International Research Journal of Pure & Applied Chemistry

21(24): 137-146, 2020; Article no.IRJPAC.64441
ISSN: 2231-3443, NLM ID: 101647669

Glycemic Index of Selected Indian Rice Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Author MMA conceived and wrote the MS. Author AJ carried out the experiments and collected data. Author KUM supervised the works. Author TR edited the manuscript. Author AW carried out statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i2430343
Editor(s):
(1) Dr. Hao-Yang Wang, Shanghai Institute of Organic Chemistry, China.
Reviewers:
(1) Madhumitha. K, SASTRA University, India.
(2) Sri Nur Aminah Ngatimin, Hasanuddin University, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64441

Original Research Article

Received 25 October 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

Aims: For prevention and management of type II diabetes among rice eating population, consumption of rice with lower Glycemic Index (GI) is highly desirable as low GI food decreases plasma glucose levels and plasma insulin demand. As there is paucity of information on the GIs of commonly consumed rice varieties in India, the aim of this study was to determine GI of selected five rice varieties, and to find relationship of GI with their cooking and eating quality traits.

Study Design, Place and Duration: In vivo experiment was conducted at PG&RC, PJTS Agricultural University, Hyderabad, India, during March, 2017 to February, 2018. During this period, cooking and eating quality traits of selected rice varieties were determined in ICAR- Indian Institute of Rice Research, Hyderabad, India.

Methodology: GIs were determined by feeding10 fasted human subjects a fixed portion of foods and subsequently measuring plasma glucose of their blood samples at specific interval of time and GIs were calculated using standard formula. Cooking and eating quality traits were determined using standard procedure.

Results: The estimated GI values were 56.38(SEM 1.57), 59.23(SEM 1.02), 71.73 (SEM 1.75), 87.40 (SEM 1.90), and 94.05 (SEM 1.21), respectively for Sampada, Dhanrasi, DRR Dhan 42, DRR

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Dhan 43, and Jarava. Alkali spreading value (ASV), Gel consistency (GC), and Water uptake (WU) values of these five varieties ranged from 4 to 6, 22 mm to 54.5 mm, and 80 ml/ 100 g to 255 ml/100 g, respectively.

Conclusion: Two varieties were identified with moderate GI values (Sampada, 56.38 ± 1.57; Dhanrasi, 59.23± 1.02). These varieties can prove to be a healthier option to incorporate in nutritional therapeutic diet. It is also concluded that lower ASV, higher GC, and lower WU, are good predictors for lower GIs of rice varieties. These relationships may be used for screening of low GI rice cultivars in breeding programme.

Keywords: Glycemic index; rice; alkali spreading value; gel consistency; water uptake upon cooking.

1. INTRODUCTION

With a national diabetes prevalence of 10.4 %, India is home to the second largest number (77 million) of adults with diabetes worldwide which is expected to reach to 101.0 million by 2030 [1]. India needs to implement preventive measures to reduce the burden of diabetes as the annual cost of diabetes care would be very huge. The estimated annual expenditure in 2019 for treatment of diabetic population in India was 7053.2 million USD [1]. The cost of treatment will further increase in future due to escalating cost of treatment, hospitalization and management of complication and increasing number of patients.

The reasons for the increase in the number of diabetic patients have been attributed to changes in diet and physical activity levels wrought by economic development, industrialization, and urbanization [2]. Among dietary factors, the role of dietary carbohydrates, particularly the quantity and quality of the staple cereal, has received widespread attention. Carbohydrate foods, based on glycemic response, foods are categorized as low (GI value $\leq$ 55), medium (GI value 56-69) or high GI foods ($\geq$ 70) [3]. Diets high in GI have been shown to increase the risk for chronic diseases like cardiovascular disease and type 2 diabetes because of their impact on blood glucose and insulin levels [4]. In contrast, low GI diets have several health benefits such as decreasing plasma glucose levels, plasma insulin demand, and levels of inflammatory markers [5]. Thus, for prevention and management of diabetes and other related problems, food with a low glycemic index is to be favored.

Rice is the staple food of more than 65% population of India with per capita consumption of 103 kg/year which is higher than the world average of 79.7 kg/year in 2017 [6]. Among the rice varieties in the world, Glycemic index have been found to vary from as low as 48 of white rice of the Australian Doongara variety to a GI of 109 for Thailand Jasmine white rice [7,8]. Like high GI foods, high GI white rice [9,10] has also been found to be associated with the metabolic syndrome and type 2 diabetes in cross-sectional and longitudinal studies in several Western and Asian populations [11,12,13]. Therefore, for prevention and management of type II diabetes and other related problems among rice eating population, consumption of rice with lower GI values is highly desirable.

Although, India has developed more than one thousand varieties and hybrids during the period from 1965 to 2014, for various ecosystems [14], there is lack of published data on glycemic index of these varieties and hybrids. Therefore, the present study aims to analyze some selected commonly consumed rice varieties to generate information on their GIs and identify the varieties with lower GI values. The analyzed rice varieties include Sampada, Dhanrasi, DRR Dhan 42, DRR Dhan 43, and Jarava. It was also aimed to find relationship between GI and cooking and eating quality traits of these varieties if any. This information may be of importance to health practitioners who have the responsibility of advising diets which give controlled glycemic response.

2. MATERIALS AND METHODS

2.1 Materials

Rough rice samples (Sampada, Dhanrasi, Jarawa, Dhan 42, Dhan 43) were obtained from Plant Breeding Department of Indian Institute of Rice Research, Hyderabad, India.

2.2 Methods

2.2.1 Sample preparation

Samples were sun dried to a grain moisture content of 12-14%. All dried rough rice samples were cleaned, dehulled, and milled for 120 seconds following standard laboratory procedure

[15] to obtain white rice. White rice so obtained were cleaned, made free of dust, dirt and foreign materials and packed in air tight containers at room temperature for further analysis.

2.2.2 Quality traits analysis

Apparent Water uptake (WU) of white rice samples was determined using the method of Beachell and Stensel [16] with slight modification and calculated the value using the equation:

$$WU\ (g/100\ g) = [(mc-mo)/mo]\ x100,$$

Where WU is the percent apparent water uptake, mc is the weight of cooked rice and mo is the weight of uncooked rice in gram.

Alkali spreading value (ASV) of milled rice was measured following the method of Little et al [17]. The extent of disintegration of kernel due to alkali was rated visually based on a 7-point numerical spreading scale. Gel consistency (GC) of white rice samples after powdering was measured following the method of Cagampang et al. [18]. Movement of the gel was measured and recorded in millimeter (mm).

2.2.3 Chemical composition

Raw milled rice were ground to fine powder and analyzed in triplicate for proximate composition (moisture, ash, fat content) as per AOAC methods [19]. The moisture content was analyzed using the oven drying method, ash content was determined using dry ashing method and fat content was determined using soxhlet extraction method. Dietary fiber was measured using the method of Prosky et al. [20]. Total carbohydrate in rice grain was estimated using the method of DuBois et al. [21]. Available carbohydrate of each sample was obtained from the difference between the total carbohydrate and dietary fiber values. Iron and zinc contents were estimated using XRF method [15]. Amylose content was analyzed using the method described by Juliano [22].

2.2.4 Glycemic response

2.2.4.1 Selection of subjects

a total of 15 healthy adults with normal glucose tolerance and without medical history of diabetes mellitus formed the subjects of the study. Inclusion criteria for subjects were as follows: men or non-pregnant women, aged between 18 to 30 years (average age, 22.6±1.2 years), normal body mass index (BMI) (19 - 24.9 kgm^{-2}, Mean: 23±0.4 kgm^{-2}) and with fasting blood glucose (FBG) of < 100 $mgdL^{-1}$ (Mean: 84.7±7.1 $mgdL^{-1}$). The study was conducted as per wolver methodology [3] at Post Graduate & Research Center.

2.2.4.2 Preparation of foods

Dextrose (D (+) Glucose monohydrate, Merck KGaA, Germany) was used as reference food. It was served by dissolving 50 g of pure glucose powder in a glass of 250 ml of water. Test foods were prepared fresh, shortly before being fed for testing. The required portions of white rice samples (Sampada, 65.6 g; Dhanrasi, 65.0 g; DRR Dhan 42, 67.3 g; DRR Dhan 43, 66.0 g; and Jarava, 65.4 g) containing 50 g available carbohydrate, were cooked in electric rice cooker (420 W) using two volumes of water for each weight of rice.

2.2.4.3 Experimental protocol

GI testing was carried out on seven occasions (one test of each test samples and two repeated tests for reference food) with each subject. The subjects ate a regular evening meal and then fasted for 10 - 12 h overnight before the start of their test session the next morning. The next morning, the subjects under fasting condition reported to the research centre. After 10 - 15 min, baseline blood glucose levels were obtained by collecting two finger-prick capillary blood samples (0.5 ml), taken 5 min apart (−5 min, 0 min). After the fasting blood samples were obtained, subjects were given a fixed portion of a test food or reference food, which they consumed with additional plain water (200 ml) at a comfortable pace within 10 min. The subjects were then required to remain seated at the research centre and refrain from additional eating and drinking during the next 2 hours of blood collection. Finger-prick blood samples were taken 15, 30, 45, 60, 90 and 120 min after eating had commenced.

2.2.4.4 Blood glucose analyses and Glycemic index calculation

Blood glucose was measured using glucometer (Accu-Chek ® Active, Roche Diagnostics GmbH, Mannheim, Germany) which was calibrated using the control solutions. The GI value of the rice samples was calculated based on the method described by Wolever [3]. The blood glucose responses for every point of time over 2-hours were used to calculate the incremental area under the curve (IAUC) for the test rice samples and reference food. The incremental area under the curve (IAUC) was calculated geometrically using the trapezoid rule, for each food in every subject separately and termed as glucose response by the subject [3]. The following equation was used for the calculation of GI [3].

GI = [IAUCt / IUACr] x 100

Where,

IAUCt = incremental area under the blood glucose response curve for the test food
IAUCr = incremental area under the blood glucose response curve for the reference food (glucose).

The GI for each tested food was calculated as the mean from the respective GIs of the 10 subjects. The variability of GI for each tested food was assessed according to standard deviation of the mean.

2.3 Statistical Analysis

Statistical analyses were performed with Microsoft Office Excel 2007. Data are shown as mean with SE unless otherwise stated. For any subject, GI values that were greater than 2 SD plus the group mean GI, were considered to be outliers (n=2) and were excluded from the analysis. Moreover, those with intra-individual variability (CV%) of >30% for reference glucose were considered as outliers and not included for the GI of test food calculation (n=3). Hence, the data from a total of 10 volunteers were considered for the calculation of GI. The correlations between the GI of test foods and their cooking and eating quality traits were computed using free statistics software offered by Wessa [23].

3. RESULTS AND DISCUSSION

3.1 Results

The nutrient composition, AC, GC, ASV, & WU of un-cooked test samples are presented in Table1. The carbohydrate content of all the rice varieties ranged from 74.29% to 76.45%. Iron content in these uncooked polished rice samples varied from 7.1 mg/Kg to 8.4 mg/Kg while zinc content in these samples varied from 10.9 mg/Kg to 13.9 mg/Kg.

Amylose content in these rice varieties ranged from 22.82% in Sampada to 26% in Dhanrasi. Amylose contents in DRR Dhan 42, DRR Dhan 43 and Jarava were 24.3%, 23.6% and 25.02%, respectively. Based on the amylose content classification [22], rice varieties Sampada, DRR Dhan 42 and DRR Dhan 43 were included in the intermediate amylose rice group (amylose content, 20-25 %), while Dhanrasi (26%) and Jarava (25.02%) were grouped under high amylose rice (amylose content, >25%).

Alkali spreading value (ASV) of these five varieties ranged from 4 to 6. ASV of Sampada (5) and Dhanrasi (4) indicated that their GT comes under intermediate temperature category (70-74 ^{o}C) while GTs of remaining three varieties (DRR Dhan 42, DRR Dhan 43 and Jarava) which have above five ASV values come under low GT values (55-69 ^{o}C) [17]. Gel consistency among these varieties ranged from 22 mm in Jarava to 54.5 mm in Sampada. In terms of classification Sampada (54.5 mm) and DRR Dhan 42 (42 mm) have medium GC, while remaining three varieties (Dhanrasi, 37 mm; DRR Dhan 43, 34.0 mm; and Jarava, 22.0 mm) have hard GC. Water uptake values of these varieties ranged from 80 ml/ 100 g in Sampada to 255 ml/100 g in DRR Dhan 43 and Jarava.

Table 2 shows the mean blood glucose of the subjects at different time points observed after consuming the test foods (rice) and reference food (glucose). Although there was individual variations in blood glucose levels among ten subjects both before and after consuming rice, there was no significant difference at time 0 (fasting) among the subjects for each test rice and the reference food ($p>0.05$). There was a significant increase in fasting blood glucose ($p<0.001$) after ingestion of each test rice and the reference food and the blood glucose reached the peak values at 30 minutes.

The blood glucose response curves are shown in Fig. 1 wherein blood glucose values (mg/dL) are plotted against time (min). It was observed that reference glucose curve had the maximum average peak of 163.8±3.34 mg/dL while all the test rice samples had lower peak values (125.36±3.36 mg/dL, Sampada; 135.30±2.91 mg/dL, Dhanrasi; 139.32±1.70 mg/dL, DRR Dhan 42; 155.16±2.68 mg/dL, DRR Dhan 43;

and 158.76±2.41 mg/dL, Jarava). Table 3 summarizes the results of the mean IAUC and GI values for all rice varieties. The mean blood glucose incremental area under the curve for reference food (glucose) was 4956.38 mins.mg/ dL (SEM 107.43) and the values for test foods were 2794.5 mins.mg/ dL (SEM 83.83), 2935.5 mins.mg/ dL (SEM 78.17), 3554.7 mins.mg/ dL (SEM 41.23), 4331.85 mins.mg/ dL (SEM 45.65), and 4661.55 mins.mg/ dL (SEM 72.06), respectively, in Sampada, Dhanrasi, DRR Dhan 42, DRR Dhan 43, and Jarava. The Statistical data analysis of the IAUC values indicates that the difference between Sampada and Dhanrasi was non-significant while differences among the remaining three rice varieties were strongly significant ($p < 0.001$). Estimated GI values for Sampada, Dhanrasi, DRR Dhan 42, DRR Dhan 43, and Jarava, were 56.38 (SEM 1.57), 59.23 (SEM 1.02), 71.73 (SEM 1.75), 87.40 (SEM 1.90), and 94.05 (SEM 1.20), respectively (Table 3). There was no statistically significant difference in GIs between Sampada (56.38 ± 1.57) and Dhanrasi (59.23± 1.02). But the GIs of other varieties were significantly different ($p < 0.001$) from each other.

On the basis of classification of carbohydrate foods described by Wolever [3], Sampada (56.38 ± 1.57) and Dhanrasi (59.23± 1.02) which had significantly lower GI than the reference food (glucose; GI=100) can be categorized as intermediate GI food (56 to 69). GI of remaining three varieties (DRR Dhan 42, 71.73±1.75; DRR Dhan 43, 87.40 ± 1.90; and Jarava, 94.05 ±1.21) will come under the category of High GI food (≥70).

3.2 Discussion

3.2.1 Glycemic index

This study reports the GI of milled rice of five Indian rice varieties. Two varieties were found to have intermediate GI (Sampada, 56.38 ± 1.57; Dhanrasi, 59.23± 1.02). The remaining 3 varieties DRR Dhan 42, DRR Dhan 43 and Jarava had high GI values. This information is of great value as Asian Indians have higher susceptibility to type 2 diabetes, CVD and central obesity. Hence, being informed about the GI is important for population where rice is consumed in considerable quantities.

Very few Indian rice varieties have been studied for the estimation of GIs. Shobana et al. [9] studied three commonly consumed Indian rice varieties and found that all the three varieties (Sona Masuri, 72.0 ± 4.5; Ponni, 70.2 ± 3.6; and Surti Kolam, 77.0 ± 4.0) had high GI values. Another set of three rice varieties studied by Deepa et al. [24] were also found to have high GI values (Njavara, 74.8±0.41; Jyothi, 73.1±2.19; IR 64, 73.2±1.40).

Only few Indian rice varieties have shown low GI /intermediate GI value. Those varieties were RNR 15048 with GI value of 51.72 [25], Pradhyumna (GI=51.3) and Anjana (GI=52.7) [26], and Improved Samba Mahsuri (GI= 50.99) [27]. Some basmati rice samples collected from markets have also shown low GI values [28] but name of the varieties of the samples collected from market is not known. Identified rice varieties (Sampada and Dhanrasi), in the present work, with moderate GI values will improve the availability of low GI diet.

3.2.2 Relationship between GI and Cooking and eating quality traits

There are very limited studies on relationship of cooking and eating quality traits of rice with glycemic index (GI). ASV, AC, GC, WU are the traits which influence the cooking and eating quality of rice. These traits are extensively analyzed in rice breeding program to develop rice cultivar with desired eating and cooking quality of the rice. ASV is the indirect measure of Gelatinization temperature (GT). ASVs of 1–2, 3, 4–5 and 6–7 correspond to high, high-intermediate, intermediate and low GT types, respectively [15,17].

In the present study, significantly strong positive correlation was observed between GI and ASV ($r=0.833$, $p=0.039$). The rice varieties having lower ASV (Sampada, 5; Dhanrasi, 4) have lower GI values (Sampada, 56.38±1.57; Dhanrasi, 59.23±1.02) while the varieties having higher ASV (DRR Dhan 43, 5.5; Jarava, 6) have higher GI values (DRR Dhan 43, 87.40±1.90; Jarava, 94.05± 1.20). Finding of the present work is in agreement with the previous works [29] where it was found that food comprising starch with a low gelatinization temperature has a higher GI than food comprising starch with a high gelatinization temperature Thus, gelatinization temperature is inversely linked to GI. In other words, GI is positively associated with ASV.

Previous studies have shown negative relationship between amylose content and GI value [30] implying that rice with low amylose content have high GI value and the high amylose rice had a lower GI than the normal-amylose and waxy-rice varieties. The authors concluded that only high amylose (28%) varieties are potentially useful in low GI diets.

In the present study, amylose content did not show any correlation with the glycemic index of the rice variety. Despite of lower amylose content (22.82 %), the rice variety Sampada was found to have low GI (56.4) and the rice variety Jarava (AC= 25.05%) which comes under high amylose category (≥25%), has highest GI value (94.04) among the five rice varieties. This is in agreement with Panlasigui et al. [31] who reported that amylose content in rice is not a good predictor for starch digestibility and glycemic response and there was no correlation between amylose content and GI. Rice varieties high in amylose have been shown to have lower [32], higher [31], or similar [33] starch-digestion rates and glycemic responses than have rice varieties low in amylose.

Other studies have also supported that Low amylose rice variety can also come under low GI or moderate GI food category. An Indian rice variety RNR 15048 having intermediate amylose content (20.72%) was found to have low GI value of 51.72 [25].

The reported conflicting results can be explained on the basis of molecular weight and chain length of their amylose and amylopectin. It has been found that the varieties having ≥10 % long chain amylose (DP>1000) and > 10% long chain amylopectin (DP 121-1000), will come under low GI (<55) category. If the proportion of short chain amylopectin (DP6-36) is ≥50%, the variety will have either intermediate GI or high GI [31,34,35].

Significant negative association was observed between GI and Gel consistency (r= -0.834, p=0.039). Jarava which has highest GI (94.05) was found to have lowest GC (22 mm) while Sampada having lowest GI (56.38) has highest GC value (54.5 mm). Negative relationship of GI with gel consistency has also been reported by earlier workers [31].

Association between GI and the percent water uptake of the varieties was significantly positive (r=0.879, p=0.0246). Water uptake of Sampada which has lowest GI (56.38) is lowest (80 ml/100 g rice) while the varieties having very high GI (Jarava, 94.05; DRR Dhan 43, 87.40) have highest water uptake (255 ml/ 100 g rice). Total carbohydrate content, ash content, fat content, crude fat content, iron and zinc etc did not show any correlation with GI of the rice varieties.

Table 1. Physico-chemical characteristics of selected varieties

	Sampada	Dhanrasi	DRR Dhan 42	DRR Dhan 43	Jarava	r* (GI)
Available Carbohydrate#	76.21	76.92	74.29	75.75	76.45	-0.115(P=0.426)
Moisture (%)	10.5	10.1	11.6	10.8	11.5	0.5174(P=0.186)
Ash (%)	0.45	0.39	0.36	0.29	0.30	-0.5217 (P=0.1836)
Fat (%)	0.7	1.01	0.62	0.55	0.8	-0.369 (p=0.273)
Crude fiber content (%)	0.82	0.80	0.90	1.02	0.7	0.052 (p=0.466)
Iron (mg/kg)	7.10	8.5	7.7	8.4	7.8	0.2748 (P=0.3273)
Zinc(mg/kg)	13.9	13.4	10.9	12.3	12.9	-0.3715 (P=0.2691)
Amylose (%)	22.82	26	24.3	23.6	25.02	0.0743(p=0.905)
ASV	5	4	5.2	5.5	6.0	0.833** (p=0.039)
GC (mm)	54.5	40	42	34	22	-0.8394** (p=0.044)
Water uptake	80	140	245	255	255	0.8797** (p=0.0246)
Glycemic Index (GI)	56.38	59.23	71.73	87.40	94.05	1

**Correlation coefficient between the physicochemical properties and glycemic index (GI); ** Significant at p<0.05; # g/ 100 g*

Table 2. Serum glucose responses (mg/dL) of the subjects (n =10) at different time points after consuming the test foods

	0 min	15 min	30 min	45 min	60 min	90 min	120 min
Reference#	84.70±2.25	104.33±2.35	163.80±3.34	150.80±2.81	138.63±2.86	120.80±2.96	97.20±2.55
Sampada	84.70±2.25	101.44±2.64	125.36±3.37	119.40±2.42	112.50±2.70	105.60±2.35	95.40±2.64
Dhanrasi	84.70±2.25	102.00±2.78	135.30±2.91	124.40±2.48	116.30±2.92	100.20±2.84	94.40±2.36
DRR Dhan 42	84.70±2.66	102.60±2.52	139.45±1.70	130.24±2.07	121.00±2.26	111.92±2.02	94.60±2.58
DRR Dhan 43	84.70±2.25	103.68±3.14	155.16±2.68	141.20±2.61	130.00±2.36	115.00±2.77	99.00±1.98
Jarava	84.70±2.25	103.78±2.32	158.76±2.41	149.58±2.68	133.60±3.63	120.20±2.14	93.10±2.59

** Mean ± standard Error of Mean (SEM); # Glucose*

Table 3. Incremental area under the blood glucose response curve (IAUC) and glycemic index (GI) values of rice samples (test food/IAUCt) and reference food (glucose/IAUCr) (Glucose GI= 100) (n=10)

subject	Reference Food#	Sampada		Dhanrasi		DRR Dhan 42		DRR Dhan 43		Jarava	
	IAUCr	IAUCt	GI	IAUCt	GI	IAUCt	GI	IAUCt	GI	IAUCt	GI
1	4446.75	2912.25	65.49	2683.5	60.35	3570.75	80.30	4275	96.14	4365	98.16
2	5573.25	3112.5	55.85	3180	57.06	3473.25	62.32	4383.75	78.66	4835.25	86.76
3	5207.25	2918.25	56.04	2966.25	56.96	3595.5	69.05	4366.5	83.85	4725	90.74
4	4716	2317.5	49.14	2689.5	57.03	3300	69.97	4102.5	86.99	4252.5	90.17
5	5110.5	3168.75	62.00	3255.75	63.71	3731.25	73.01	4451.25	87.10	4893.75	95.76
6	5043.75	2739.75	54.32	3040.5	60.28	3619.5	71.76	4391.25	87.06	4826.25	95.69
7	4647	2735.25	58.86	2944.5	63.36	3744	80.57	4597.5	98.93	4549.5	97.90
8	5250	2760.75	52.59	3204	61.03	3525	67.14	4312.5	82.14	4942.5	94.14
9	4732.5	2440.5	51.57	2516.25	53.17	3485.25	73.65	4136.25	87.40	4631.25	97.86
10	4836.75	2839.5	58.71	2874.75	59.44	3502.5	72.41	4302	88.94	4594.5	94.99
Average*	4956.38	2794.5[e]	56.38[a]	2935.5[e]	59.23[a]	3554.7[f]	71.73[b]	4331.85[g]	87.40[c]	4661.55[h]	94.05[d]
SEM(±)	107.43	83.86	1.57	78.17	1.02	41.23	1.75	45.65	1.90	72.06	1.20

**IAUC and GI values with unlike superscript letters differ significantly. #Glucose Values with superscripts of different small alphabets are significantly different ($p<0.05$)*

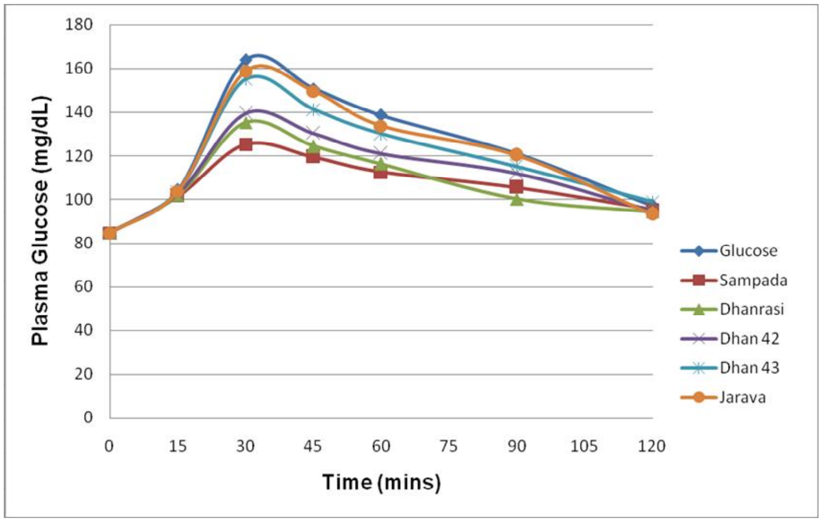

Fig. 1. Plasma glucose response curves of reference and test foods

4. CONCLUSION

Glycemic Index (GI) of five rice varieties studied in this work ranged from 56.38 to 94.05. Two varieties have been identified with moderate GI values (Sampada, 56.38; Dhanrasi, 59.31) which can form part of low GI diet and may also reduce the glycemic load when incorporated in a meal. Due to high prevalence of diabetes in India such low GI alternatives can prove to be a healthier option to incorporate in nutritional therapeutic diets. This study also showed that lower Alkali Spreading Value, higher gel consistency, lower water uptake upon cooking are good predictors for lower GIs of rice varieties. As the cooking and eating quality traits are either positively or negatively associated with GI, these relationships may be used for screening or preliminary selection of low GI rice cultivars.

CONSENT AND ETHICAL APPROVAL

The study was approved by Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, India, after approval of the ethics committee of the Department, the study was conducted. The purpose and protocol of the study were explained to the subjects and participant’s written consent was obtained.

ACKNOWLEDGEMENTS

We would like to thank Director, ICAR-Indian Institute of Rice Research, Hyderabad, TS, India; and Head of Post Graduate & Research Center, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500030, TS, India for providing required facilities for this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/64441