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Glycaemic index values and physicochemical properties of five brown rice varieties cooked by different domestic cooking methods

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ABSTRACT

Background: The prevalence of diabetes has increased dramatically in recent decades in the regions where people excessively consume white rice. Due to higher nutritional values and bioactive components, low to medium glycaemic index (GI) brown rice could be a potential alternative to white rice in these regions.

Methods: Five varieties, Chiang (CH), Sungyod (SY), Lepnok (LP) from Thailand, Long grain specialty 1 (LS_1) and Long grain specialty 2 (LS_2) from Malaysia were tested for GI. Ten test foods were prepared from 5 varieties by 2 cooking techniques (pressure cooker, PC and rice cooker, RC). Overnight fasted 10 healthy subjects were fed with 25 g glucose as a reference food (RF) on 3 occasions and amount equivalent to 25 g available carbohydrate portion of test food (TF) on 1 occasion in separate days. Fasting and post-prandial capillary blood glucose was measured via finger-prick methods at 0, 15, 30, 45, 60, 90 and 120 min, and the incremental area under curve (iAUC) was determined. The GI of each TF was calculated as percentage of incremental area under curve (iAUC) of TF over RF.

Results: The mean GI values of SY (72 – 81, high), CH and LP (59 – 65, medium) and LS_1 and LS_2 (64 – 73, medium to high) for cooking were discovered by PC and RC methods. The GI did not vary significantly ($p>0.05$) among varieties as well as between cooking methods. GI showed a significant negative correlation with the amylose content ($r = –0.70$, $p<0.05$) and significant positive correlation with cold peak viscosity ($r = 0.80$, $p<0.01$).

Conclusions: All five rice varieties irrespectively of the cooking method used are classified as medium to high GI foods. Medium GI varieties could have potential of being used in diabetic diet. Cooking methods did not significantly alter the glycaemic characteristics of the studied varieties. Amylose content and pasting properties can be used for predicting GI of brown rice. It is urgent to explore low GI brown rice varieties in these regions.

Keywords: Glycaemic index, diabetes, brown rice, cooking methods

BACKGROUND:

The protective effects of low glycaemic index (GI) carbohydrate foods on type II diabetes have been well established [1]. On one hand, the consumption of white rice has been associated with high risk of type II diabetes [2]. On the other hand, the consumption of brown rice (BR) has been associated with improved metabolic indicators [3] and lowering the risk of type II diabetes [4].

The high consumption of white rice in South East Asia has increased the risk of type II diabetes in the region. Therefore, change in feeding practice to brown rice is highly suggested, primarily due to lower GI values (as low as <55) [5]. At the same time, several intrinsic factors such as variety, amylose content [6] and other extrinsic factors like cooking conditions [7–9] have pronounced effects on the GI. In particular, cooking destroys the complex food matrix, enhances digestibility and promotes higher glycaemic response. It also leads to gelatinization where higher degree of deformation of starch structure occurs making it easily accessible to enzyme to act upon [10]. Presence of the intact bran layer in brown rice may limit swelling and leaching of molecules during cooking as well as portion of bran that adheres to starch may delay the action of enzymes leading to a lower glycaemic response.

Rice cooking methods are different in various regions of South East Asia, methods which include open pan boiling, electric cooking using rice cooker (RC), and high pressure cooking using pressure cooker (PC). The use of high temperature and pressure over a short period of time could have the advantages of saving energy, time, and nutrients, with improvement in texture. The GI of white rice and brown rice prepared by boiling method or normal rice cooker method have been extensively studied. Nevertheless, information regarding GI of cooked brown rice by PC is lacking. Therefore, the primary objective of this study was to investigate the GI of five brown rice varieties along with the impact of two cooking methods, PC and RC. Furthermore, the effect of amylose content, peak viscosity, and variety on GI was also determined.

MATERIALS AND METHODS:

Sample collection and preparation: Three Thai varieties of paddies, *Sungyod* (SY), *Chiang* (CH) and *Lepnok* (LP) were grown and stored for one year in Phatthalung Rice Research Centre in Thailand. The paddies were dehusked using rubber roller dehusker (Satake Corporation, Tokyo, Japan) in order to get brown rice. Two commercial long grain brown rice varieties originated in East Coast of Peninsular Malaysia namely *Long Grain Specialty 1* (LS_1) and *Long Grain Specialty 2* (LS_2) (10 months after harvest) were purchased from the local market of Kelantan, Malaysia. Rice samples were vacuum packed and stored at 4 ^{o}C until further analysis. Samples were equilibrated at room temperature before analysis.

Rice cooking procedure and cooking properties: One hundred gram of brown rice (12%, moisture content) was pre-soaked in distilled water for 2 h and cooked by pressure cooker (PC) (4 L capacity, working pressure 80 kPa, Local brand, Thailand) and rice cooker (RC) (4 L, National brand, Japan). Cooking time was determined as the time when there was no opaque core in the cooked rice kernel, observed by pressing between two glass slabs [11]. The amount of water required to cook each 100 g of CH and SY variety was 320 mL and 280 mL, respectively while for remaining three varieties (LP, LS_1 and LS_2) was 300 mL water for PC method. Similarly, each of the variety was cooked in 420 mL water using RC method except for SY that required 400 mL. On average, 15.5 – 16.2 min and 28.2 – 30.3 min were used as optimum cooking time for all five rice varieties using PC and RC method respectively.

Elongation ratio (ER), length/breadth ratio (L/B ratio) and water uptake ratio (WUR) of cooked rice was determined using slight modification according to Singh et al [11]. ER was determined by dividing the cumulative length of 10 cooked kernels by cumulative length of 10 raw kernels. L/B ratio of cooked rice was calculated by dividing the length of 10 cooked kernels by the breadth of 10 cooked kernels. WUR was determined by dividing the weight of cooked rice by initial weight of raw rice. At least three replicate values were generated for ER, L/B ratio and WUR.

Pasting properties: Cooked brown rice was dried at 60 ^{o}C for 6 hours in air drying oven. Both raw rice and cooked rice were separately ground by cyclotec sample mill (Foss cyclotec TM1093, Sweden) and passed through a 250 μm sieve. The moisture content of flour was determined using the hot air oven method [12]. Pasting properties of cooked and raw rice flour were evaluated using cold extrusion (non-alcohol method) by Rapid Visco Analyser (RVA 4D, Newport Scientific, Australia, Thermocline Software version 2.0). Three grams of flour sample (dry basis, d.b.) and 25 mL distilled water were put into a canister, carefully stirred to break the lumps, and then observed for the pasting profiles. The sample was run for 2 min at 25 ^{o}C and the temperature was raised to 95 ^{o}C within 5 min. The sample was held for 3 min at 95 ^{o}C, cooled to 25 °C in 5 min and held at this temperature for another 5 min. The total time for the cold extrusion (non-alcohol) method was 20 min. Parameters such as cold peak, raw peak viscosity, hold viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time were measured.

Glycaemic index:

Subject characteristics: A total of 10 healthy subjects, age between 21–50 years, BMI between 18.0 and 24.9 kg/m^2, fasting blood glucose ≤6.0 mmol/L participated in the study. The eligible subjects had stable weight for last three months and absent of food restriction, dieting or abnormal eating behaviours. They were free of AIDS, hepatitis, renal diseases, coronary disease, and irritable bowel diseases. Written consent was obtained from all subjects. The study protocol was approved by the ethics committees of Universiti Sains Malaysia (USM), Kelantan, Malaysia (Approved Ethical No. FWA reg. no. 00007718; IRB reg. no. 00004494).

Study design: This experiment was conducted according to FAO/WHO [14] protocol. Subjects were informed to fast from 9:00 pm on the previous evening until the morning (7:00 am) of the experiment. They were instructed not to drink alcohol, consume heavy meals, or exercise vigorously on previous day, in addition to not walking or cycling for a long distance in order to attend the test. Each subject attended 3 test sessions for standard glucose as reference food (RF) and 10 sessions (5 varieties, two cooking methods) for ten test foods (TF) in random days. There was a minimum gap of two days for each subject in between two test sessions. In the test session, fasting blood glucose level of the subject was measured (0 min) at first. Then, RF (25 g in 250 mL drinking water) or 25 g available carbohydrate portion (Table 1) of TF was consumed by the subject within 15 min. Capillary blood samples were collected using finger prick method and analysed for blood glucose (mmol/L) by dry chemistry analyzer (Reflotron Plus, Roche, Germany) at 15, 30, 45, 60, 90 and 120 min from the beginning of consumption of given food. Subjects were allowed to drink water (250 mL) during consumption of TF.

The exact amount of cooked rice was calculated on the basis of proximate composition and total dietary fibre to get 25 g available carbohydrate portion of each variety (Table 1). Glucose (Glucolin^{TM}) was used as RF and prepared by dissolving 25 g of glucose powder in 250 mL drinking water for the experiment purpose.

Table 1. Available carbohydrate per 100 g of cooked rice, portion size (25 g available carbohydrate) and cooking procedure of 5 varieties of brown rice (BR)

Rice variety	Cooking method	Available carbohydrate of cooked rice (g/100 g)[a]	Portion size (25G available carbohydrate basis)[b]	Cooking procedure[c] (On 100 g BR basis)
CH	PC	78.1	92.2	320 mL water and cooked 16.2 min
	RC	80.1	89.8	420 mL water and cooked for 30.2 min
SY	PC	78.9	91.3	280 mL water and cooked for 15.5 min
	RC	79.5	90.5	400 mL water and cooked for 30.1 min
LP	PC	79.6	90.5	300 mL water and cooked for 15.9 min
	RC	80.5	89.4	420 mL water and cooked for 30.3 min
LS_1	PC	82.9	86.9	300 mL water and cooked for 15.8 min
	RC	81.8	88.0	420 mL water and cooked for 28.3 min
LS_2	PC	81.9	87.9	300 mL water and cooked for 15.5 min
	RC	83.8	85.9	420 mL water and cooked for 28.2 min

[a]measured in dry basis; [b]measured in wet basis; [c]cooking time determined by pressing the cooked kernels between two glass plates until the absence of opaque core; CH, Chiang; SY, Sungyod; LP, Lepnok; LS_1, Long grain specialty 1; LS_2, Long grain specialty 2; PC, Pressure cooker; RC, Rice cooker

Calculation of GI: Blood glucose response after consumption of RF and TF from each subject were used to find incremental areas under blood glucose response curves (iAUCs) by applying trapezoid method (area below fasting baseline was ignored) [14]. If coefficient of variations (CV) of iAUC of three observations of RF for the same subject were found to be higher than 22%, the two closest iAUCs were taken for GI calculation [15]. GI was calculated with the following formula.

$$GI = \frac{\text{Incremental area under blood glucose response curve (iAUC) for test food}}{\text{Incremental area under blood glucose response curve (iAUC) for reference food}} \times 100$$

The GI of RF was considered 100. The GI of each TF was calculated as the mean GI from all subjects. Subjects were excluded from the evaluations when their GI exceeded 2 standard deviations (SD) of the mean GI of the given TF.

Statistical analysis: Data are expressed as means ± standard deviation (SD) except results of GI and iAUC as mean ± the standard error of the mean (SEM). Repeated measurements of ANOVA was used to assess data at $p<0.05$. Relationship between GI and physicochemical parameters was assessed using Pearson correlation coefficient. Data analysis was done using SPSS 20.0 software (SPSS, Inc., Chicago, IL) and MS Excel 2007.

RESULTS AND DISCUSSION:

Cooking properties: The effect of PC and RC methods on cooking properties is shown in Table 2. The optimum cooking time for PC (15.5 – 16.2 min) was significantly different ($p< 0.05$) from RC (28.2 – 30.3 min). PC reduced the gelatinization time of brown rice by half compared to RC. The WUR, L/B ratio and ER properties among 4 varieties were not significantly ($p>0.05$) affected by the cooking methods except for ER properties of LP variety. The presence of pericarp, seed coat and aleurone layer in brown rice had a tendency to increase the cooking time [16]. It has been reported that heat and water transfer required for gelatinization of starch under pressure is faster than in normal cooking [10]. Unlike white rice kernels, cooked brown rice kernels showed fissures along the ventral surface, resulting in exposed endosperm due to swelling and bursting of bran layer

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Table 2. Cooking properties of five varieties of brown rice by two methods

Variety	Cooking Method	MCT (min)	WUR	L/B ratio	ER
CH	PC	16.2 ± 0.2	2.12 ± 0.2	2.88 ± 0.2	1.23 ± 0.1
	RC	30.2 ± 1.0*	2.13 ± 0.1	2.95 ± 0.1	1.23 ± 0.0
SY	PC	15.5 ± 0.6	2.11 ± 0.2	2.39 ± 0.2	1.13 ± 0.1
	RC	30.1 ± 0.2*	2.07 ± 0.1	2.78 ± 0.4	1.09 ± 0.1
LP	PC	15.9 ± 0.5	1.98 ± 0.0	2.8 ± 0.3	1.06 ± 0.1
	RC	30.3 ± 2*	1.92 ± 0.1	2.61 ± 0.4	1.40 ± 0.2*
LS_1	PC	15.8 ± 0.3	2.26 ± 1.0	3.45 ± 0.4	1.21 ± 0.1
	RC	28.3 ± 2.0*	2.21 ± 0.1	3.2 ± 0.3	1.33 ± 0.1
LS_2	PC	15.5 ± 0.4	2.13 ± 0.0	3.06 ± 0.1	1.18 ± 0.1
	RC	28.2 ± 0.2*	2.12 ± 0.1	3.01 ± 0.4	1.38 ± 0.1

Values are mean ± SD; Values with * represent significant difference of same variety of brown rice between PC and RC methods ($p<0.05$); CH, Chiang; SY, Sungyod; LP, Lepnok; LS_1, Long grain specialty 1; LS_2, Long grain specialty 2; PC, Pressure cooker; RC, Rice cooker; MCT, minimum cooking time; WUR, water uptake ratio; L/B ratio, Length/breadth ratio; ER, elongation ratio.

Pasting properties of raw and cooked rice flours: PC and RC cooking methods induced significant changes in pasting properties of five rice varieties (Table 3). Cold peak viscosity, an indication of good hydration properties, of cooked rice flours was found higher than raw rice flours [17]. Cooking disintegrates starch crystallinity, resulting in the rise of viscosities of cooked flours in cold temperature. Pasting properties such as raw peak, breakdown, setback and final viscosities of cooked rice decreased sharply while peak time increased. Significant decrease in breakdown, setback and final viscosity of cooked flours demonstrated the effectiveness of cooking to disrupt the crystalline starches.

Table 3. Pasting properties of raw and cooked brown rice flours of five varieties

		Brown rice variety				
Pasting property	Method	CH	SY	LP	LS_1	LS_2
Raw peak viscosity (cP)	Raw	3344 ± 75	2364 ± 25	3263 ± 47	4252 ± 52	3682 ± 17
	PC	370 ± 2	1171 ± 8	657 ± 13	1312 ± 19	881 ± 9
	RC	404 ± 10	1888 ± 115	768 ± 20	1482 ± 153	1031 ± 25
Breakdown viscosity (cP)	Raw	428 ± 32	507 ± 32	1337 ± 125	1380 ± 46	1066 ± 25
	PC	0.33 ± 1	102 ± 32	22 ± 2	190 ± 60	65 ± 7
	RC	3 ± 2	18 ± 9	1 ± 2	90 ± 39	8 ± 11
Final viscosity (cP)	Raw	4309 ± 96	4000 ± 30	6524 ± 53	5723 ± 103	5120 ± 158
	PC	584 ± 8	2168 ± 22	1143 ± 19	2493 ± 88	1478 ± 25
	RC	653 ± 31	3790 ± 219	1388 ± 40	3014 ± 208	1857 ± 19
Setback viscosity (cP)	Raw	1392 ± 167	2143 ± 47	4598 ± 108	2851 ± 98	2516 ± 136
	PC	213 ± 7	1099 ± 35	512 ± 11	1370 ± 58	663 ± 19
	RC	246 ± 24	1921 ± 95	619 ± 23	1622 ± 92	834 ± 19
Peak time (min)	Raw	8.6 ± 0	8.3 ± 0	8.1 ± 0	8.8 ± 0	8.9 ± 0
	PC	9.9 ± 0	8.4 ± 0	8.7 ± 0	8.2 ± 0	8.5 ± 0
	RC	9.9 ± 0	9.5 ± 0	10.0 ± 0	9.3 ± 0	9.8 ± 0
Cold peak viscosity (cP)	Raw	17 ± 1	19 ± 3	18±3	18 ± 2	17 ± 3
	PC	34 ± 1	254 ± 12	57±2	88 ± 8	59 ± 5
	RC	31 ± 2	133 ± 7	48±1	82 ± 8	51 ± 4

Data are mean ± SD; CH, Chiang; SY, Sungyod; LP, Lepnok; LS_1, Long grain specialty 1; LS_2, Long grain specialty 2; PC, Pressure cooker; RC, Rice cooker

Raw peak viscosity was higher for raw flours compared to cooked flours. Collado & Corke [18] reported that hydrothermally treated sweet potato starch gave lower raw peak than untreated, similar to the present study. Peak viscosity of raw flours indicated swelling of starch granules and the corresponding high values referred to the high swelling capacity [19]. In this study, breakdown viscosity (0.33 – 190 cP*)* of cooked flours was found significantly lower than of raw flours (428 – 1380 cP). Previous study on sweet potato starch has also demonstrated similar results due to hydrothermal treatment [18]. Furthermore, raw starch contains starch granules, which absorbs water and swells rapidly to give a maximum viscosity (raw peak viscosity), but ruptures due to bursting of granules which has a tendency to lower the viscosity value as breakdown viscosity [19]. In this current study, low breakdown viscosity of cooked flours indicated presence of low or negligible ungelatinized starch.

Glycaemic index: The demographic characteristics of subjects are presented in Table 4. The average age was 26.5±1.8 years and the average BMI was 23.6±1.4 Kg/m^2, respectively. The average coefficient of variation (CV) of blood glucose responses of 10 subjects for the RF (standard glucose) was 11.2%.

Table 4. Subject characteristics

Gender (no.)	Age (y)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Male (n= 5)	27.8±3.5	168.6±4.5	69.4±7.2	24.5±3.0
Female (n=9)	25.2±2.6	157.7±6.0	55.7±7.4	22.6±3.0
Total (n=14)	26.5±1.8	163.1±7.7	62.5±9.7	23.6±1.4

Data are mean ± S.D.; BMI, Body mass index

Figure 1 shows the average postprandial blood glucose response of 10 healthy subjects after consumption TF and RF foods. Average blood glucose level of TF (CH and LP) reached the highest concentration at 30 min postprandially, while that of SY, LS_1 and LS_2 at 45 min by PC and RC methods. The blood glucose response between TF and RF was not significantly different ($p>0.05$) at 0 min (fasting level), 30 min and 60 min, but was significantly different for CH (RC), SY (RC) and LP (RC) at 15 min and CH (PC), LP (RC) at 45 min. Furthermore, the blood glucose response of CH (RC), SY (PC), LS_1 (PC) and LS_2 (RC) at 90 min and CH (RC), LP (PC), LP (RC), LS_1 (PC) and LS_2 (PC) at 120 min were significantly different ($p<0.05$) to that of RF.

Table 5 summarizes the results of mean iAUC and GI values of five varieties of brown rice prepared by two cooking methods. The mean iAUC (mmol x min/l) of 10 subjects for RF was 162 ± 15 (mean ± SEM). For GI calculation, the mean iAUC (RF) of individual subject obtained from blood glucose response of RF food who were fed on 2 or 3 occasions was used. Among 5 varieties, CH and LP prepared by both cooking methods showed medium GI values. GI values (mean ± SEM) of CH ranged from 58 ± 8 (PC) to 65 ± 7 (RC) while that of LP ranged from 59 ± 6 (PC) to 62 ± 10 (RC). CH (PC) recorded the lowest GI (58) and SY (PC) had the highest GI (81). GI values between PC and RC cooked rice of same variety did not differ significantly ($p>0.05$). This indicates that minimum cooking by either method has an insignificant effect on hydrolysis of carbohydrates induced by digestive enzymes.

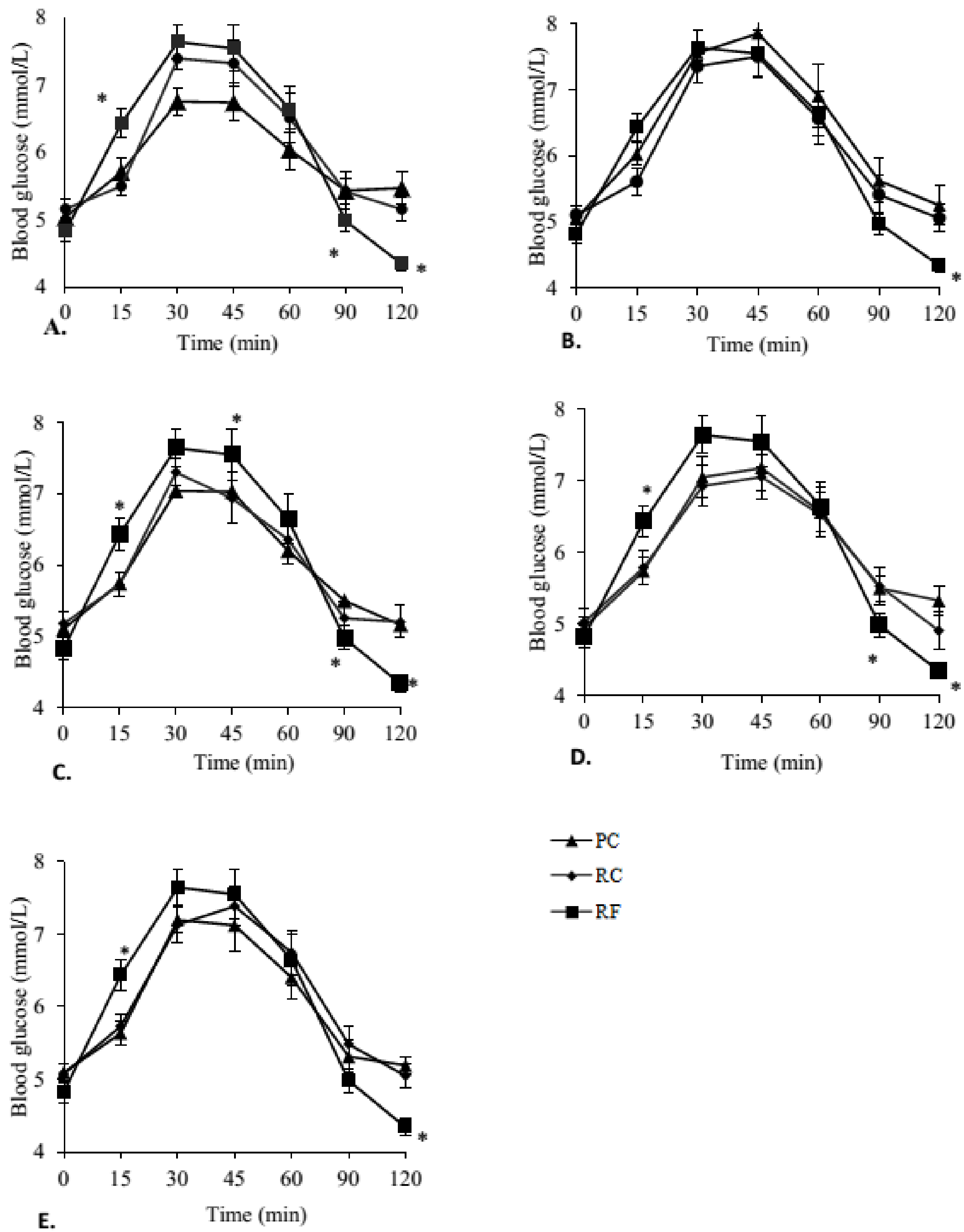

Figure 1. Blood glucose response curves of reference glucose food (RF), pressure cooker (PC) and rice cooker (RC) cooked rice: CH (A), SY (B), LP (C), LS_1 (D) and LS_2 (E). Asterisk indicates a significant difference of blood glucose level at the corresponding time among RF, PC and RC ($p<0.05$). Values are mean ± SEM, Number of subjects = 10).

However, GI values for PC cooked CH, LP and LS_2 varieties were 4 – 10% lower than the values observed for RC cooked varieties while PC cooked SY and LS_1 varieties were 12 – 14% higher than same varieties cooked by RC. The two cooking methods were different in terms of time and temperature of cooking. In the present study, domestic PC that works on elevated temperature due to higher pressure (approximately 80 kPa) maintained inside the PC resulted in reduction of MCT [20] by half compared to RC. But the fact that WUR, L/B ratio and ER (Table 2), for the majority of the varieties were not significantly affected, indicated less impact of cooking method on cooking properties. Pasting properties such as breakdown viscosity was low for cooked flours, an indication of negligible presence of ungelatinized starches. These properties also indicated that MCT in either cooking method was sufficient to cause gelatinization of starch present in brown rice.

A wide range of GI values have been reported for rice. A previous study reported GI values of BR and white rice to be 66 and 72 respectively [21]. A recent study reported and classified American-grown jasmine rice to have high GI (96 – 116) food [22]. Another study of 12 rice products from three commercial rice varieties found the GI of rice to fall in the range of 64 to 93, and additionally recommended the need of further work on GI of rice of different varieties from different locations [5]. The GI values of white rice (boiled) and brown rice (boiled) have been reported as 73 ± 4 and 68 ± 4 by Atkinson et al [23]. The present study revealed that GI of BR lied in a range of 58 – 81, in agreement with previous studies.

Table 5. iAUC and GI values of five varieties of cooked brown rice [a]

Variety	PC method			RC method			Mean iAUC (RF) [b] (mmol x min/l)
	iAUC (mmol x min/l)	GI	GI category	iAUC (mmol x min/l)	GI	GI Category	
CH	95 ± 16	58 ± 8	Medium	104 ± 15	65 ± 7	Medium	162 ± 15
SY	140 ± 25	81 ± 9	High	117 ± 20	72 ± 10	High	
LP	94 ± 13	59 ± 6	Medium	98 ± 18	62 ± 10	Medium	
LS_1	114 ± 19	73 ± 11	High	110 ± 20	64 ± 6	Medium	
LS_2	105 ± 14	65 ± 6	Medium	127 ± 15	72 ± 7	High	

Values are mean ± SEM (No. of subjects = 10); iAUC, Incremental area under curve; GI, Glycaemic index; CH, Chiang; SY, Sungyod; LP, Lepnok; LS_1, Long grain specialty 1; LS_2, Long grain specialty 2; PC, Pressure cooker; RC, Rice cooker; RF, Reference food.

[a] No significant difference exists between GI values of same variety due to PC and RC methods ($p>0.05$).

[b] iAUC for RF is calculated separately to each subject and applied to calculate GI but the given value represents only the mean iAUC (RF) of 10 subjects.

The brown rice varieties in the present study could be classified according to amylose content to be low amylose (SY, 12.5%) and medium (LP, 20.5%, LS_1, 21.0%, LS_2, 20.9%) and high amylose (CH, 25.7%). Cooking properties, as well as post prandial glucose response, can be affected by the amylose content of rice [10]. An increase in amylose content leads to slower rate of digestion due to the formation of amylose-lipid complexes [7, 24]. In this respect, lower GI value of CH and higher of SY varieties have supported the previous study. However, LP, LS_1 and LS_2 with similar amylose content varieties showed GI values in the range of 59 – 73. Such variations in GI values could be explainable since GI variations might occur due to variations in gelatinization properties due to size of starch granule, porosity, presence of non-starch portions as well as presence of thick pericarp layer rather than amount of amylose alone [25].

As mentioned previously, cooking with PC and RC methods significantly changed the starch properties of raw rice (Table 3). This could be a reason for the variation in GI values for example CH and LP (58 – 65) with relatively lower raw peak viscosity (370 – 768 cP) and final viscosity (584 – 1388 cP). Lower raw peak viscosity indicates the slow hydration and swelling of cooked rice flours. Although gelatinization of CH and LP is complete, as indicated by very low breakdown viscosity (0.33 – 22 cP) and setback viscosity (213 – 619 cP), resulted in difference in raw peak viscosities, final viscosities and the GI values. In this study, the results also revealed that GI values were slightly higher for CH, LP and LS_2 using the RC method than with the PC method. However, the differences were not statistically significant, which could be explainable by the biological variations due to subjects as well as varietal differences of rice. A previous study revealed that *in-vitro* digestibility of rice flours was independent of supra-molecular structure and likely to be governed by physicochemical factors other than particle size, cell wall intactness and non-starch polysaccharides [26]. Researchers have identified several associated factors which influence GI of starchy foods. For example, a recent study revealed that processing techniques such as steaming and baking caused marked differences on starch digestibility and hence the GI values [27]. High water absorption, swelling as well as high degree of gelatinization due to difference in processing conditions may influence enzymatic action of digestive enzymes on starch [26].

Compared to many varieties of brown rice in Thailand, SY variety is among the most popular for its antioxidant properties [28]. Despite the presence of higher phenolic and flavonoid components in SY variety, people with high risk of diabetes should be aware of its higher GI values. On the other hand, results of pasting properties showed that SY rice could be suitable for baby food preparations. It is well documented that brown rice is highly beneficial due to its high dietary fibre, anti-oxidant properties of anthocyanin, flavonoid and germ oil. In light of these other studies, in addition to the present study, GI values cannot be overlooked. The rice varieties such as CH and LP (medium GI) could impart health beneficial effects especially for diabetics. Long grain LS_1 and LS_2 are popular brown rice varieties in the Malaysian community, but the GI value which is in higher GI range indicates its potential of hyperglycaemic effects.

Correlation between GI and physicochemical properties: Correlation between GI and selected physicochemical properties of cooked rice was established. A significant negative correlation was observed between GI and amylose content of brown rice (r = –0.70, p=0.02). This indicated that high amylose rice elucidated low GI and vice-versa, similar results were reported by Brand-Miller [5]. Among RVA pasting properties, only cold peak viscosity showed significant positive correlation with GI (r = 0.80, $p<0.01$).This indicated that cold peak viscosity given by RVA might be a useful predictor of the GI values of cooked brown rice.

CONCLUSION:

In this study, the GI values and other quality parameters of five varieties of brown rice were investigated using PC and RC methods. The five varieties of brown rice were categorized as medium to high GI foods. The cooking method did not affect the GI value of rice, but some differences were observed in terms of rice variety. Among the 5 brown rice varieties, LP and CH could be recommended for diabetic patients due to its lower GI characteristics. However, SY variety of high GI value could be inappropriate for diabetic patients, instead being more suitable for baby foods due to its antioxidant function and properties. GI was found positively correlated with cold peak viscosity while being negatively correlated with amylose content. Understanding the GI values of these 5 varieties can help consumers especially in these areas to choose the right variety of rice as a means to control their blood glucose. Cold peak viscosity could be one of the potential predictor for the GI. Therefore, further in-depth study may be needed.

Competing Interests: The authors have no conflict of interest.

Authors' Contributions: All authors have contributed to this study.

Abbreviations: GI, Glycaemic index; CH, Chiang; SY, Sungyod; LP, Lepnok; LS_1, Long grain specialty one; LS_2, Long grain specialty two; PC, Pressure cooker; RC, Rice cooker; RF, Reference food; TF, Test food; iAUC, Incremental area under curve; ER, Elongation ratio; L/B, Length/Breadth; WUR, Water uptake ratio; M.C., Moisture content; BR, Brown rice; CV, Coefficient of variations; SD, Standard deviation; SEM, Standard error of mean; MCT, Minimum cooking time; RVA, Rapid visco analyser

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