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Full Length Research paper

Glycemic index of three common varieties of Bangladeshi rice in healthy subjects

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Rice is a major staple food in Asian countries and it is a rich source of carbohydrate. Since Glycemic Index (GI), Glycemic Load (GL) and Insulinemic Index (II) (three important measures of clinical concern in the management and prevention of diabetes and metabolic syndrome) vary from population to population, we have measured these parameters in healthy Bangladeshi subjects with 3 commonly consumed rice (BR-14, BR-29 and BR-44). Participants consisted of ten healthy subjects (male 5, female 5, age 28.6 years, BMI 22.5) were studied under a cross-over design. The test meals contained 50 g of total carbohydrate and were given to the participants for ingestion within 10 min with 200 ml water. Serum levels of glucose were estimated at 0, 30, 60, 90 and 120 min respectively. Serum glucose was measured by glucose-oxidase and C-peptide was used as the marker of insulin and was measured by chemiluminescent ELISA method. Classification of GI was taken from the international table (GI: High ≥ 70, Medium 56 - 69 and low ≤ 55; GL: High ≥ 20, Medium 11 - 19 and low ≤ 10). All the varieties of rice showed significantly lower serum glucose response compared to that of the reference food (that is, Glucose) [iAUC (M ± SD): 316.4 ± 151.6 in Glucose vs 154.8 ± 51.8 in BR-14, 155.6 ± 78.3 in BR-29 and 109.4 ± 59.3 in BR-44; $p < 0.05$ and 0.015 respectively]. The GI of BR-14, BR-29 and BR-44 were 54.5 ± 16.1, 50.3 ± 19.3 and 43.1 ± 38.4 respectively. The basal values of serum c-peptide among the 4 groups did not differ with each other. The postprandial serum c-peptide value of BR-14, BR-29 and BR-44 were significantly lower at all time points [120 min; (4.3 ± 1.4), (4.3 ± 1.0) and (4.2 ± 1.3); $p < 0.015$ and 0.001 respectively] compared to the reference food (6.2 ± 1.1).The GL of BR-14, BR-29 and BR-44 were 25, 22 and 20 respectively. Bangladeshi BR-14, BR-29 and BR-44 rice varieties have low GI. This property is not due to their insulin secretion and their content of dietary fibers, but it may relate to their amylase contents. Higher serving size, however, may turn these varieties into high GL rice and health providers should make people aware of this fact.

Key words: Glycemic index, glycemic load, BR-14, BR-29, BR-44, Bangladesh, obesity, type II diabetes.

INTRODUCTION

The glycemic index (GI) is an indicator of the blood glucose raising potential of carbohydrate containing foods. Lower GI foods are considered to confer benefit as a result of the relatively low glycemic response following ingestion. Since the GI is determined for a particular quantity of carbohydrate in the food being tested and since the actual amount of carbohydrates consumed in a meal or snack varies greatly, the GI concept has been expanded to include the concept of glycemic load (GL). The GL is determined by multiplying the GI of a food by the grams of carbohydrates in a serving.

The GI has been recommended to develop a guide for major carbohydrate food choices (FAO/WHO, 1998) because it has been reported that a high GI diet may have adverse health consequences by increasing the risk for chronic diseases (Augustin et al., 2002; Ludwig et al.,

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Abbreviation: GI, Glycemic index; **GL,** glycemic load; **iAUC,** incremental area under the curve; **BMI,** body mass index; **Giwb,** glycemic index of white bread; **AICP,** absolute incremental changes of C-peptide; **Mmol,** millimole; **Ng**, nanogram.

Table 1. Clinical and socioeconomic characteristics of study subjects (n = 10).

Parameter	Values
Age (years, M ± SD)	28.6 ± 5.7
BMI (M ± SD)	22.5 ± 2.5
Male: Female	1:1
Waist: Hip	0.86 ± 0.5

2002). Recent evidence suggests that high GI/GL diets may increase the risk for cardiovascular diseases (Liu et al., 2000; Amano et al., 2004) and type 2 diabetes (Salmeron et al., 1997a; Salmeron et al.,1997b; Hodge et al., 2004; Schulze et al., 2004). A high GI diet may increase the risk for chronic disease through the stimulation of hyperglycemia and hyperinsulinemia (Ludwig et al., 2002). In contrast, a low GI diet has been reported to have health benefits (Augustin et al., 2002; Ludwig et al., 2002; Colombani, 2004; Opperman et al., 2004). Epidemiological data indicate that a low GI diet has a protective role against development of type II diabetes (Salmeron *et* al., 1997a; Salmeron et al.,1997b), coronary heart disease (Liu et al., 2000; Jenkins et al., 2002), and the metabolic syndrome.

Being one of the world's most important carbohydrate sources, the glycemic response to rice has been investigated in numerous test meal studies. These studies have shown large variations in the GI of rice, ranging from GI_{wb} 54 to 133 (Jenkins et al., 1981) and, consequently, these findings have lead to large disagreements as to whether rice should be considered a high or low GI food. It is now increasingly accepted that the large differences in the glycemic response to rice are in part due to variations in the physio-chemical properties of rice varieties as well as in the processing. It also seems to depend on the adaptation of the gut to specific food types in different populations (Larsen et al., 2000). Much of the variations in the GI of rice are due to differences in the proportion of starch present as amylose, that is: amylopectin ratio. Most rice contain 20% amylose but varieties that contain a higher proportion of amylose (example, 28%) have been shown to have a slower rate of digestion and produce lower glycemic and insulin responses (Luliano et al., 1986).

In addition to GI the amount of insulin secreted in response to food is also centrally important in the management of diabetes and cardiovascular diseases. Since insulin is known to be atherogenic a low GI at the expense of hyperinsulinemia may not be useful. Thus, a ranking of food based on their insulin secretory capacity along with the glycemic response is necessary. Generally, improved glycemic control will increase insulin sensitivity and decrease hyperinsulinemia which might be of major clinical significance in type 2 diabetic population.

The objective of the present study was to determine the blood glucose and insulin response after consumption of three types of Bangladeshi rice commercially available and the GI value of each type of rice in healthy Bangladeshi respondents.

MATERIALS AND METHODS

Subjects

Ten healthy volunteers with normal glucose tolerance test were part of the present study. The male-female ratio was 1:1 and their mean age (years) and body mass index (BMI) were 28.6 ± 5.7 and 22.5 ± 2.5, respectively (Table 1). The subjects were not on any medication. They were requested to maintain their usual daily food intake and activity schedule throughout the study period.

Tested foods

Three rice varieties included in the study were BR 14, BR 29 and BR 44. Pure glucose was given as the reference food. All the rice varieties were professionally prepared (by Bangladesh Rice Research Institute) followed by the standard quality, the portions were packed and marked with a set sign. Both test rice and reference food consisted of 50 g available carbohydrates. To get 50 g available carbohydrate raw weight of rice varieties were 65.93, 67.40 and 65.58 g and cooked weight of rice were 0.18, 0.15 and 0.175 kg for BR 14, BR 29 and BR 44 respectively.

First we weighed the rice, washed twice with enough water and boiled with sufficient water until it got to appropriate softness. After boiling, the water was drained and samples were then transfered into a plate. The test meal was then served at room temperature.

Study design

Subjects were required to go through the study protocol on five separate occasions (one trial for test food and two repeated trial for the reference food) in the morning after a 10 – 12 h overnight fasting. The test with the reference food was repeated to obtain at least two values, in each subject, thus the precision was improved (Brouns et al., 2005). Test and reference meals were given to the subjects under a cross-over design with a wash out period of 7 days to avoid the 'second meal effect' (Wolever et al., 1988). Patients were advised to rely on recommended standard carbohydrate diet and also instructed not to eat legumes in the meal preceding the fast.

An intravenous cannula was inserted into a superficial vein in the forearm on the day of experiment, drawing the fasting (0 hr) blood sample of the patient, after that subjects were requested to consume the test rice with 250 ml plain water (for the protocol of the test rice) or the glucose in 250 ml water (for the protocol of the reference food) in random order at a comfortable place within 10 min. Further blood samples were taken at 30, 60, 90 and 120 min after the initial intake of sample. Whole blood samples were obtained by an intravenous cannula which was inserted into a superficial vein in the forearm. Blood sample was allowed to centrifuge at 3000 rpm for 15 min. Separated serum was allocated in the labeled Eppendrof tubes and preserved at –70°C before biochemical analysis.

Laboratory method

Serum glucose was estimated by glucose-oxidase (GOD-PAD) method using reagents from SERA PAK, USA (Trinder, 1969), Insulin (measured by c-peptide as a marker of insulin) was

Table 2. Nutrient composition and cooking properties of the Test Meals (g per 100 g)

Test rice	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)	Carbohydrate (%)		Cooking time (min)	Elongation ration	Volume expansion ratio
							Amylose (%)			
BR-14	12.77	1.22	7.5	1.97	1.0	75.83	27	18	1.4	3.6
BR-29	13.45	1.07	7.0	2.35	1.1	74.11	29.4	18.5	1.4	4.4
BR-44	11.2	1.01	8.8	1.75	1.0	76.24	27.2	22	1.5	4.4

Source: Bangladesh Rice Research Institute (BRRI).

Table 3. Serum glucose responses of the subjects (n=10) at different time point after consuming the test foods.

Test foods	Serum glucose (mmol/l)					iAUC (mmol/l)	GI	GL
	0 min	30 min	60 min	90 min	120 min			
Glucose	5.2 ± 0.4 (100)	8.2 ± 1 .6 (157 ± 29)	9.3 ± 2.0 (178 ±36)	8.1 ± 2.4 (156 ± 42)	6.3 ± 1.5 (120 ± 28)	316.4 ± 151.6		
BR-14	5.1 ± 0.5 (100)	7.1 ± 0.6 (140 ± 14)	7.0 ± 1.3 (138 ±16) a**	5.9 ± 0.9 (117 ± 11) a*	5.7 ± 0.4 (114 ± 7)	154.8 ± 51.8 a**	54.5 ± 16.1	25
BR-29	5.0 ± 0.5 (100)	6.9 ± 1.5 (139 ± 29)	6.5 ± 1.2 (130 ±19) a**	5.9 ± 0.9 (117 ±13) a*	5.6 ± 0.5 (111 ± 8)	155.6 ± 78.3 a**	50.3 ± 19.3	22
BR-44	5.4 ± 0.5 (100)	7.5 ± 0.9 (140 ±14)	6.2 ± 1.5 (114 ± 22) a***	5.7 ±1.2 (107 ± 21) a**	5.6 ± 0.3 (105 ± 8)	109.4 ± 59.3 a**	43.1 ± 38.4	20

Results expressed as mean ± SD; *p < 0.05 and **p < 0.01 was taken as the level of significance in paired students t-test; a, Glucose; b, BR-14; c, BR-29; d, BR-44. BR-14, BR-29 and BR-44 has 75.83/100 g, 74.11/1000 g and 76.24/100 g of carbohydrate respectively. To calculate GL serving size was 60 g/serve (rice); n, Number of subjects; iAUC, Increment area under the curve.

determined by ELISA method using kits from DRG Diagnostics (Germany).

Ethical consideration

The protocol was approved by the Ethical Review Committee of the Diabetic Association of Bangladesh.

Statistical analysis

All analysis were done using the Statistical Package for Social Science (SPSS) software for Windows. The incremental areas under the curve (iAUC) was calculated by the standardized criteria (Wolever et al., 1991), ignoring any area below the baseline. The average iAUC for the two glucose tests was used as the reference value and each subject's individual GI for each food was calculated. Significance between Mean values of GI were calculated using paired t-test. All parametric variables were expressed as M ± SD and non-proportional data were expressed in percentages. P < 0.05 and p < 0.001 was considered as statistically significant.

RESULTS

Characteristics of the subjects

Table 1 shows the characteristics of the participants. Participants consisting of ten healthy subjects (male 5, female 5; age 28.6 ± 5.7 years, mean ± SD). The mean BMI of the study subjects were ± SD, 22.5 ± 2.5 while the mean waist-hip ratio was found to be 0.86 ±0.5 (Table 1).

Glycemic response to the food items

The nutrient composition and the cooking properties of the test foods are shown in Table 2. All the varieties of rice showed significantly lower serum glucose response compared to that of glucose [iAUC (M ± SD): 316.4 ± 151.6 in glucose vs 154.8 ± 51.8 in BR-14, 155.6 ± 78.3 in BR-29 and 109.4 ± 59.3 in BR-44; p < 0.05 and 0.015 respectively]. The GI (M ± SD) of BR-14 was 54.5 ± 16.1, BR-29 50.3 ± 19.3 and that of BR-44 was 43.1 ± 38.4. The GL of BR-14, BR-29 and BR-44 were 25, 22 and 20 respectively (Table 3).

C-peptide response of the food items

The basal values of serum c-peptide among the 4 groups did not differ with each other. The postprandial serum c-peptide value of BR-14, BR-29 and BR-44 were significantly lower at all time points [120 min; (4.3 ± 1.4),

Table 4. Fasting and postprandial serum C-peptide responses of the study subjects (n =10) after ingestion of test meals.

Test foods	Serum C-peptide (ng/ml)		AICP (ng/ml)	C-peptide: Glucose ratio	
	0 min	120 min		0 min	120 min
Glucose	2.8 ± 0.7	6.2 ± 1.1	3.4 ± 1.3	0.53 ± 0.12	1.02 ± 0.21
BR-14	2.5 ± 0.7	4.3 ± 1.4 a**	1.7 ± 1.0 a**	0.51±0.17	0.74 ± 0.23 a**
BR-29	2.5 ±0.4	4.3 ±1.0 a***	1.7 ±1.0 a**	0.51 ± 0.10	0.77 ± 0.18 a**
BR-44	3.2 ±1.5	4.2 ±1.3 a***	1.0 ±0.9 a***	0.59 ± 0.27	0.74 ± 0.20 a**

Results expressed as mean ± SD; *p < 0.05 and **p < 0.01 was taken as the level of significance in paired students t-test and nonparametric (Mann-Whitney) test were performed where appropriate to calculate statistical difference between groups. a, Glucose; b, BR-14; c, BR-29; d, BR-44. AICP, Absolute incremental changes of C-peptide over basal values.

(4.3 ± 1.0) and (4.2 ± 1.3); p < 0.015 and 0.001 respectively] compared to reference food (6.2 ± 1.1). This was also supported by the 120 min C-peptide: glucose ratio (Table 4). Homa%B and Homa%S were calculated and no significant difference has observed among the groups (table not shown).

DISCUSSION

All the three types of rice tested in the present study (BR-14, BR-29 and BR-44) were found to have low GI. Some studies on Bangladeshi rice varieties have also shown low GI, but the population and the processing procedures were different (Larsen et al., 2000; Larsen et al., 1996). Wide differences in digestibility and GI values of rice products have been ascribed to various factors. These include the fiber content (Augustin et al., 2002), the botanical source (Brand-Miller et al., 1992), food processing (Sagum and Arcot, 2000) and physiochemical properties particularly gelatinization characteristics (Panlasigui et al., 1991), particle size (Holt and Miller, 1994), amylase to amylopectin ratio and the presence of lipid-amylose complexes (Hu et al., 2004).

High fiber is believed to reduce the blood glucose response and hence lower the GI of the rice. However, all the three types of low GI rice contained only 1 to 1.2 g fiber per 100 g of rice (Vosloo, 2005); thus, the present values of GIs seem to be independent to the fibre content.

Many studies have shown that the classification of rice as low or high GI food may depend on the amylose content of the commercial varieties (Iuliano et al., 1986). In general most of the rice contains about 20% of amylose and 80% of amylopectin (Brand-Miller et al., 1992). Rice with high amylose fraction of about 28% (such as Basmati and Doongara brown rice) have been shown to produce a lower blood glucose and insulin response (Brand-Miller et al., 1992). The present findings confirm to these results. The amylose content of the three tested rice samples (BR-14, BR-29 and BR-44) were 27, 29.4 and 27.2% respectively and they could be categorized as having low GI values.

The glycemic load (GL) values were also calculated. It expresses the glycemic effect of realistic serving sizes of different foods. The GL can be defined as the product of the glycemic index (GI) of a food and the amount of carbohydrate in a serving (Foster-Powell et al., 2002). Based on the serving size in the Bangladeshi society, the present rice varieties can be considered as high GL food and this should be taken into consideration by the physicians and nutritionists while giving dietary advice. In Bangladesh the dietary practice of the population is to take rice with other dishes like vegetables and pulses etc. GL is dependent upon the amount of the serving size, so the reduced amount of serving size of this rice and the increased amount of vegetables or other low carbohydrate dishes can balance our overall glycemic load of the complete diet as well as it can fill the meal satiety.

Insulin is the central hormone in maintaining blood glucose homeostasis and it has a life saving role. Since c-peptide is secreted in equimolar concentration with insulin and since it has a much higher half-life than insulin, it was used as a marker for the insulin response of the subjects. Higher level of insulin in blood (hyperinsulinemia) has been shown to be associated with increased atherosclerosis leading to cardiovascular disorders (Kaplan et al., 1996). In this context, effect of rice on serum insulin has important implications. In this study the three rice products did not affect insulin secretion in a disproportionate way and, thus, the beneficial GI values of BR-14, BR-29 and BR-29 does not seem to be consequence of hyperinsulinemia.

In conclusion, Bangladeshi BR-14, BR-29 and BR-44 rice varieties have low GI. This property is not due to their insulin secretion and their content of dietary fibers, but it may relate to their amylase contents. Higher serving size, however, may turn these varieties into high GL rice and health providers should make people aware of this fact.

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