	Milling Yield (%)	Length (mm)	Breadth (mm)	L/B ratio	Size and Shape
BR-3	70.8	5.88	2.42	2.43	MB
BR-11	72.3	5.43	2.10	2.59	MB
BR-16	71.8	6.70	2.05	3.27	LS
BR-26	70.9	6.54	1.82	3.59	LS
BRRI Dhan-28	71.7	6.19	1.89	3.28	LS
BRRI Dhan-29	71.0	6.06	1.91	3.17	LS
BRRI Dhan-30	72.3	6.01	2.07	2.90	LB
BRRI Dhan-40	71.3	5.32	2.42	2.20	MB
PAJAM	70.0	4.50	2.03	2.22	SB
CHINIGURA	69.0	3.93	1.92	2.05	SB

Most consumers prefer long or medium long and slender translucent grains. The grain size and shape of most modern rice varieties is short to medium bold with translucent appearance (Biswas et al., 1992). Chinigura is popular for its attracting aroma though it is of short bold type. Preference for grain size and shape vary from one group of consumer to another (Khush et al., 1979). High income group of people in Bangladesh prefer long slender grain, whereas, lower income group prefer bold grain (Anonymous, 1997).

Whereas consumers consider physicochemical qualities of rice grain (Merca and Juliano, 1981), the rice millers prefer varieties with high milling yield. Milling yield is one of the important properties to the millers. Milling yield is the measure of rough rice performance during milling. The milling yield of modern rice varieties ranges from 69-73% (Biswas et al., 1992). Less than 67% milling yield is not acceptable. All the tested varieties in this study gave more or less similar and higher milling yield of greater than 69.0% (Table 1). Highest milling yields (72.3%) were found in BR-11 and BR-30 and are considered to be more acceptable to rice millers. Grain chalkiness is attributed to cause low milling yield and poor consumer acceptance.

Quality of cooked rice largely depends on the amylose content, gel consistency and aroma. The amylose content of rice is considered as the main parameter of cooking and eating qualities (Juliano, 1972). Intermediate amylose rice are preferred in most rice growing areas of the word, except where low amylose Japonicas are grown.

Table-2: Amylose content of selected rice varieties

Variety	Amylose content (%)	
	P.B.(Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	28.5 ± 0.95	28.5 ± 0.92
BR-11	27.4 ± 0.82	28.3 ± 0.85
BR-16	28.9 ± 0.95	28.9 ± 0.87
BR-26	22.8 ± 1.0	23.0 ± 0.92
BRRI Dhan-28	27.6 ± 0.87	28.9 ± 1.02
BRRI Dhan-29	27.4 ± 0.92	29.1 ± 0.92
BRRI Dhan-30	27.8 ± 0.89	26.6 ± 0.88
BRRI Dhan-40	27.8 ± 0.96	27.6 ± 1.05
PAJAM	25.6 ± 0.87	25.8 ± 0.89
CHINIGURA	-	21.4 ± 0.82

The results of this study showed that amylose content of the milled rice from different cultivars were found to range between 22.8% and 28.9% for parboiled group and between 21.3% and 29.1% for unparboiled group (Table-2). This range is different from the range obtained by Singh et al. (2003) who have reported an amylose content range of 5.5–11.7% for milled rice from different cultivars. Thus the tested varieties are said to contain high amylose content. The modern rice varieties of BRRI were found to have high amylose (Biswas et al., 1992) and our findings corroborate these results.

In this study considerable intervarietal differences were found for amylose content. This difference is attributed to be caused by genetic factors as well as environmental factors such as temperature. The variation in amylose content in rice varieties has been described by a single nucleotide polymorphism in an allele of the waxy gene encoding the granule-bound starch synthase (GBSS) enzyme by Ayres et al. (1997). This polymorphism has been observed to be temperature dependent (Larkin and Park, 1999).

Largely the amylose content and gelatinization temperature (GT) determines the cooking quality. The result showed that gelatinization temperature range for BR-3, BR-11, BRRI Dhan-28, BR-30, BR-40, Pajam and Chinigura were found to equal (55-69ºC) and lower than that of BR-16, BRRI Dhan-29 and BR-26 for which the range was 70-74ºC (Table-3). Varieties with intermediate amylose content and intermediate gelatinization are preferred.

Table-3: Gelatinization temperature of selected rice varieties

Variety	Gelatinization Temperature (°C)
	U.P.B
BR-3	55-69
BR-11	55-69
BR-16	70-74
BR-26	70-74
BRRI Dhan-28	55-69
BRRI Dhan-29	70-74
BRRI Dhan-30	55-69
BRRI Dhan-40	55-69
PAJAM	55-69
CHINIGURA	55-69

Fortunately, there seems to be no genetic barrier to combining these quality traits with high yield or other adaptability traits. Varietal difference in GT seems to be caused by genetic inheritance and environmental factors. High air temperature after flowering raises the gelatinization temperature (which lowers grain quality) and low air temperature reduces it (Jennings et al., 1979).

On the other hand, degree of gelatinization is associated with the starch digestibility. The starch digestibility of rice is affected overall by the degree of gelatinisation during cooking, the granule particle size, the amylose/amylopectin ratio, starch protein interaction, amylose/lipid complexes and the level of resistant starch. Result of the study showed the high (>70.4%) starch digestibility for all tested varieties (Table-4).

Table-4: Digestibility of starch of selected rice varieties

Variety	In Vitro digestibility of starch (%)	
	P.B.(Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	83.4 ± 2.8	79.77 ± 2.75
BR-11	84.03 ± 2.98	86.4 ± 2.8
BR-16	77.2 ± 3.15	72.0 ± 3.05
BR-26	74.13 ± 3.07	78.2 ± 2.9
BRRI Dhan-28	74.3 ± 2.8	70.2 ± 2.7
BRRI Dhan-29	83.4 ± 3.8	74.2 ± 2.9
BRRI Dhan-30	82.2 ± 3.4	83.4 ± 3.1
BRRI Dhan-40	86.56 ± 2.9	80.3 ± 2.7
PAJAM	83.45 ± 2.75	78.13 ± 2.6
CHINIGURA	-	74.2 ± 3.1

BRRI Dhan-40 (86.56%) was the most digestible rice variety in the parboiled group as BR-11 (86.4%) was in the unparboiled group (Table 4). The lowest starch digestibility was found in BR-26 (74.13%) among the parboiled samples and, among unparboiled samples, it was found in BRRIdhan-28 (70.2%). The marked improvement of starch digestibilities in rice may be attributed to the gelatinization of starch granules, characterised by irreversible swelling of the granules, increase in viscosity as the order and crystallinity of the starch molecules are broken down by heat allowing more water penetration and hydration of the granules (Juliano, 1984).

Amylose content, volume expansion, water absorption influences many of the starch properties of rice (Juliano, 1979; 1985). Starch is the inevitable constituent of rice grain and occupies the majority of carbohydrate content of rice. Rice varieties differ widely on the basis of carbohydrate content. Carbohydrate content of the tested rice samples varied from 78.03% to 81.18% (Table-5). This difference was found to be insignificant (P>0.05) between the parboiled and unparboiled group.

Table-5: Carbohydrate content of different rice varieties

Variety	Carbohydrate content (%)	
	P.B. (Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	79.14 ± 1.07	79.08 ± 0.88
BR-11	78.22 ± 0.98	78.93 ± 0.79
BR-16	80.41 ± 0.78	80.13 ± 1.05
BR-26	78.03 ± 0.69	80.93 ± 0.77
BRRI Dhan-28	79.85 ± 0.87	79.76 ± 0.96
BRRI Dhan-29	81.18 ± 0.88	80.77 ± 1.06
BRRI Dhan-30	80.25 ± 0.92	80.59 ± 0.85
BRRI Dhan-40	80.49 ± 1.02	79.95 ± 1.08
PAJAM	78.75 ± 0.54	79.99 ± 0.76
CHINIGURA	-	80.04 ± 0.88

Among two groups (parboiled and unparboiled), the highest amount of carbohydrate was measured in parboiled BRRI Dhan-29 (81.18%) and the lowest amount was found in parboiled BR-26 (78.03%). In the Unparboiled group BR-26 (80.59%) was found to contain highest amount of carbohydrate and BR-11 (78.93%) contained the lowest amount (Table 5).

The nutritional value depends on the total quantity and quality of protein. Rice is an important source of protein and supplies more than 60% of the total protein consumed in Bangladesh. Many researches mentioned variability of protein contents in different varieties of rice up to 15% (Sotelo et al., 1990; Lam-Sanchez et al., 1993; Kennedy and Burlingame, 2003) which verify the precision of the study that showed that protein content of tested rice varieties ranged from 5.8 to 8.8% for parboiled form and from 5.5 to 7.5% for unparboiled form. Though the protein content between parboiled and unparboiled group did not vary significantly (P>0.05), for parboiled category the highest and lowest protein content were found in BR-26 (8.8%) and BRRI Dhan-29 (5.8%), respectively (Table-6).

Table-6: Protein content of selected rice varieties

Variety	Protein content (%)	
	P.B. (Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	7.5 ± 0.08	7.5 ± 0.10
BR-11	8.3 ± 0.15	7.3 ± 0.12
BR-16	6.5 ± 0.20	6.5 ± 0.14
BR-26	8.8 ± 0.18	6.0 ± 0.13
BRRI Dhan-28	6.8 ± 0.11	6.7 ± 0.10
BRRI Dhan-29	5.8 ± 0.13	5.5 ± 0.09
BRRI Dhan-30	7.3 ± 0.09	6.4 ± 0.11
BRRI Dhan-40	7.4 ± 0.15	6.7 ± 0.13
PAJAM	8.5 ± 0.16	7.2 ± 0.087
CHINIGURA	--	6.9 ± 0.10

For unparboiled category the highest and lowest were found in BR-3 (7.5%) and BRRI Dhan-29 (5.5%), respectively. The protein content is higher with wider plant spacing, where more nitrogen is available to plants. It also increases with better water management and better weed control, probably because of higher efficiency in nitrogen utilization.

High protein content in rice is related to the high dietary protein. But bioavailability of protein depends on its digestibility. The result of the study showed a high in vitro digestibility of protein (up to 98.5%) (Table-7). The increased in vitro protein digestibility of rice may be attributed to the inactivation of protease inhibitors and the opening up of the protein structure through denaturation. Cooking may destroy the anti-nutritional factors present in rice and render rice protein more digestible. This study revealed an in vitro protein digestibility of 88.34%, which is comparable to the reported in vivo value of 85% in humans (Eggum, 1973).

Table-7: In vitro protein digestibility of protein of selected rice varieties

Variety	In vitro digestibility of Protein (%)	
	P.B(Mean ± SE)	U.P.B(Mean ± SE)
BR-3	98.4 ± 1.8	98.4 ± 1.7
BR-11	91.57 ± 2.9	96.99 ± 1.7
BR-16	96.62 ± 2.67	98.0 ± 1.9
BR-26	93.66 ± 2.8	90.70 ± 2.6
BRRI Dhan-28	89.7 ± 3.15	89.55 ± 2.1
BRRI Dhan-29	96.20 ± 2.98	98.4 ± 1.5
BRRI Dhan-30	89.31 ± 2.8	89.54 ± 2.9
BRRI Dhan-40	89.45 ± 3.6	88.34 ± 3.0
PAJAM	92.13 ± 2.7	92.25 ± 2.08
CHINIGURA	--	91.92 ± 3.2

Rice is not a significant source of dietary fat. The fat content of tested rice sample ranged from 0.15 to 0.67% for parboiled sample and from 0.19 to 0.57% for unparboiled rice sample (Table 8). These values were similar to those reported in some food composition tables (Scherz et al., 2000; USDA, 2004; USP, 2004) and by Juliano (1985).

Table-8: Fat content of selected rice varieties

Variety	Fat content (%)	
	P.B. (Mean ± SE)	U.P.B (Mean ± SE)
BR-3	0.15 ± 0.04	0.24 ± 0.08
BR-11	0.28 ± 0.04	0.19 ± 0.06
BR-16	0.29 ± 0.03	0.22 ± 0.05
BR-26	0.40 ± 0.05	0.39 ± 0.05
BRRI Dhan-28	0.32 ± 0.025	0.27 ± 0.08
BRRI Dhan-29	0.24 ± 0.02	0.31 ± 0.075
BRRI Dhan-30	0.30 ± 0.02	0.33 ± 0.06
BRRI Dhan-40	0.31 ± 0.024	0.57 ± 0.03
PAJAM	0.67 ± 0.03	0.32 ± 0.02
CHINIGURA	-	0.45 ± 0.03

Moisture content affects rice quality in several ways. To gain and maintain the optimum milling quality, rice must be harvested at proper moisture content and should be dried carefully up to 14%. Compositional data for moisture content from the rice samples investigated in this study are shown in Table 9.

Table-9: Moisture content of selected rice varieties

Variety	Moisture content (%)	
	P.B	U.P.B
	Mean ± SE	Mean ± SE
BR-3	12.02 ± 0.62	12.12 ± 0.72
BR-11	11.92 ± 0.52	12.36 ± 0.65
BR-16	11.77 ± 0.74	12.26 ± 0.78
BR-26	11.68 ± 0.98	11.73 ± 0.69
BRRI Dhan-28	11.87 ± 0.76	12.12 ± 0.79
BRRI Dhan-29	11.53 ± 0.98	12.45 ± 0.87
BRRI Dhan-30	10.87 ± 0.76	11.77 ± 0.85
BRRI Dhan-40	10.76 ± 0.65	11.97 ± 0.88
PAJAM	11.03 ± 0.42	11.62 ± 0.63
CHINIGURA	-	11.82 ± 0.75

The results of this study showed that the moisture content of the different rice varieties were low, ranging between 10.76% and 12.02% for parboiled group and between 11.62% and 12.45% for unparboiled group. This range is comparable to that found by Dipti et al (2003) who reported the range of 12.1 to 13.0% for Rice Varieties of Bangladesh. Rice grain from BRRI Dhan-40 variety had the lowest moisture content whilst BR-3 had the highest in the parboiled group. In the unparboiled group BRRI Dhan-29 had the highest (12.45%) followed by BR-11 (12.36%) and Pajam had the lowest (11.62%). The low moisture level may be due to the initial moisture content (<14%) of the paddy of the various rice varieties prior to milling.

Although fiber remains an important constituent of food, it cannot be considered as an essential nutrient. Rice is not a significant source of dietary fiber. The crude fiber content of various tested rice varieties ranged between 0.87% and 0.47% for parboiled group and between 0.88% and 0.34% for unparboiled group. Among the parboiled group, Pajam had the lowest fiber content and that of the BR-11 the highest. Whereas BR-11 had the highest (0.88%) and Chinigura had the lowest (0.34%) fiber content among unparboiled group (Table-10).

Table-10: Dietary Fiber content of selected rice varieties

Variety	Dietary Fiber content (%)	
	P.B.(Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	0.74 ± 0.12	0.71± 0.15
BR-11	0.87 ± 0.09	0.88 ± 0.12
BR-16	0.57 ± 0.15	0.60 ± 0.11
BR-26	0.52 ± 0.12	0.45 ± 0.12
BRRI Dhan-28	0.67 ± 0.13	0.63 ± 0.13
BRRI Dhan-29	0.61 ± 0.08	0.54 ± 0.09
BRRI Dhan-30	0.69 ± 0.12	0.47 ± 0.10
BRRI Dhan-40	0.49 ± 0.07	0.51 ± 0.12
PAJAM	0.47 ± 0.08	0.42 ± 0.09
CHINIGURA	-	0.34 ± 0.12

Processing/ thermal treatments such as cooking, baking, frying, extrusion, etc., that involve formation of nonenzymatic browning (NEB) compounds, have been found to increase the apparent fibre content of foods (Van Soest, 1965). The brown Maillard polymers, being insoluble and indigestible substances with the physical properties of lignin, contribute to the insoluble fiber fraction and, as a result, the TDF (total dietary fiber) values appear higher (Schaller, 1978).

The ash content of rice grain is an important component in determining the quality of the milled rice. This is because the degree of milling of rice grain is determined based on the content of ash and crude fat, degree of whiteness and yield of the polished rice (Hogman & Deobald, 1961). The results of the study showed BRRI Dhan-29 having the highest amount of ash (0.64%) and BR-11, the lowest (0.41%), among parboiled group (Table-11). Similarly, BRRI Dhan-28 contained the highest ash content (0.52%), followed by BR-26 (0.50%), and BR-16 showed the lowest (0.29%) among the unparboiled group. Parboiled rice and unparboiled rice presented similar ash contents ($P>0.05$), indicating that the parboiling did not cause a significant loss of minerals, as had been observed previously by Doesthale et al. (1979).

Table-11: Ash content of selected rice varieties

Variety	Ash content (%)	
	P.B	U.P.B
BR-3	0.45	0.35
BR-11	0.41	0.34
BR-16	0.46	0.29
BR-26	0.57	0.50
BRRI Dhan-28	0.49	0.52
BRRI Dhan-29	0.64	0.43
BRRI Dhan-30	0.59	0.44
BRRI Dhan-40	0.55	0.30
PAJAM	0.58	0.45
CHINIGURA	-	0.45

In comparison with unparboiled group, parboiled rice sample had a trend of higher ash content except BRRI Dhan-28 for which unparboiled sample had a slightly higher ash content over the corresponding parboiled counterpart. This can be said to be the cause of milling as described by Heinemann et al. (2005) who reported that parboiled milled rice had a mean ash reduction of 53.4%, whereas non-parboiled milled samples had ash loss of 61.6%. Therefore, parboiling plus milling resulted in an 18% higher mineral retention than just milling. Similar values were also found in literature as reported by Doesthale et al. (1979).

The ability of phytic acid to complex with minerals is well known and is one of the main nutritional concerns. The mean value of phytic content for parboiled and unparboiled group was found to range between 4.25 to 6.65 mg/g and 4.05 to 6.35 mg/g, respectively (Table-12). The variability of the phytate content of rice was also found in other studies (Toma and Tabekhia, 1979, Graf and Dintzis, 1982, Mameesh and Tomar, 1993).

Table-12: Phytate content of selected rice varieties

Varieties	Phytic acid (mg/g)	
	P.B.(Mean ± SE)	U.P.B.(Mean ± SE)
BR-3	6.65 ± 0.27	6.35 ± 0.15
BR-11	6.65 ± 0.05	6.30 ± 0.20
BR-16	5.35 ± 0.15	5.35 ± 0.15
BR-26	5.46 ± 0.14	5.35 ± 0.05
BRRI Dhan-28	4.25 ± 0.05	4.05 ± 0.05
BRRI Dhan-29	5.5 ± 0.30	5.25 ± 0.25
BRRI Dhan-30	4.68 ± 0.29	4.65 ± 0.20
BRRI Dhan-40	4.55 ± 0.25	4.25 ± 0.15
PAJAM	5.00 ± 0.20	4.95 ± 0.05
CHINIGURA		4.05 ± 0.05

The highest amount of phytic acid content was found in BR-3 (6.65 ± 0.27 mg/g) and BR-11 (6.65 ± 0.05 mg/g) among parboiled samples. They also represent the highest amount between parboiled and unparboiled group whereas BR-3 alone showed the highest content (6.35 ± 0.15 mg/g) in the unparboiled group. Phytic acid reduces the mineral absorption from the gastrointestinal tract. The lowest amount of phytic acid content in the parboiled group was found in BRRI Dhan-28 which was 4.25 ± 0.05 mg/g. In the unparboiled group Chinigura and BRRI Dhan-28 had the lowest content (4.05 ± 0.05mg/g). They also showed the lowest content between parboiled and unparboiled group. Thus these varieties have less impact on mineral absorption.
Parboiled rice samples were found to possess higher amount of amount of phytic acid than the corresponding unparboiled one. The reason may be laid in milling condition of rice grain. Unparboiled rice are relatively soft compared to parboiled one and a significant loss of phytic acid occurs from the outer surface of the unparboiled rice during milling.

Although rice is not a rich source of minerals we measured iron, zinc, calcium and selenium content of selected rice varieties. Iron content varies gently from one variety to another. The maximum concentration of iron was found in Pajam among the parboiled sample and in the unparboiled group BR-3 represented the maximum (Table-13) but BR-3 had a high phytic acid content (6.65 ± 0.27mg/g). Both human and animal systems have been used to study the effect of phytate on iron absorption (Turnbull el al., 1962; Apte and Venkatachalam, 1962, 1964; Sathe & Krishnamurthy, 1953; Davies & Nightingale, 1975).

Table-13: Fe and Zn content of selected rice varieties

Variety	Fe content (mg/g)		Zn content (mg/g)	
	P.B	U.P.B	P.B	U.P.B
BR-3	0.03949	0.04369	0.02163	0.03676
BR-11	0.03139	0.02606	0.02160	0.02579
BR-16	0.02920	0.02032	0.02525	0.02535
BR-26	0.0289	0.0294	0.0236	0.0147
BRRI Dhan-28	0.01702	0.02631	0.02400	0.04249
BRRI Dhan-29	0.02819	0.02594	0.02604	0.03012
BRRI Dhan-30	0.0302	0.0332	0.0357	0.0218
BRRI Dhan-40	0.0297	0.0406	0.0529	0.0614
PAJAM	0.0444	0.0217	0.0703	0.0740
CHINIGURA	-	0.0294	-	0.0705

The zinc content varies greatly from rice to rice (Table-13). This difference may be due to genetic diversity. Pajam showed the highest amount of zinc content among both parboiled and unparboiled group which were 0.0703 and 0.0740 mg/g respectively, this variety had a to acceptably low phytate content (Table-12). Chinigura had a high zinc content but low phytic acid content.

The maximum concentration of calcium was found in BR-3 (0.02269 mg/g) among the parboiled sample (Table -14) but it also has a high phytic acid content. In the unparboiled group, BRRI Dhan-28 (0.03192 mg/g) represented the maximum calcium but it had lowest phytic acid content both in parboiled and unparboied group. On the basis of calcium and phytic acid content, BRRI Dhan-28 can be considered as sustainable variety.

Table-14: Ca and Se content of selected rice varieties

Variety	Ca content (mg/g)		Se content (μg/g)	
	P.B	U.P.B	P.B	U.P.B
BR-3	0.02269	0.02635	0.0158	0.0160
BR-11	0.01260	0.01651	0.0224	0.01497
BR-16	0.01862	0.02424	0.01138	0.01728
BR-26	0.01921	0.02521	0.0221	0.02141
BRRI Dhan-28	0.02184	0.03192	0.01599	0.01291
BRRI Dhan-29	0.01566	0.01767	0.02297	0.02316
BRRI Dhan-30	0.02145	0.02321	0.01921	0.01341
BRRI Dhan-40	0.01892	0.01845	0.01832	0.01681
PAJAM	0.01921	0.01921	0.01962	0.02144
CHINIGURA	-	0.02014	-	0.02451

Selenium is an essential component in the anti-oxidant proteins glutathione peroxidase and thioredoxin reductase enzymes that have selenocysteine within their active site and are selenium-dependent for activity. Rice provides bodies need for selenium. Selenium content of analyzed rice varieties were found to be in the range of 0.01138 to 0.02297 μg/g for parboiled and 0.01291 to 0.02451 μg/g for unparboiled group (Table-14). Selenium concentration of a particular food may be variable and dependent on the geographic origin of the raw agricultural product with regard to the soil in which the agricultural crop was grown (Gupta et al., 2000; Finley et al., 1996). The selenium concentrations of the regular rice in China, except the rice from Enshi County, Hubei Province, were <0.06 μg/g, some being <0.02 μg/g (Licheng chen et al., 2002). Supplementation of fertilizer with selenium is a safe and effective means of increasing the selenium content in different varieties.

Although rice is not a rich source for most of the vitamins specially this is true for milled rice. But parboiled rice is fairly a good source of B complex vitamins. We analyzed only three water soluble vitamins like Thiamine, Riboflavin, and Niacin (Table-15). Thiamine content was from 0.15 to 1.5μg/g in the selected rice varieties, Riboflavin was from 0.12 to 0.61 μg/g and Niacin content was from 5.8 to 18.3 μg/g.

Table-15: Vitamin content of selected rice varieties

Varieties	Thiamine (µg/g)		Riboflavin (µg/g)		Niacin (µg/g)	
	P.B	U.P.B	P.B	U.P.B	P.B	U.P.B
BR-3	trace	0.15	0.17	0.12	6.0	5.8
BR-11	0.55	0.86	0.43	0.36	7.9	8.2
BR-16	0.98	0.88	0.29	0.28	17.5	16.9
BR-26	0.92	0.89	0.31	0.29	16.8	15.6
BRRI Dhan-28	0.95	0.87	0.34	0.27	14.5	12.5
BRRI Dhan-29	0.85	0.75	0.52	0.45	18.3	17.2
BRRI Dhan-30	1.1	1.0	0.61	0.30	17.6	15.6
BRRI Dhan-40	0.85	0.65	0.55	0.45	12.0	10.5
PAJAM	0.98	1.2	0.29	0.25	16.0	16.5
CHINIGURA		1.5		0.18		12.5

Glycemic Index (GI), the blood glucose response of dietary carbohydrate was ranged from 49.87 to 74.2 in parboiled varieties and from 52.3 to 76.3 in unparboiled varieties. Only two varieties (BR-16 and Pajam) are in the low GI group (55 and below), most of the varieties are within medium GI group (56-69). High GI value (70 and above) are BRRI Dhan-29 and Chinigura, also BR-26 and BRRI Dhan-28 are also near high GI value (Table 16).

Table-16: Glycemic Index of selected rice varieties

Variety	Glycemic Index (GI)	
	P.B (Mean ± SE)	U.P.B (Mean ± SE)
BR-3	54.7 ± 10.5	62.4 ± 9.8
BR-11	61.5 ± 8.9	64.8 ± 7.9
BR-16	49.87 ± 9.8	52.3 ± 6.9
BR-26	68.5 ± 10.7	71.4 ± 10.5
BRRI Dhan-28	65.9 ± 12.7	70.5 ± 10.2
BRRI Dhan-29	74.2 ± 12.9	76.3 ± 10.3
BRRI Dhan-30	59.6 ± 10.8	62.4 ± 9.8
BRRI Dhan-40	56.2 ± 9.8	59.5 ± 10.2
PAJAM	54.2 ± 7.9	58.6 ± 9.5
CHINIGURA	-	70.2 ± 9.2

Table-17: Rapidly digestible starch content of selected rice varieties

Variety	Rapidly Digestible Starch (RDS)	
	P.B (Mean ± SE)	U.P.B(Mean ± S.E)
BR-3	7.71±0.56	7.6±0.25
BR-11	8.87±0.23	10.71±0.24
BR-16	9.21±0.35	9.71±0.58
BR-26	11.0±0.6	12.8±0.54
BRRI Dhan-28	9.57±0.21	10.28±0.36
BRRI Dhan-29	11.21±0.54	11.86±0.41
BRRI Dhan-30	11.1±0.23	12.1±0.27
BRRI Dhan-40	9.85±0.54	9.4±0.44
PAJAM	4.23±0.32	6.18±0.45
CHINIGURA	_	12.36±0.61

Pajam showed the lowest RDS content of 4.23%, whereas BRRI Dhan-29 had the highest RDS content of 11.21±0.54 % followed by BRRI Dhan-30 (11.1±0.23%) in the parboiled group. On the other hand, BR-26 showed the highest RDS content of 12.8% followed by Chinigura (12.36±0.61%) and BRRI-Dhan-30 (12.1±0.27%), whereas BR-3 had the lowest RDS content of 7.6% in the unparboiled group (Table 17).

Although BR-16 had highest amylose content and lowest GI value, but in some cases there was no co relation between GI value and amylose content like BRRI-Dhan-29, which has high amylose content but also has high GI value. But when we consider the higher RDS value of BRRI-Dhan-29, then it explains the higher GI value. A significant correlation ($r=0.62$, $p = 0.004$) was found between GI values and RDS content (Figure 1).

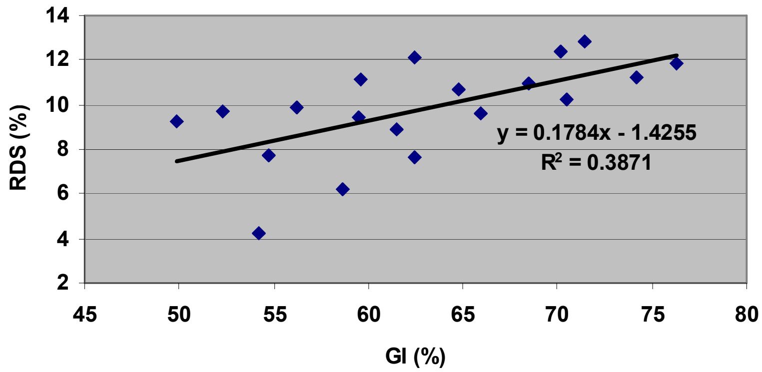

Figure 1: Correlation between Rapidly Digestible Starch (RDS) content and Glycaemic Index (GI) of some selected rice varieties of Bangladesh ($p = 0.004$)

KEY FINDINGS

●Carbohydrate content showed an intervarietal range from 78.03% to 81.18%. the highest amount of carbohydrate was measured in parboiled BRRI Dhan-29 (81.18%) and the lowest amount was found in parboiled BR-26 (78.03%). In the Unparboiled group BR-26 (80.59%) was found to contain highest amount of carbohydrate and BR-11 (78.93%) contained the lowest amount. BRRI DHAN-40 (86.56%) was the most digestible starch in the parboiled group as BR-11 (86.4%) was in the unparboiled group. The lowest starch digestibility was found in BR-26 (74.13%) among the parboiled samples and, among unparboiled samples, it was found in BRRI Dhan-28 (70.2%).

●Protein content ranged from 5.8 to 8.8% for parboiled form and from 5.5 to 7.5% for unparboiled form. For parboiled category the highest and lowest were found in BR-26 (8.8%) and BRRI Dhan-29 (5.8%), respectively. For unparboiled category the highest and lowest protein were found in BR-3 (7.5%) and BRRI Dhan-29 (5.5%), respectively. Both parboiled and unparboiled BR-3 rice showed 98.4% digestibility. The same digestibility was also shown by unparboiled BR-16 rice. The lowest digestibility was found in BR-30 (89.31%) among the parboiled group and in BRRI Dhan-40 among the unparboiled group.

●The fat content of tested rice sample ranged from 0.15 to 0.67% for parboiled sample and from 0.19 to 0.57% for unparboiled rice sample. Pajam contained the highest fat (0.67%) and BR-3 contained the lowest amount (0.15%).

●Amylose content was found to range between 22.8% and 28.9% for parboiled group and between 21.3% and 29.1% for unparboiled group. BR-26 showed the lowest amylose content of 22.8%, whereas BR-16 had the highest amylose content of 28.9% followed by BR-3 (28.5%) in the parboiled group. On the other hand, BRRI Dhan-29 showed the highest amylose content of 29.1% followed by BR-16 (28.9%) and BRRI Dhan-28 (28.9%), whereas Chinigura had the lowest amylose content of 21.4% in the unparboiled group.

●Glycemic Index (GI), the blood glucose response of dietary carbohydrate was ranged from 49.87 to 74.2 in parboiled varieties and from 52.3 to 76.3 in unparboiled varieties. Only two varieties (BR-16 and Pajam) are in the low GI group (55 and below), most of the varieties are within medium GI group (56-69). High GI value (70 and above) are BRRI Dhan-29 and Chinigura, also BR-26 and BRRI Dhan-28 are also near high GI value.

CONCLUSIONS

On the basis of the present study and the data available from the literature, considerable vareital difference was found for carbohydrate, fat, protein, ash, fiber, moisture, amylose content, phytic acid content, mineral content, vitamin content and glycemic index as well as for in vitro digestibility of starch granules and protein. It was also found that parboiling has no significant effect on these parameters of among the tested rice varieties.

POLICY RECOMMENDATIONS

High glycemic load and glycemic index were strongly associated with diabetes mellitus. Many other investigators reported the positive correlation of glycemic index and coronary heart disease (CHD). In Bangladesh, a large number of people are suffering from Diabetes mellitus (a disorder of carbohydrate metabolism). Diabetes mellitus (DM) is a metabolic disorder characterized by chronic hyperglycemia, resulting from defects in insulin secretion, insulin action or both. The disease is associated with significant increased risk of long-term microvascular and macrovascular complications. Currently DM has reached epidemic proportions, affecting more than 170 million individuals worldwide, with an estimated increase of at least 50 percent by 2010, especially in developing countries. Majority of the diabetic populations in Bangladesh are not properly managed. Most of them are beyond the proper medical care. Those who get the medical care, cannot follow the prescribed diet chart due to poverty. Due to their food habit, they consume a significant amount (460g a day) of rice (normally they take food three times a day).

Simply reducing the carbohydrate intake does not improve the glycemic control of diabetic patients. Reducing glycemic responses by reducing carbohydrate intake increases postprandial serum free-fatty acids (FFA) and does not improve overall glycemic control in diabetic subjects. By contrast, low-GI diets reduce serum FFA and improve glycemic control. Thus, current evidence supports FAO/WHO recommendations to maintain a high-carbohydrate diet and choose low-GI starchy foods.

From the findings of the present study it was found that although BRRI Dhan-29 is a very popular variety and it covers a major part of total cultivation, it is a poor variety from nutritional point of view. BR-16 was found having lowest glycemic index which is very important finding of our study. Considering all aspects, Pajam was found similar in some cases superior to the other BRRI developed varieties. So during development of new varieties, we recommend to use the rice germplasm cultivars of higher nutritional quality. If the yield does not vary significantly, compared to BR-16, we recommend to discourage farmers to cultivate BRRI Dhan- 29.

AREAS FOR FURTHER RESEARCH

1) Determination of RDS and SDS to explain the GI value.
2) Determination of factors responsible for person to person variation of GI value for a single variety.
3) Screening for rice germplasm cultivars for high nutritional value and low GI value, which will be used for development of new variety.

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