The *in vivo* glycaemic response of different rice varieties in Sri Lanka

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ABSTRACT

Introduction: Diabetes poses a heavy economic burden in Sri Lanka. High glycaemic index (GI) diets are known to promote a higher risk of diabetes. This study was aimed to determine the GI values of nine improved and three traditional rice varieties of Sri Lanka including Bg406, H.H.Z.36, Ld368, Bw367, Bg94-1, At405, At362, Bg300, Bg352, Sudu heenati, Madathawalu, and Pachchaperumal. Furthermore, comparisons of GI values between improved and traditional varieties, as well as the effect of subject gender and colour of pericarp on GI were described. **Methods:** Fourteen healthy subjects consisting of seven males and seven females were fed with a reference food and cooked rice varieties containing 50 g available carbohydrate; GI were calculated. **Results:** The GI of 12 rice varieties varied from 40-69. All traditional varieties including Sudu heenati, Madathawalu and Pachchaperumal were in the low GI category presenting GI values of 51, 54, and 41, respectively. Rice with red pericarp obtained significantly lower GI compared to those with white pericarp. Yet, GI values obtained in males were significantly higher than females. **Conclusion:** The result of this study suggested that all traditional varieties and improved rice H.H.Z 36, Ld368, and Bg406 could have beneficial effects on lowering the glycaemic response in healthy subjects. Glycaemic index can be predicted from the colour of the rice grain. Gender should be considered in the determination of GI.

Keywords: glycaemic index, glycaemic response, rice, Sri Lanka

INTRODUCTION

All over the world including Asia, Africa, America and the Pacific, rice is the predominant staple food which provides 20 percent of the global dietary energy supply (Saragih *et al.*, 2019). There are thousands of varieties grown all over the globe, having genetic diversity and available in various colours, including brown, red, purple, black etc., in its natural non-milled state. These varieties of colourful rice are also prized for their health properties and there is a wide variation of preference among consumers based on the colour of pericarp.

Starch is the storage form of carbohydrate in rice grain, and it is a homopolymer of glucose. Since rice is rich in starch as its major nutrient, it contributes to blood glucose level.

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Glycaemic response (GR) means the appearance of glucose in the bloodstream after taking a meal, and it is a normal physiological process that depends on the rate of glucose intake, absorption, and hepatic glucose release. The GR of a food is expressed as a percentage of GR of the reference food (usually a glucose solution or white bread). In fact, the glycaemic index (GI) value is expressed as a relative to GR. The concepts of GI, glycaemic load (GL) determination and their relationship with common metabolic diseases, such as diabetes and obesity, have been investigated. Presently, low GI diets have a favourable effect on the prevention and management of diabetes, heart disease, and obesity (Augustin *et al.*, 2015; Suara *et al.*, 2019). Both the amount and types of carbohydrates in the diet should be considered in conjunction with formulating dietary advices for patients with type 2 diabetes (Vlachos *et al.,* 2020).

The GI of the various rice varieties in the world may be different, and it depends on several factors including the degree of processing, amylose content, cooking time, and other botanical structure variations. Several studies have shown inconsistencies in GI of the same variety due to the difference in processing, cooking time, and geographical variation, which may affect the physical and chemical properties of the rice grain (Gunathilaka & Ekanayake, 2015). According to the Food and Agriculture Organization (FAO)'s Food and Nutrition Division (2004), unmilled rice has a higher nutrient content than milled or polished white rice. Rice varieties grown in Sri Lanka are usually categorised as white and red rice based on pericarp colour.

The knowledge of GI may provide consumers and health professionals with accurate and reliable information about the GI of foods and its application needs to be developed. Owing to the fact that most studies done on Sri Lankan foods have been conducted among non-diabetic healthy volunteers with mixed carbohydrate meals (Hettiaratchi *et al.,* 2012; Nisanka & Ekanayake, 2016; Pirasath *et al.,* 2015), the influence from side dishes to GI calculation have been discounted (Sandrasegarampillai & Arasaratnam, 2010). Only a few studies have been done with single meal among healthy volunteers.

The objective of this study was to determine the GI and GL of 12 selected traditional and improved varieties of rice grown in Sri Lanka, namely Bg94-1, At405, Bw367, H.H.Z.36, Ld368, Bg406, At362, Bg300, Bg352, Madathawalu, Suduheenati, and Pachchaperumal; and to compare the GI in order to determine its association with the colour of the pericarp of rice and effect of gender.

MATERIALS AND METHODS

Study subjects

A group of 14 healthy volunteers of both genders was selected for the study. Blood pressure was measured using a sphygmomanometer. Volunteers with normal body mass index (BMI) (18.5-24.5 kg m^{-2}) and aged between 20-30 years were selected for the study. Those who were diagnosed with diabetes or any other signs and symptoms of medical co-morbidity, dieting or restricting their carbohydrate intake, with fasting blood glucose of more than 120 mg dL^{-1}, and under any medication were excluded from the study. The volunteers were advised to maintain their customary dietary intake for three days prior to the testing date (Bur *et al.*, 2003). They were also requested to refrain from smoking, alcohol, and strenuous exercise during the study period. Before being admitted to the study, a detailed written and oral explanation of the different procedures involved in the study was provided and written informed consent was obtained

from all subjects. The protocol was approved by the Ethics Committee, Postgraduate Institute of Science, University of Peradeniya.

Rice varieties and reference food

Dehulled rice samples of improved (Bg94-1, At405, Bw367, H.H.Z.36, Ld368, At362, Bg300, Bg352, and Bg406) and traditional rice varieties (Madathawalu, Suduheenati and Pachchaperumal) (Table 1) were obtained from the Rice Research and Development Institute, Bathalagoda. The twelve tested rice varieties consisted of 6 red and 6 white. The rice was washed well in water and cooked (1:2; rice:water) for about 20 minutes until palatable (Hettiaratchi *et al.,* 2009).

Glucoline (GSK Glaxco Wellcome Ceylon Ltd., Sri Lanka) dextrose monohydrate, after being dissolved completely in 250ml of water, was used as the reference food (containing 50 g glucose) (Gunathilaka & Ekanayake, 2015).

Experimental design

The subjects were studied on fifteen separate occasions: twelve occasions on which they consumed different test foods and three occasions (first, seventh, and fifteenth sessions) were dedicated to the reference food. According to the randomisation list established prior to the commencement of the study, the twelve varieties of rice were provided to each participant in a randomised order in between the three reference food tests. The tests were carried out one week apart for each participant.

In the morning of each session, the subjects were instructed to report to the laboratory following a period of 10 hours fasting. Capillary blood glucose levels were measured two times using a glucometer (Prodigy pocket blood glucose meter, Prodigy Diabetes Care, NC USA). The average blood glucose level was considered to be the baseline concentration (fasting). The cooked rice portion containing 50 g of available carbohydrates (Table 2) together with

Table 1. Total carbohydrate content and weight of raw and cooked rice containing 50g carbohydrate

Rice variety	Colour of pericarp	Available starch content (g) in 100g	Weight of consumed raw rice containing 50g of carbohydrate (g)	Weight of cooked portion containing 50g of carbohydrate (g)
At405	White	77.54	64	158.7
Bg94-1	White	74.34	67	214.5
Bg300	White	70.21	71	153.3
Bg352	White	74.74	67	151.6
Bw367	White	73.99	68	211.0
H.H.Z.36	White	73.11	69	181.8
At362	Red	68.71	73	173.0
Bg406	Red	69.63	71	172.6
Ld368	Red	69.28	72	132.0
Madathawalu	Red	72.30	69	192.1
Pachchaperumal	Red	71.36	70	124.3
Sudu heenati	Red	77.70	64	189.7

250 ml of water were served for each subject and these were consumed within 10 to 15 minutes duration. After that, capillary blood glucose levels were measured at 30, 60, 90, 120 minutes following ingestion of the test food.

Table 2. Baseline measurements of participants (Mean±*SE*)

	Male	*Female*
Number (n)	7	7
Age (year)	25.7±2.4	27.0±3.0
Height (m)	1.7±0.1	1.6±0.1
Weight (kg)	63.0±4.8	53.7±7.5
BMI (kg m^{-2})	21.5±2.4	21.0±2.2
Fasting blood glucose (mg dL^{-1})	93.6±2.3	88.7±3.0
Blood pressure		
Systolic (mm Hg)	115±8	110±6
Diastolic (mm Hg)	80±0	75±5

For each variety of rice and reference food, GI was calculated using the incremental area under the curve (IAUC), following the equation below and presented by taking the average of the ratios (Wolever *et al.,* 1991).

$$GI = \frac{IAUC\ of\ rice}{IAUC\ of\ glucose}\ X100$$

The GL corresponds mathematically to GL = GI × available carbohydrate (g) /100 (Brand-Miller *et al.*, 2003). The maximum increase in blood glucose (MIBG) was an increase in the postprandial blood glucose subtracted by fasting blood glucose (FBS) (Olausson *et al.*, 2014).

Statistical analysis
The Graph Pad Prism 5.0 (Graph Pad Software Inc., San Diego, CA, USA) statistical software was used for calculating the IAUC. Data obtained from each subject were fitted into a completely randomised design (CRD). The results were considered significant at $p<0.05$. To determine the significance of the rice pericarp colour, gender, traditional/ improved breeding on GI, the Student's *t*-test was performed, considering an α error of 0.05 to be statistically significant at 95% confidence interval. Unpaired *t*-test was applied to test the group differences between males and females.

RESULTS

Baseline measurements of subjects
The anthropometric measurements of the subject group (n=14) indicated that they were within the acceptable normal limits. There were no significant gender differences in BMI, anthropometric measurements, fasting blood glucose level, and blood pressure (Table 2). All participants were between 20-30 years old, with the average age of males (n=7) and females (n=7) being 25.7±2.4 years and 27.0±3.0 years, respectively.

Glycaemic index (GI), glycaemic load (GL) and maximum increase in blood glucose (MIBG) of tested rice
The GI of the 12 tested rice varieties varied from 40-69, with a mean value of 53.5±8.5. The highest GI was reported in At405 (GI= 69) and the lowest was in Ld368 (GI=40). The variations in the mean GI among the 12 varieties were statistically different (p=0.003) (Table 3). Sudu heenati, Bg406, H.H.Z.36, Ld368, Madathawalu, and Pachchaperumal were at the low GI category, while the other six varieties, namely BW367, Bg94-1, At405, At362, Bg300, and Bg352, had medium GI. Interestingly, among the tested varieties, all the three traditional varieties were referred as low GI. Average GI values of traditional varieties and new varieties were 49±6.8 and 55±8.6, respectively. Yet, there was no significant difference in the GI of both traditional and new rice varieties (p=0.196). The GL of the selected rice varieties varied from 20-34. Similar to GI, the highest and lowest GL could be identified in At405 and Ld368, respectively. All rice

Table 3. Maximum increase in blood glucose (MIBG), glycaemic load (GL) and glycaemic index (GI) with their category for each test rice

Rice variety	GI	Glycaemic category	GL	GL category	MIBG (mg dL^{-1})
At405	69±10.2[b]	Medium	34	High	45±9.1
Bg94-1	56±9.1[ab]	Medium	28	High	36±15.3
Bg300	64±1.6[ab]	Medium	32	High	47±11.3
Bg352	56±8.3[ab]	Medium	28	High	62±15.6
Bw367	58±13.2[ab]	Medium	29	High	30±17.4
H.H.Z.36	50±11.3[ab]	Low	25	High	36±13.9
At362[†]	56±7.6[ab]	Medium	28	High	47±33.9
Bg406[†]	47±11.4[ab]	Low	24	High	38±13.8
Ld368[†]	40±11.6[a]	Low	20	High	30±10.7
Madathawalu[†]	54±6.7[ab]	Low	27	High	38±15.6
Pachchaperumal[†]	41±11.0[a]	Low	20	High	28±13.3
Sudu heenati[†]	51±9.2[ab]	Low	26	High	31±10.2
Mean±*SE*	53.5±8.5				39±9.8
Probability	0.003				0.006

Data are mean±*SD*, unless otherwise indicated
[†]rice varieties with red pericarp, while others are white
GI value is referred as low (≤ 55), medium (≥ 56 - ≤ 69) and high (≥ 70)
GL is categorised as low (≤ 10), medium (≥ 10 - ≤ 20) and high (≥ 20)
Means in each group, followed with a different superscript letter in each column were significantly different ($p<0.05$), as analysed by one-way ANOVA

varieties were categorised as high in GL. The MIBG in 12 rice varieties varied from 28-62 mg dL^{-1}, with a mean value of 39±9.8 mg dL^{-1} (Table 3). Further, the MIBG was observed within 30 minutes after the ingestion of all rice varieties and a significant variation was observed among the rice varieties (p=0.006).

Effect of pericarp colour on GI and GL

Among the six tested white and red varieties, the GI of white rice ranged from 50-69, while the GI of red varieties ranged from 40–56. The mean GI of white rice varieties showed a significantly higher value (p=0.001) compared to red rice, with mean GIs of 59.3±10.2 and 49.02±10.1, respectively (Figure 1). GL of white and red rice varieties varied from 25-34 and 20-28, respectively. Similar to GI, a significantly higher GL (p=0.023) was seen in white rice varieties (29.3±1.3; n=6) in comparison to red rice varieties (24.2±1.4; n=6).
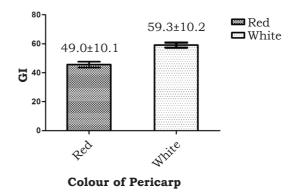

Figure 1: Comparison of GI among red and white rice varieties

Effect of subject gender on GI and MIBG

The GI obtained from all the rice varieties on males ranged between 32-87, with a mean value of 57.6 ±17.0; the GI obtained for 12 rice varieties on females ranged between 20-58, with a mean value of 38.9±12.3. The GI values obtained on males were significantly higher than those of females (p=0.006). The MIBG level between males and females varied between 31-73 mg dL^{-1} and 22-51 mg dL^{-1}, respectively; the MIBG values of males were significantly higher than females (p=0.016), with mean values of 45.3±14.5 mg dL^{-1} and 32.7±8.3 mg dL^{-1}, respectively (Figure 2).
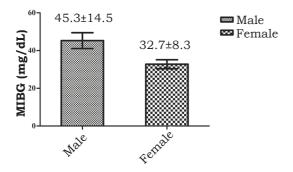

Figure 2: Comparison of MIBG level among male and female subjects

DISCUSSION

A group of 14 healthy volunteers of both sexes (female=7, male=7), aged 20-30 years, with normal BMI (BMI=21.5±3 kg/m^2) were recruited for the study, as it has been reported that high BMI or obesity are directly affected with hormonal regulation of blood glucose, especially with increased insulin secretion rate and decreased insulin clearance rate (Jung *et al.,* 2018).

The results of this study showed that different Sri Lankan rice varieties has a wide range of GI. Some of the commercial rice cultivars of Sri Lanka have shown GI values ranging from 67% to 72%, with the majority of them classified as medium GI rice (Darandakumbura *et al.*, 2013). Studies in other countries have also shown that there is a wide variation in the GI of different varieties of rice (Kaur *et al.,* 2016; Prasad *et al.,* 2018). In this study, six out of 12 varieties were categorised as "low GI" and six were categorised as "medium GI". The variation in the mean GI among the 12 varieties was statistically different (p=0.003), and the variation could be due to the resistant starch content of each variety. Darandakumbura *et al.* (2013) showed that resistant starch content of variety At405 was significantly higher than Bg300 and Bg358. Thus, in the mentioned research, At405 was categorised as a medium GI rice, while Bg300 and Bg358 were categorised as high GI rice. Further, the result of this study has also proven that the colour of pericarp has a significant effect on the variation of GI.

All the 12 rice varieties were categorised as "high" in GL in this study. GL can be influenced either by changing GI or by changing the amount of carbohydrates consumed, or both. In this study, the amount of carbohydrates consumed was equal in all rice varieties, which was 50g. As GI of all rice varieties were more than 40, and their GLs were also more than 20, which is the cut-off value, they were categorised as "high". A previous study indicated the GI for Bg352 (parboiled) as 40±13 (Nisanka and Ekanayake, 2016), while GI for the same variety was indicated as 60±2 for parboiled rice and 67±3 for raw rice (Pathiraje *et al.*, 2010); in this study, it was 56.0±8.3 for Bg352 (raw). Furthermore, the GI for Bg300 was reported as 61±3 and 73±2 for Bg406 in a previous study (Pathiraje *et al.*, 2010), whilst this study indicated a GI of 64.0±1.6 for Bg300 and 47.0±11.4 for Bg406. Therefore, this indicated that the GI obtained for similar rice varieties

were slightly varied in different studies. The differences between the GI values obtained for rice in published research could be mainly due to differences in the food item itself, processing method, the methodologies employed in calculating the carbohydrate content, as well as the variations in subject characteristics, such as gender, age, metabolic state etc.

Pathiraje *et al.* (2010) used different methods to calculate the carbohydrate content in rice, while Nisanka & Ekanayake (2016) adapted the Holm's method to calculate digestible carbohydrate. In this study, available carbohydrate was calculated by polarimetry method (US ISO 6493: 2000). Meanwhile, the accompaniment of test food with different side dishes and water, such as 5 g of chilli paste and 250 mL of water (Pathiraje *et al.,* 2010) or 25 g of coconut sambol (scraped fresh coconut kernel mixed with chilly, onion, salt and lime) and 250 ml of water (Nisanka & Ekanayake, 2016) may contribute to a difference. It is well informed that the co-ingestion of rice with fat and protein in mixed meals can reduce the glycaemic response compared to rice alone, thus the estimation of GI in mixed meal using predicted or adjusted formula has provided contradictory findings (Osman *et al.,* 2017). In the current study, the test food was accompanied with only 250 ml of water, which minimised the interference from side dishes when calculating GI (Sandrasegarampillai & Arasaratnam, 2010). Further, it has been shown that the GI for the same rice variety can vary based on the variation of subject's metabolic state (Vrolix & Mensink, 2010).

In addition to the new rice varieties grown in Sri Lanka, there are traditional rice varieties which fuel the diet of the Sri Lankan people in the past. However, consumers still believe that traditional rice varieties have better nutritional properties, and they tend to keep them under satiety condition for a longer time. All three traditional varieties tested were referred as low GI compared to the new varieties. As such, this result revealed that traditional rice produced a non-significant (p=0.196), lower postprandial glycaemic effect than did the new varieties. Further, Pathiraje *et al.* (2010) confirmed this fact as they reported that the traditional varieties of Rathkaral, Wedaheenaty, and Heendikwel produced lower postprandial glycaemic effect over the new varieties. However, according to his finding, GI of fully polished traditional rice varieties belonged to medium GI category. This difference is due to the high fibre content of unpolished rice, which has been confirmed to negatively affect the GI value of rice (Somaratne *et al.*, 2017).

This study implied that GI can be predicted from the colour of pericarp as there were significant differences between the mean GI of white and red rice varieties. In general, nutritionists and medical professionals believe that for patients with diabetes, the consumption of red raw rice varieties is better than white rice. The results of the present study further confirmed that most of the red rice varieties had a low GI compared to white rice (p=0.001). A similar conclusion has been made by earlier studies of Somaratne *et al.* (2017) and *Saleh et al.* (2019), indicating the higher levels of total phenolic content and total anthocyanin content in red rice than white rice, which are also negatively correlated with GI. As reported in several studies, higher levels of total phenol and anthocyanin in the red rice bran layer could affect the digestion of starch in rice by inhibiting the activity of enzymes such as α-glucosidase, β-glucosidase, and α-amylase (Boue *et al.,* 2016; Somaratne *et al.,* 2017).

Moreover, the current study disclosed the significantly higher GI obtained by the male subjects than the females

(p=0.001). Simultaneously, the MIBG glucose in males was higher compared to females (p=0.006). However, there were no significant differences in the BMI and age between males and females. In 2015, the National Survey of Health and Nutrition in Japan indicated that 15.5% of Type 2 diabetes mellitus patients were men and that 9.8% were women (Ishii *et al.,* 2016). Probably, a higher sensitivity to insulin upon glucose and dietary starch in females, as shown in the present research, may be one of the reasons for the above findings. In addition to that, it was reported that men had significantly higher fasting plasma glucagon concentrations and glucagon-like peptide (GLP)-1 (Carroll *et al.*, 2007), which further justify the results. In males, as glucagon and GLP-1 levels were higher throughout the 2-hour study period, MIBG could be higher in this study. Thus, it would directly affect the high GI obtained in male subjects. Therefore, the results of this study suggested that it is necessary to consider gender when measuring the GI of foods.

CONCLUSION

Based on the results of the present study, it can be concluded that GI values varied according to rice variety. Therefore, there is a necessity for formulating and implementing a policy on food labelling in Sri Lanka, so that consumers can easily obtain information about the glycaemic indices of different varieties of rice. Traditional rice varieties raised blood glucose levels slower than new varieties. The results of this study also suggested that gender should be considered in the determination of GI.

Only certain varieties of red raw rice, such as Pachchaperumal and Ld368, can be specially recommended for patients with obesity, diabetes, and coronary heart disease compared to the white varieties. The results of this study

are applicable to normal weight young adults that are not hyperglycaemic or hypertensive. Future studies are needed to observe the relationship between amylose:amylopectin ratio, resistant starch, and GI of rice varieties. Furthermore, a large sample size including both males and females is needed to validate and generalise the results of gender variation.

Author's contribution

RMHWR, carried out the experiments and wrote the manuscript with input from all authors; JGSR, conceived the study and was in charge of overall direction, planning and supervised the project; SSPS, performed the analysis and helped supervise the project. All authors provided critical feedback and helped shape the research, analysis and contributed to the final manuscript.

Conflict of interest

The authors of the current study certify that they have no affiliations with or involvement with any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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