Original Article:

Most of the popular rice varieties in Bangladesh are of medium glycemic index (GI)

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Abstract:

Objective: Carbohydrate rich food is the most widely consumed nutrient globally, but when consumed in excess it can have undesirable effects on health. Glycemic index (GI) could be a degree of the impacts of carbohydrates on blood glucose levels. ***Materials and methods:*** We selected eight Bangladesh Rice Research Institute (BRRI) developed varieties and two local varieties. ***Results and Discussion:*** The highest amount of carbohydrate was measured in BRRI Dhan-29 variety (81.18%), and the lowest amount was found in BR-26 (78.03%). The highest starch digestibility was found in BRRI Dhan-40 (86.56%), and the lowest starch digestibility was found in BRRI Dhan-28 (70.20%).GI ranged from 49.87 to 74.20 in parboiled varieties. Only two varieties (BR-16 and Pajam) are in the low GI group (55 and below), with most of the varieties are within medium GI group (56-69) (BR-11, BR-26, BRRIDhan-28, BRRIDhan-30 and BRRIDhan-40). High GI value (70 and above) are BRRI Dhan-29 and Chinigura. Although BR-16 had the highest amylose content and lowest GI value, however, in some cases, for example, BRRI-Dhan-29 has high amylose content as well as a high GI value. There was no significant correlation between GI and amylose content. However, when the elevated rapidly digestible starch value of BRRI Dhan-29 is being considered, at that point, it clarifies the higher GI value. A noteworthy relationship ($r=0.62$, $p< 0.01$) was found between GI values and RDS content. ***Conclusion:*** Low GI rice with good nutritional composition may encourage farmers as well as consumers for their high demand and economic benefit.

Keywords: Rice, Amylose, Rapidly digestible starch, Starch digestibility, Glycemic Index.

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Introduction

Majority of the world population depend on rice as their staple food and it is cultivated in more than 100 countries. Bangladesh and other countries including China, India, Indonesia, Thailand, and Vietnam yield approximately 80 percent of the world's rice[1]. Bangladesh is geographically challenged because of its utmost populace density, where the mainstream of rice growing regions are rain encouraged and flood prone[2]. Rice growing accounts for 95 percent of the food grain production in Bangladesh[3]. Though it is the most extensively consumed nutrient globally, but if consumed in excess it has an adverse effect on the health of individuals. Carbohydrate has an aptitude to increase blood glucose beyond the normal range (3.9 and 7.1 mmol/L, tested while fasting and who are not fasting should be below 6.9 mmol/L)[4]. Therefore, it is important to know more about the capacity of carbohydrate rich foods increase glucose levels.

GI can be defined as a degree of the effects of carbohydrates on blood glucose levels[5]. The GI comprise a scale from 1 to 100, specifying the rate at which 50 grams of carbohydrate in a certain food is retained into the circulatory

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system as blood-sugar. Glucose is considered as the main reference point which is marked 100. Carbohydrate rich foods can be classified into three based on glycemic index. These are: High Glycemic Index Foods (GI 70+) that induce a rapid rise in blood glucose levels. Intermediate Glycemic Index Foods (GI 56-69) that cause an average augmentation in blood glucose. Low Glycemic Index Foods (GI 55 or less), that trigger a slower rise in blood-glucose[6].

Bangladeshi people consume a large amount of rice daily (367 g per day) according to a preliminary report of the Household Income and Expenditure Survey (HIES), 2016[7].This high intake of CHO may increase their risk of high blood glucose and put pressure on the pancreas to release the high amount of insulin. In Bangladesh, a large number of people (10% of the population) are suffering from Diabetes Mellitus (DM), a disorder of carbohydrate metabolism[8]. This disease is associated with significantly increased risk of long-term microvascular and macrovascular complications[9]. Currently DM has come to scourge extents, influencing 422 million individuals worldwide[10]. The majority of the diabetic populations in Bangladesh do not receive adequate clinical care. Those who receive medical care have challenges to follow prescribed diet charts that can be attributed to poverty. However, rice remains accessible to most, so if low GI rice varieties are identified it will be beneficiary for carbohydrate and lipid metabolism and can improve glucose tolerance in diabetic patients. Furthermore, obesity is an increasing issue globally and strongly associated with high glycemic index food. Identification of low GI rice varieties with great nutritional composition may empower cultivators to support production of these types, while consumers will utilize these for their health benefits. Both actions will provide an ongoing economic and health benefit for the Bangladeshi people.

The study was designed to identify the glycemic indices for popular rice varieties in Bangladesh. It will also have an immense effect on the efficiencies of our individuals. Rice with low GI and great nutritional value may in cite growers as well as consumers for their large demand and financial welfare.

Methods

Sample Collection and preparation

Bangladesh Rice Research Institute (BRRI) given ten varieties of rice paddy collected on diverse events from their distinctive stations found at diverse parts of the nation. These varieties were BR-3, BR-11, BR-16, BR-26, BRRI Dhan-28, BRRI Dhan-29, BRRI Dhan-30, BRRI Dhan-40 and two local varieties (Pajam and Chinigura). Each variety was accumulated at three individual time points. Collected paddies were run through a process of parboiling. After evacuating the husk of the paddy by employing a blender, paddy was changed over to rice. To carry out diverse physical and biochemical investigation collected rice grains are utilized as a raw sample. Individual samples were analysed in triplicate for all parameters.

Physical analysis

Determination of Milling Yield and L/B ratio:[11] 200g of brown rice was processed with a Satake grain testing mill utilizing the 36 mesh abrasive cylinder for 1 minute at 800 rpm to get 10% milling. Length and breadth were measured using a slide callipers and L/B ratio was determined by dividing length with breadth (Supplementary Table 1).

Biochemical analysis

Determination of basic nutrients: Rice protein content was measured by Microkjeldahl Method[12]. Briefly, 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[12]. The total fat content was measured according to methods from Choudhury and Juliano[13]. Dried powdered rice sample was taken in a round joint flask and fat extracted with n-hexane. 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[12]. The moisture and ash content were measured according to the method developed by Yang etal, Madamba et al and Anonymous[14-16].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.

Determination of amylose content and In vitro digestibility of starch of rice: Treating with dilute alkali causes released of Amylose from rice. Tri-iodide ion reacts with amylose and amylose turns into blue color which is then measured spectrophotometrically at 600nm as defined by Be Miller, (1964)[17]. In vitro digestibility of starch

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

Table-2: Gelatinization temperature of selected rice varieties:

Rice varieties	Gelatinization Temperature (°C)
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

from rice samples were determined using the α-amylase[18].

Determination of Gelatinization Temperature of Starch Granules (alkaline spreading method): Gelatinization temperature of starch granule was identified according to the protocol described byBhattacharya[19]. 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 intermediate gelatinization temperature (70-74ºC); and a rating of 6 to 7 corresponds to gelatinization temperature below 70ºC.

Determination of Glycemic Index (GI):[20] To determine the GI of selected rice varieties, we recruited 15 healthy volunteers (healthy, male subjects) aged from 25 to 32 years (BMI= 20.5-23.5kg/m^2). The study was approved by the Human Ethical Review Committee of Faculty of Biological Sciences, Dhaka University prior to the study. Written consents were taken from study subjects. Rice of 50 g carbohydrate equivalent was fed to each volunteer after overnight fasting and blood was collected (venous blood) at fasting, 30, 60 and 120 minutes after eating of rice (as test food) and glucose (as standard). Blood glucose was measured immediately. Glucose (as standard) 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): By the action of enzymes α-amylase and amyloglucosidase free glucose is produced from rice and this is then measured by the Glucose oxidase reagent kit. Light pink colour is formed and the absorbance is taken at 510 nm[21].

Statistical analysis

Data for all were expressed as mean ± SEM. Statistical Package of Social Science (SPSS), version 17 and Graph pad Prism version-5 were utilized to analyse the data. The differences between two groups were established by unpaired t-test. Pearson correlation was carried out to identify any correlation between RDS and GI. *P* values less than 0.05 were set as the level of statistical significance.

Results

Table 1 shows the characteristics of grain quality. The grain quality in rice depends on grain size, shape and appearance, and higher milling recovery. 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. Long or medium-long and slender translucent grains are popular to most consumers. A similar and higher milling yield of greater than 69.0% were found in all varieties in this study. BR-11 and BRRIDhan-30 hadthe highest milling yields (72.3%).

The result indicated that gelatinization temperature range for BR-3, BR-11, BRRI Dhan-28, BRRI Dhan-30, BRRI Dhan-40, Pajam and Chinigura

Table-3: Amylose, In Vitro digestibility of starch, Carbohydrate content of the selected rice varieties:

Rice Varieties	Amylose content (%)	In Vitro digestibility of starch (%)	Carbohydrate content (%)
BR-3	28.5 ± 0.95	83.4 ± 2.8	79.14 ± 1.07
BR-11	27.4 ± 0.82	84.03 ± 2.98	78.22 ± 0.98
BR-16	28.9 ± 0.95	77.2 ± 3.15	80.41 ± 0.78
BR-26	22.8 ± 1.0	74.13 ± 3.07	78.03 ± 0.69
BRRI Dhan-28	27.6 ± 0.87	74.3 ± 2.8	79.85 ± 0.87
BRRI Dhan-29	27.4 ± 0.92	83.4 ± 3.8	81.18 ± 0.88
BRRI Dhan-30	27.8 ± 0.89	82.2 ± 3.4	80.25 ± 0.92
BRRI Dhan-40	27.8 ± 0.96	86.56 ± 2.9	80.49 ± 1.02
PAJAM	25.6 ± 0.87	83.45 ± 2.75	78.75 ± 0.54
CHINIGURA	21.6± 0.67	76.4 ± 2.4	80.79 ± 0.92

Data are presented as mean ± SEM (standard error of mean) of three readings.

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 2). The amylose content of the milled rice from different cultivars was between 21.6% and 28.9% (Table 3). The starch digestibility of rice is influenced overall by the degree of gelatinization during cooking, the granule molecule estimate, the amylose/amylopectin proportion, starch protein interaction, amylose/lipid complexes and the level of resistant starch. We found high starch digestibility (>70.4%) for all tested varieties.

The highest starch digestibility was found in BRRI Dhan-40 (86.56%). The lowest starch digestibility was found in BR -26 (74.13%). Starch is the inevitable constituent of rice grain and occupies most of the 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%. The highest amount of carbohydrate was measured in BRRI Dhan-29 (81.18%) and the lowest amount was found in BR-26 (78.03%) (see Table 3).

Glycemic Index (GI), the blood glucose response of dietary carbohydrate ranged from 49.87 (BR-16) to 74.2 (BRRI Dhan-29) in tested varieties. Only two varieties (BR-16 and Pajam) are in the low GI group (55 and below), and the majority of the varieties are within medium GI group (56-69) (list them all). High GI value (70 and above) varieties are BRRI Dhan-29 and Chinigura (Table 4). 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%).

There was no significant correlation between GI value and amylose content ($p>0.05$). For example, although BR-16 had highest amylose content and lowest GI value, BRRI-Dhan-29, has high amylose content but also has high GI value. However, when we consider the higher RDS value of BRRI-Dhan-29, then it explains the higher GI value. A significant correlation ($r=0.62$, $p < 0.01$) was found between GI values and RDS content (Figure 1).

Discussion

Rice (Oryza sativa L.) is one of the driving nourishment crops of the world and is a staple food of over roughly one-half of the world populace and grows in more than 100 countries. The rice is grown under an assortment of climatic conditions. In Bangladesh, rice accounts for 95% of the food grain production. Rice possesses over 75% of the entire cropped area of the country. In this study, BRRI varieties were examined since most of the varieties developed by BRRI are being broadly cultivated that produce high yields (3.0-6.5 ton/hector) as well as to meet requirement for cattle feed and roofing materials for farming communities. These varieties have brief development term and fine grain. All the BRRI varieties are appropriate for development under favorable rice developing biological systems in Bangladesh.

The grain size and shape of most advanced rice varieties is short to medium bold with translucent appearance[22]. Chinigura is prevalent for its attractive smell in spite of the fact that it is of a short bold type. Inclination for grain size and shape vary from one group of consumers to another[23]. High income groups in Bangladesh prefer long slender grain, whereas, lower income group prefer a bold grain type[16]. While consumers consider the appearance, aroma and taste qualities of rice grain[24], the rice millers incline varieties with high milling yield. Milling yield and its financial implications are one of the vital properties to

Table-4: Glycemic Index and Rapidly digestible starch content of selected rice varieties:

Rice Varieties	Glycemic Index (GI)	Rapidly Digestible Starch (RDS)
BR-3	54.7 ± 10.5	7.71±0.56
BR-11	61.5 ± 8.9	8.87±0.23
BR-16	49.87 ± 9.8	9.21±0.35
BR-26	68.5 ± 10.7	11.0±0.6
BRRI Dhan-28	65.9 ± 12.7	9.57±0.21
BRRI Dhan-29	74.2 ± 12.9	11.21±0.54
BRRI Dhan-30	59.6 ± 10.8	11.1±0.23
BRRI Dhan-40	56.2 ± 9.8	9.85±0.54
PAJAM	54.2 ± 7.9	4.23±0.32
CHINIGURA	70.2 ± 9.2	11.86±0.41

Glycemic Index (GI) data are presented as mean **± SEM** (n=15). RDS data are presented as mean ± SEM of three readings.

the mill operators. Milling yield is the measure of rough rice performance during milling. The milling yield of modern rice varieties ranges from 69-73% [22] with a milling yield <67% not acceptable to millers. All the tested varieties in this study gave similar high milling yields of greater than 69.0% (Table 1). Highest milling yields (72.3%) were found in BR-11 and BRRIdhan -30 and are considered to be more acceptable to rice millers.

To a great extent, the amylose content and gelatinization temperature (GT) decide the cooking quality. The amylose content of rice is considered as the main parameter of cooking and eating qualities[25]. Intermediate amylose rice varieties are favored in most rice developing areas of the world, except where low amylose Japonicas are grown in the northeast plain and Yangtze River region.

The results of this study showed that amylose content of the milled rice from different cultivars were between 22.8% and 28.9%. This range is different from the range obtained by Sodhi, & Singh (2003)[26] who have reported an amylose content range of 5.5–11.7% for milled rice from different cultivars. The tested varieties are said to contain high amylose. The modern rice varieties of BRRI were found to have high amylose[22] and our findings corroborate these results. In this study, considerable inter varietal differences were found for amylose content. This difference is attributed to genetic 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[27]. This polymorphism has been observed to be temperature dependent[28].

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 GT (which lowers grain quality) and low air temperature reduces it[29]. 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 gelatinization 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.

Starch digestibility is one of the major qualities of carbohydrate foods to contribute to the GI. The highest starch digestibility was found in BRRI Dhan-40 (86.56%) and the lowest starch digestibility was found in BRRI Dhan-28 (70.2%). The marked improvement of starch digestibility in rice may be attributed to the gelatinization of starch granules, characterized 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[30]. Amylose content, volume expansion, water absorption influences many of the starch properties of rice. Starch is the inevitable constituent of rice grain and occupies most of the 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%.

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

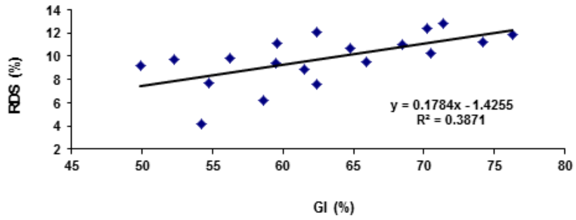

Figure 1: Correlation between Rapidly Digestible Starch (RDS) content and Glycaemic Index (GI) of some selected rice varieties of Bangladesh (p = 0.004)

overall glycemic control in diabetic subjects. By contrast, low-GI diets reduce serum free fatty acids (FFA) and improve glycemic control. Thus, current evidence supports (Food and Agriculture Organization of the United Nations /World Health Organization (FAO/WHO)recommendations for those who maintain a high-carbohydrate diet they should try to choose low-GI starchy foods[31]. Individual countries should have their own GI testing, particularly of raw agricultural products, which are more likely to vary from one geographical location to another compared to processed products.

Conclusion

This study revealed that in spite of the fact that BRRI Dhan-29 is an exceptionally well-known variety in Bangladesh due to its high yield, and it covers a major portion of total cultivation, it is nutritionally poor variety. Importantly, BR-16 was found to have the lowest glycemic index in our study. Considering all aspects (nutritionally and agriculturally), Pajam was found comparative in few cases predominant to the other BRRI established varieties. During development of new varieties, we have to consider the higher nutritional quality, low glycemic index with high yields.

Supplementary Table 1. Scale for length and breadth (L/B) ratio.

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

Conflict of interest: The authors declare no conflict of interest.

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