International Journal of Agricultural Technology 2022Vol. 18(6):2573-2584
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Comparative evaluation of the nutritional compositions of different Sri Lankan rice varieties on glycaemic regulation

Rathnayake, R. M. H. W.[1*] and Ranasinghe, J. G. S.[2]

[1]Department of Medical Laboratory Science, Faculty of Allied Health Sciences, University of Peradeniya, Peradeniya, Sri Lanka; [2]Department of Biochemistry, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka.

Rathnayake, R. M. H. W. and Ranasinghe, J. G. S. (2022). Comparative evaluation of the nutritional compositions of different Sri Lankan rice varieties on glycaemic regulation. International Journal of Agricultural Technology 18(6):2573-2584.

Abstract The primary nutrition of rice (*Oryza sativa*) is carbohydrates in starches, sugars and fibre. The amount and type of carbohydrates are detrimental to health as they increase blood glucose levels, leading to the risk of diabetes. As intrinsic and extrinsic factors affect the glycaemic response of foods, understanding the influence of proximate composition and mineral content of rice on GI is useful. The nutritional composition and glycaemic potential of twelve rice varieties grown in Sri Lanka; Bg94-1, At405, Bw367, H.H.Z.36, Ld368, At362, Bg300, Bg352, Bg406, Madathawalu, Sudu heenati and Pachchaperumal were studied. The GI was calculated using fourteen healthy subjects consisting of seven males and seven females fed with cooked rice containing 50g carbohydrate and a reference food. The nutritional composition of the rice was compared with the GI of each variety. The GI of 12 rice varieties varied from 40- 69. The proximate and mineral compositions were significantly different except for the moisture level. This study suggested a significant negative correlation between GI and calcium content. Among the studied rice varieties, "Sudu heenati" showed a high level of calcium, chromium, protein and fibre values with low GI, which consumers would desire.

Keywords: Glycaemic index, Minerals, Proximate composition, Rice, Sri Lanka

Introduction

In many Asian countries, including Sri Lanka, rice (*Oryza sativa*) is known as the staple food, and the average intake of rice is 3-4 servings per day. The primary nutrition acquired from rice is carbohydrates in the form of starches, sugars, and fibre in the rice granule's endosperm.

The GI of a food is determined by several factors, including the type of carbohydrate and the protein, fat, and fibre content and type (water-soluble dietary fibre delays postprandial glycemia, whereas non-water-soluble fibre does not have this effect). Finally, food particle size and pH are factors to consider (lower pH delay postprandial glycemia) (Vlachos *et al.*, 2020). Most

[*] **Corresponding Author**: Rathnayake, R. M. H. W.; **Email**: hwasundara@ahs.pda.ac.lk

of these factors alter the rate of gastrointestinal motility, digestion and absorption, which influence GI. There is increasing evidence that both the amount and type of carbohydrate may be detrimental to the health, as it increases blood glucose level, which leads to the risk of metabolic diseases like diabetes, heart disease and obesity. Low GI diets have a favourable effect on preventing and treating diabetes, heart disease, and obesity (Augustin *et al.*, 2015; Esfahani *et al.*, 2009).

In recent research, minerals of the food have been shown to play a role in insulin production, release, and function. Among these minerals are zinc, calcium, chromium and phosphorous, which are essential for glucose metabolism homeostasis (Brandão-Lima *et al*., 2018; Lin *et al.*, 2018; Pizzorno *et al*., 2016; Shah and Garg, 2019). According to studies, chromium reduces fasting glucose, improves glucose tolerance, and lowers insulin (Pizzorno *et al*., 2016). In-vitro studies have proven that zinc increases the activity of glycolytic enzymes like phosphofructokinase and pyruvate kinase in a time-dependent manner (Canesi *et al.*, 2001; Tamaki *et al.*, 1983). Calcium plays an essential role in controlling body weight and maintaining insulin sensitivity in adipose tissue (Brandão-Lima *et al.*, 2018). It has been revealed that a low Pi diet significantly enhanced insulin receptor β (IRβ) levels in skeletal muscles and increased insulin-induced glucose uptake into the skeletal muscle cells (Lin *et al*., 2018).

Findings from large observational-prospective or cross-sectional studies reviewed by Cho *et al*. (2013) and Della Pepa *et al*. (2018) have consistently demonstrated high intakes of cereal fibre or mixtures of whole grains and bran are linked to a lower risk of diabetes. Information on the nutritional value, functional properties, and blood glucose response after consuming rice from specific rice is important, especially in developing healthy food sources and preserving the food source. Rice is generally regarded as a high or medium glycaemic index (GI) food. There is a need to assess the nutritional value and blood glucose response derived from traditional and improved rice in Sri Lanka. In addition, no studies have evaluated the relationship of the intake of chromium (Cr^{3+}), zinc (Zn^{2+}), phosphorous (P^{3-}) and calcium (Ca^{2+}) ion contents in consumed rice with the glycaemic control. The objective of the current study was to determine the association between GI of 12 rice varieties with proximate composition and micronutrient content.

Materials and methods

Study subjects

A group of 14 healthy volunteers from both sex (F=7, M=7, age=20-30 years, BMI=21.5±3 Kg/m2) was selected for the study. Blood pressure was measured using a sphygmomanometer. Weight, height, and waist circumference among the anthropometric measurements were taken. BMI of all participants was calculated using standardized techniques (Centers for Disease Control and Prevention, 2015). Volunteers with a BMI of less than18.5 Kg m-2 and more than 24.5 Kg m-2, aged between 20 to 30 years, known diabetes or any other sign and symptoms of medical comorbidity, dieting or restricting their carbohydrate intake, fasting blood glucose more than 120 mg dL-1 and having on any medication were excluded from the study. The study subjects were instructed to continue their usual lifestyle and were advised to maintain their regular dietary intake for three days before the fasting days (Bur *et al.*, 2003). However, they were requested to refrain from smoking and alcohol and strenuous exercise during the study period. The test was carried out for the participants 1 week apart. The protocol was approved by the ethics committee, Postgraduate Institute of Science, University of Peradeniya.

Rice varieties and reference food

Dehulled rice samples of Bg94-1, At405, Bw367, H.H.Z.36, Ld368, At362, Bg300, Bg352 and Bg406, Madathawalu, Sudu heenati and Pachchaperumal were obtained from Rice Research and Development Institute, Bathalagoda. The rice was washed well in water and cooked (1:2; rice: water) for about 20min using a rice cooker providing a similar condition until palatable (Hettiaratchi *et al*., 2009).

Glucolin (GSK Glaxo Wellcome Ceylon Ltd. Sri Lanka) dextrose monohydrate was used as the reference food after dissolving completely in 250ml of water. The three rice varieties were consumed randomly between the reference food sessions, with at least a week between measurements to minimise carry-over effects. To avoid the effect of starch retrogradation, all the tested rice varieties were cooked fresh and served to the subjects and then fed to each subject along with 150 ml of water.

Experimental design

The subjects were given cooked rice portions containing 50 g of available carbohydrates after fasting for 10-12 hours, consumed over 10 to 15 minutes. The postprandial capillary blood glucose levels were measured using a glucometer (Prodigy pocket blood glucose meter, Prodigy Diabetes Care, NC USA) at 0 (fasting), 30, 60, 90, 120 min after the ingestion of test food.

For each variety of rice and reference food, the incremental area under the curve (IAUC) was calculated using Graph Pad Prism 5.0. (Graph Pad Software Inc., San Diego, USA). GI was calculated using the following equation and presented by taking the average of the ratios (Wolever *et al.*, 1991).

$$\text{Glycaemic index} = \frac{\text{Incremental AUC of rice}}{\text{Incremental AUC of glucose}} \text{X } 100$$

Chemical and mineral analyses of rice

The distillers' dried rice samples were prepared in triplicate, and the average results for the proximate analyses of moisture, protein, fat, fibre, and ash content were determined using the Association of Official Analytical Chemists' standard method (AOAC).

The forced air draft oven method was used to determine the moisture content (AOAC 934.01). Total protein was analysed by the Kjeldahl method (AOAC 984.13) by drying 5 g of the sample at 105 ℃ for 3h in an air oven. The total ash content was found by adding 2.2g of sample to a crucible and ashed in a muffle furnace at the temperature of 550 ℃ for 12 h (AOAC 942.05). Then weighed the cooled crucible after placing it in a desiccators; The crude fat content was determined by continuously extracting with light petroleum ether for 30 minutes and then removing the solvent by distillation using Soxhlet extraction equipment. The residue was dried at 100 ℃, and the fat content was determined gravimetrically (AOAC 920. 59); The fibre content of rice samples was determined by sequential extraction with a boiling solution of sulfuric acid and sodium hydroxide. The filtration-collected insoluble residue was washed, dried, weighed, and ashed. The loss in weight by ash which corresponded to the fibre content of the sample (AOAC 962.09). The carbohydrate content of rice was estimated by solubilizing the carbohydrate with dilute hydrochloric acid, gelatinizing, and partially hydrolysing the carbohydrate. The clarified solution's total optical rotation was determined. Other substances that are soluble in 40% ethanol and optically active after treatment with dilute hydrochloric acid were corrected for optical rotation. The starch content was calculated by multiplying the corrected optical rotation by a known factor (US ISO 6493). Sugar content was calculated by the polarimetry method. The samples were quantified using flame atomic absorption spectroscopy (iCE 3000 Series' AAS, Thermo Fisher Scientific Inc.).

Statistical analysis

Data were analysed with Graph Pad Prism 5.0. (Graph Pad Software Inc.)

statistical software. The mean differences in nutritional composition, MIBG, and GI among rice varieties were analysed using one-way ANOVA and post hoc by Bonferroni comparison. Pearson's correlation coefficients determined the relationships between GI values and nutritional composition. The results were deemed significant at $p < 0.05$.

Results

Baseline measurements of subjects

The anthropometric measurements of the volunteers were within the acceptable normal limits for BMI, fasting blood glucose level and blood pressure (Table 1). No significant difference was found both on male and female anthropometric measurements.

Table 1. Baseline measurements of participants (Mean (±SE))

	Male	**Female**
Number (n)	7	7
Age (y)	25.7 ±2.4	27 ±3.0
Height (m)	1.72 ±0.1	1.60 ±0.1
Weight (Kg)	63 ±4.8	53.7 ±7.5
BMI (kg m^{-2})	21.5 ±2.4	21 ±2.2
Fasting blood glucose (mg dL^{-1})	93.6 ±2.3	88.7 ±3.0
Blood pressure		
Systolic (mm Hg)	115 ±7.6	110 ±5.8
Diastolic (mm Hg)	80 ±0.0	75 ±5.0

Glycaemic index (GI) of tested rice

The GI of 12 rice varieties varied from 40- 69, with the mean value of 53.5 ±8.5. The highest GI was reported in At405 (GI= 69), and the lowest was in Ld368 (GI= 40) (Table 2). The variation in mean GI among the 12 varieties were statistically different (p = 0.0031).

Proximate composition of the rice cultivars

The proximate composition observed among the 12 cultivars yielded the following results in Table 2. The highest level of starch was found in Sudu heenati and the lowest in At362. Interestingly, the highest fibre content (1.1%)

and lowest (0.3%) were found in Bg406 and Bw367, respectively, similar to ash content.

It showed that the moisture level of the twelve varieties was not significantly different (Table 3), whereas other macronutrients composition was significantly different.

The values for starch, sugar, protein, fat, fibre moisture and ash are shown in Table 3. Pearson correlation showed non- significant positive correlation between GI and sugar content ($r = 0.0453$, $p = 0.889$, $n = 12$) while non-significantly negative correlation showed with crude fibre ($r = -0.49$, $p = 0.105$, $n = 12$), crude protein ($r = -0.45$, $p =0.138$, $n = 12$) and fat ($r = -0.51$, $p = 0.092$, $n = 12$) in consumed rice.

Table 3. Correlation coefficients between proximate composition values

	Starch %	Sugar (g dL^{-1})	Crude Protein %	Fat %	Crude Fibre %	Moisture %	Ash %
Starch %	1.000	0.255 (0.423)	0.036 (0.911)	-0.072 (0.825)	-0.141 (0.663)	0.045 (0.890)	-0.291 (0.359)
Sugar (g dL^{-1})		1.000	0.012 (0.971)	0.021 (0.948)	0.334 (0.289)	-0.129 (0.690)	-0.166 (0.607)
Protein %			1.000	-0.031 (0.924)	0.336 (0.286)	0.504 (0.095)	0.379 (0.224)
Fat %				1.000	0.562 (0.057)	0.500 (0.098)	0.543 (0.068)
Fibre %					1.000	0.116 (0.720)	0.755 (0.005)
Moisture%						1.000	0.277 (0.384)
Ash %							1.000

*Values in parenthesis indicate probability levels

Mineral composition differences among rice cultivars

The composition of chromium ion (Cr3+), zinc ion (Zn2+), phosphorous (P3-) and calcium (Ca2+) varied significantly ($p < 0.05$) among the rice cultivars, as shown in Table 4. Sudu heenati had the highest chromium content (5.37 µg Kg-1) followed by Bg406 and Bg300, while Pachchaperumal had the most negligible value of chromium (2.46 µg Kg-1). Phosphorus occurred in a more significant proportion and with high variability among the selected rice varieties. The highest chromium (5.37 µg Kg-1) and calcium (629 µg Kg-1) concentration indicated in Sudu heenati, while the At405 187 µg Kg-1 of calcium was the least.

Table 2. Glycaemic index (GI) with their category, principal nutrient and ash content of each rice varieties on a dry basis

Rice Variety	GI	Glycaemic category	Starch %	Sugar (g dL^{-1})	Crude Protein %	Fat %	Crude Fibre %	Moisture %	Ash %
Sudu heenati	51 ±9.2^{ab}	Low	77.7 ±1.3^{a}	0.51 ±0.02^{a}	6.3 ±1.2^{a}	1.6 ±0.01^{c}	0.89 ±0.12^{cb}	8.6 ±1.6	1 ±0.1^{b}
Bg 406	47 ±11.4^{ab}	Low	69.6 ±1.7^{b}	0.32 ±0.01^{bcd}	8.5 ±1.3^{a}	1.11 ±0.02^{e}	1.1 ±0.12^{c}	8.61 ±2	1.71 ±0.11^{d}
H.H.Z.36	50 ±11.3^{ab}	Low	73.1 ±1.3^{bc}	0.44 ±0.02^{ac}	7.8 ±1.5^{a}	0.8 ±0.01^{ab}	0.5 ±0.11^{ab}	9.27 ±1.8	0.91 ± 0.11^{bc}
Ld 368	40 ±11.6^{a}	Low	69.3 ±1.7^{b}	0.31 ±0.02^{cd}	7.5 ±1.0^{a}	0.83 ±0.06^{b}	0.6 ±0.13^{ab}	8.38 ±1.7	0.7 ±0.1^{b}
Madathawalu	54 ±6.7^{ab}	Low	72.3 ±1.4^{bd}	0.25 ±0.02^{d}	6.1 ±1.1^{a}	1.33 ±0.06^{f}	0.6 ±0.14^{ab}	9.54 ±2	0.7 ±0.11^{bc}
Bw 367	41 ±11^{a}	Low	74 ±0.8^{acd}	0.27 ±0.02^{d}	6.5 ±1.0^{a}	0.41 ±0.02^{d}	0.3 ±0.13^{ad}	8.35 ±1.8	0.4 ±0.1^{a}
Pachchaperumal	58 ±13.2^{ab}	Medium	71.4 ±1.3^{bd}	0.41 ±0.14^{acd}	7.7 ±1.3^{a}	1.51 ±0.03^{c}	0.7 ±0.13^{cbd}	10.06 ±1.9	1.01 ±0.11^{b}
Bg 94-1	56 ±9.1^{ab}	Medium	74.3 ±1.0^{acd}	0.68 ±0.03^{e}	8.3 ±1.6^{a}	0.71 ±0.04^{a}	0.81 ±0.12^{cb}	8.89 ±1.8	0.4 ±0.1^{a}
At 405	69 ±10.2^{b}	Medium	77.5 ±1.4^{ac}	0.32 ±0.02^{cd}	7.9 ±1.4^{a}	0.7 ±0.03^{a}	0.41 ±0.14^{a}	8.67 ±1.9	0.4 ±0.11^{a}
At 362	56 ±7.6^{ab}	Medium	68.7 ±1.2^{b}	0.43 ±0.03^{ac}	5.7 ±1.1^{a}	1.12 ±0.05^{e}	0.57 ±0.13^{ab}	8.09 ±1.6	0.56 ±0.09^{a}
Bg 300	64 ±1.6^{ab}	Medium	70.2 ±1.8^{bd}	0.45 ±0.05^{ac}	5.5 ±1.0^{a}	0.81 ±0.03^{ab}	0.56 ±0.14^{ab}	7.93 ±1.7	0.58 ±0.17^{ac}
Bg 352	56 ±8.3^{ab}	Medium	74.7 ±1.8^{acd}	0.49 ±0.06^{a}	5.4 ±1.4^{a}	0.7 ±0.02^{a}	0.62 ±0.17^{ab}	7.72 ±2.1	0.58 ±0.1^{ac}
Mean ±SE	53.5 ±8.5		72.74 ±3.05	0.41 ±0.12	6.94 ±1.14	0.97 ±0.37	0.64 ±0.21	8.68 ±0.68	0.75 ±0.37
Probability	0.0031		< 0.0001	< 0.0001	0.0323	< 0.0001	< 0.0001	0.9345	< 0.0001

Data are means ±SD, unless otherwise indicated
GI values are referred to as low (≤ 55), medium (≥ 56 - ≤ 69) and high (≥ 70) (Mendosa, 2007)
Determined in 1000 g of cooked, dried rice and values are expressed as a percentage by mass on a dry basis
Means in each group, followed by a different superscript letter in each column, were significantly different ($p < 0.05$)

Table 4. Mineral content of rice varieties

Rice Variety	Cr ($\mu g\ Kg^{-1}$)	Zn ($\mu g\ Kg^{-1}$)	P ($\mu g\ Kg^{-1}$)	Ca ($\mu g\ Kg^{-1}$)
Sudu heenati	53.7 ± 1^{a}	22.3 ± 2.9^{b}	1373 ± 204^{a}	629 ± 178^{a}
Bg 406	35.2 ± 4^{b}	18.6 ± 2.2^{b}	802 ± 363	273 ± 16^{b}
H.H.Z.36	32.5 ± 6^{b}	20.4 ± 3^{b}	514 ± 281^{b}	520 ± 54^{ac}
Ld 368	29.1 ± 7^{b}	15.7 ± 12.5^{b}	1028 ± 104	583 ± 46^{a}
Madathawalu	28.7 ± 6^{b}	20.2 ± 3.5^{b}	677 ± 149^{b}	355 ± 16^{bc}
Bw 367	29.3 ± 7^{b}	32.5 ± 5.4	1026 ± 133	328 ± 32^{bc}
Pachchaperumal	24.6 ± 6^{b}	29.7 ± 2.1	1047 ± 18	325 ± 89^{bc}
Bg 94-1	29.9 ± 8^{b}	58.6 ± 21.1^{a}	1051 ± 1	286 ± 30^{b}
At 405	27.1 ± 5^{b}	35 ± 19.3	1429 ± 6^{a}	187 ± 27^{b}
At 362	29.3 ± 3^{b}	33.1 ± 15.7	1446 ± 53^{a}	209 ± 36^{b}
Bg 300	34 ± 3^{b}	19.3 ± 2.4^{b}	928 ± 281	279 ± 15^{b}
Bg 352	32.2 ± 2^{b}	18.2 ± 3.5^{b}	904 ± 354	280 ± 16^{b}
Mean ± SE	32 ± 7	27.0 ± 12.0	1019 ± 289	355 ± 144
Probability	< 0.0001	0.0023	0.0002	< 0.0001

Means in each group, followed by a different superscript letter in each column, were significantly different ($p < 0.05$)

Table 5. Correlation coefficients between mineral elements *

	Cr (μg Kg^{-1})	**Zn (μg Kg^{-1})**	**P (μg Kg^{-1})**	**Ca (μg Kg^{-1})**
Cr (μg Kg^{-1})	1.000	-0.257 (0.420)	0.178 (0.581)	0.562 (0.057)
Zn (μg Kg^{-1})		1.000	0.379 (0.225)	-0.403 (0.194)
P (μg Kg^{-1})			1.000	-0.187 (0.562)
Ca (μg Kg^{-1})				1.000

*Values in parenthesis indicate probability level

The correlation coefficients between the minerals in the analysed rice cultivars: Cr, Zn, P and Ca were shown in Table 5. Pearson correlation showed non-significant negative correlation between GI and Cr content in consumed rice (r = -0.108, p = 0.739, n = 12) while non-significant positive correlation revealed with Zn (r = 0.2741, p = 0.389, n = 12) and P content of consumed rice (r = 0.228, p = 0.477, n = 12). It presented a significant negative correlation between Ca content in consumed rice and GI (r = -0.622, p = 0.0308, n = 12) in consumed rice. Pearson correlation showed a significant negative correlation only between Ca content in consumed rice and GI (r = -0.622, p = 0.0308, n = 12) in consumed rice (Figure 1).

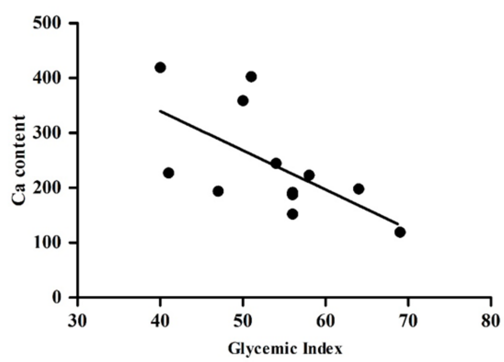

Figure 1. Relationship between GI and Ca (mg) content of the consumed rice portion (r = -0.622, p = 0.0308, n = 12)

Discussion

The group of 14 healthy volunteers of both sex (F=7, M=7, age=20-30 years, BMI=21.5±3 Kg/m2) was selected for the study. As it is reported that BMI or obesity is directly affected by hormonal regulation of blood glucose, especially with abnormalities in insulin secretion, insulin sensitivity, and glucose metabolism (Carroll *et al.*, 2007), subjects with normal BMI were recruited for the study.

It was discovered that the glycaemic indices of various Sri Lankan rice varieties vary greatly. Other studies in different countries have found a wide variation in the glycaemic indices of different rice varieties (Frei *et al.*, 2003; Prasad *et al.,* 2018). The glycaemic indices of 12 tested rice in the current study varied from 40- 69 with the mean value of 53.5 $\pm$ 8.5. Glycaemic responses to meals can vary greatly depending on the method of cooking, the heat used, amount of water used, and time of cooking (Omage and Omage, 2018), which maintained similar conditions when the preparation of rice meal in 12 varieties. GI is a measure of carbohydrate absorption in the small intestine that indicates the effect of other factors in the tested food that can influence the rate of carbohydrate absorption in the small intestine. As to the results of the study, there were significant differences in the glycaemic responses to different rice varieties.

Most GI research determines the available carbohydrate content by the difference, resulting in an overestimation of the available carbohydrate content. Furthermore, resistant starches are excluded from the different methods. As a result, when they are present, they are incorrectly counted as glycaemic or available carbohydrates (Nisanka and Ekanayake, 2016). As a result, the available carbohydrate content was measured directly in this study.

According to the results of this study, every rice type contained approximately the same crude protein levels and moisture, indicating the grains of the rice varieties maturation was uniform. However, as reported in Oko *et al.* (2012) the sugar, starch, crude fibre, crude fat, and ash differed significantly among rice varieties. The differences in the nutritional composition of the rice are dependent on rice variety and the milling process (Kalpanadevi *et al.*, 2018). Reddy *et al*. (2017) found that the contents of various minerals, fats and proteins in pigmented rice were decreased significantly after polishing (9% degree of milling).

However, no specific pattern of significant correlation was found between the proximate composition and the GI values of these tested rice varieties. The rice varieties which having red pericarp contained significantly ($p = 0.0016$) high crude fat content than the rice with white pericarp. However, Pathiraje *et al*. (2010) showed a higher crude fibre content in red pericarp than white but not significantly different crude fat content. It has been proposed that dietary fibre reduce the postprandial blood glucose responses simply by slowing carbohydrate absorption in the small intestine due to the formation of a viscous gel. However, there was no correlation between the dietary fibre content of the tested rice varieties and their GI values.

In contrast to the proximate values of rice, only trace amounts of mineral elements were discovered, particularly for the mineral elements such as chromium, zinc, phosphorous and calcium. This is to be expected given that the mineral content is derived solely from the rice's ash content. According to one study, the ash content of a food sample indicates the mineral elements present in the food sample. More minerals are lost during milling and polishing because more rice bran is removed from the grain (Oko *et al*., 2012). However, there was no significant correlation between mineral content and ash. Nevertheless, this study indicated a significant difference in mineral composition in various rice varieties. The reason could be due to genetic factors or soil mineral content (Oko *et al*., 2012). Hence it revealed a significant negative correlation between calcium and GI. Secretion of insulin hormone is a calcium-dependent biological process that necessitates an increase in calcium for both first- and second-phase insulin secretion, so the food of high calcium content as an ingredient showed a low glycaemic response leading to low GI (Suh *et al*., 2017).

Based on the findings of this study, it is possible to conclude that the GI value varies depending on the rice variety. So as the nutritional and mineral composition of the tested rice varieties. Though the proximate composition and some mineral content did not show any influence on glycaemic response, the rice with high calcium content has a low glycaemic response. So high calcium as an ingredient can be recommended for patients with diabetes since it leads to low GI and low glycaemic response.

Acknowledgements

We thank the Rice Research Development Institute, Bathalagoda, for providing the required quantities of rice, the Department of Medical Laboratory Science, Faculty of Allied Health Sciences, University of Peradeniya for allowing to carry out research. Veterinary Research Institute, Gannoruwa for allowing us to use their laboratory for chemical analysis of rice and Department of Biochemistry, Faculty of Medicine, University of Peradeniya for allowing us to use their laboratory for mineral analysis of rice.

References

Augustin, L. S. A., Kendall, C. W. C., Jenkins, D. J. A., Willett, W. C., Astrup, A., Barclay, A. W., Björck, I., Brand-Miller, J. C., Brighenti, F., Buyken, A. E., Ceriello, A., La Vecchia, C., Livesey, G., Liu, S., Riccardi, G., Rizkalla, S. W., Sievenpiper, J. L., Trichopoulou, A., Wolever, T. M. S. and Poli, A. (2015). Glycemic index, glycemic load and glycemic response: An International Scientific Consensus Summit from the International Carbohydrate Quality Consortium (ICQC). Nutrition, Metabolism and Cardiovascular Diseases, 25:795-815.

Brandão-Lima, P. N., De Carvalho, G. B., Santos, R. K. F., Santos, B. da C., Dias-Vasconcelos, N. L., Rocha, V. de S., Barbosa, K. B. F. and Pires, L. V. (2018). Intakes of Zinc, Potassium, Calcium, and Magnesium of individuals with type 2 diabetes mellitus and the relationship with glycemic control. Nutrients, 10:19-48.

Bur, A., Herkner, H., Woisetschläger, C., Vlcek, M., Derhaschnig, U. and Hirschl, M. M. (2003). Is fasting blood glucose a reliable parameter for screening for diabetes in hypertension? American Journal of Hypertension, 16:297-301.

Canesi, L., Betti, M., Ciacci, C. and Gallo, G. (2001). Insulin-like Effect of Zinc in Mytilus Digestive Gland Cells: Modulation of Tyrosine Kinase-Mediated Cell Signaling. General and Comparative Endocrinology, 122:60-66.

Carroll, J. F., Kaiser, K. A., Franks, S. F., Deere, C. and Caffrey, J. L. (2007). Influence of BMI and Gender on Postprandial Hormone Responses**. Obesity, 15:2974-2983.

Centers for Disease Control and Prevention. (2015). BMI calculation and interpretation.

Cho, S. S., Qi, L., Fahey, G. C. and Klurfeld, D. M. (2013). Consumption of cereal fibre, mixtures of whole grains and bran, and whole grains and risk reduction in type 2 diabetes, obesity, and cardiovascular disease. The American Journal of Clinical Nutrition, 98:594-619.

Della Pepa, G., Vetrani, C., Vitale, M. and Riccardi, G. (2018). Wholegrain intake and risk of type 2 diabetes: Evidence from epidemiological and intervention studies. Nutrients, 10:1288

Esfahani, A., Wong, J. M. W., Mirrahimi, A., Srichaikul, K., Jenkins, D. J. A. and Kendall, C. W. C. (2009). The glycemic index: physiological significance. Journal of the American College of Nutrition, 28:439-445.

Frei, M., Siddhuraju, P. and Becker, K. (2003). Studies on the in vitro starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines. Food Chemistry, 83:395-402.

Hettiaratchi, U. P. K., Ekanayake, S. and Welihinda, J. (2009). Do Sri Lankan meals help decrease blood glucose response ? Ceylon Medical Journal, 54:39-45.

Kalpanadevi, C., Singh, V. and Subramanian, R. (2018). Influence of milling on the nutritional composition of bran from different rice varieties. Journal of Food Science and Technology, 55:2259-2269.

Lin, Y., Berger, L. and Sun, Z. (2018). Regulation of Insulin Sensitivity by Phosphorus. Diabetes, 67:1772.

Nisanka, T. U. S. and Ekanayake, S. (2016). Rice variety and processing: contribution to glycaemic response. Ceylon Medical Journal, 61:159-162.

Oko, A., Ubi, B., Efisue, A. A. and Danbaba, N. (2012). Comparative Analysis of the Chemical Nutrient Composition of Selected Local and Newly Introduced Rice Varieties Grown in Ebonyi State of Nigeria. International Journal of Agriculture and Forestry, 2:16-23.

Omage, K. and Omage, S. O. (2018). Evaluation of the glycemic indices of three commonly eaten mixed meals in Okada, Edo State. Food Science & Nutrition, 6:220-228.

Pathiraje, P. M. H. D., Madhujith, W. M. T., Chandrasekara, A. and Nissanka, S. P. (2010). The Effect of Rice Variety and Parboiling on in vivo Glycemic Response. Tropical Agricultural Research, 22:26-33.

Pizzorno, J. E., Murray, M. T. and Joiner-Bey, H. (2016). The Clinician's Handbook of Natural Medicine. In 3rd ed. Edinburgh,Churchill Livingstone, pp.286.

Prasad, V. S. S., Hymavathi, A., Babu, V. R. and Longvah, T. (2018). Nutritional composition in relation to glycemic potential of popular Indian rice varieties. Food Chemistry, 238: 29-34.

Reddy, C. K., Kimi, L., Haripriya, S. and Kang, N. (2017). Effects of Polishing on Proximate Composition, Physico- Chemical Characteristics, Mineral Composition and Antioxidant Properties of Pigmented Rice. Rice Science, 24:241-252.

Shah, M. and Garg, A. (2019). The relationships between macronutrient and micronutrient intakes and type 2 diabetes mellitus in South Asians: A review. Journal of Diabetes and its Complications, 33:500-507.

Suh, S., Cheol, J., Jin, S., Hwan, J., Kyoung, M., Kyu, D. and Hyeon, J. (2017). Serum calcium changes and risk of type 2 diabetes mellitus in Asian population. Diabetes Research and Clinical Practice, 133:109-114.

Tamaki, N., Ikeda, T. and Funatsuka, A. (1983). Zinc as activating cation for muscle glycolysis. Journal of Nutritional Science and Vitaminology, 29:655-662.

Vlachos, D., Malisova, S., Lindberg, F. A. and Karaniki, G. (2020). Glycemic index (GI) or glycemic load (GL) and dietary interventions for optimizing postprandial hyperglycemia in patients with T2 diabetes: A review. Nutrients, 12:1561.

Wolever, T. M., Jenkins, D. J., Jenkins, A. L. and Josse, R. G. (1991). The glycemic index: methodology and clinical implications. The American Journal of Clinical Nutrition, 54:846-854.

(Received: 9 February 2022, accepted: 30 July 2022)