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Glycemic index of ten commercially Indonesian rice cultivars

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Glycemic index of ten commercially Indonesian rice cultivars

F Kusmiyati, D R Lukiwati, B A Kristanto and B Herwibawa

Laboratory of Physiology and Crop Breeding, Faculty of Animal and Agricultural Sciences, Diponegoro University, Tembalang Campus, Semarang 50275, Central Java, Indonesia

E-mail: bagus.herwibawa@live.undip.ac.id

Abstract. Ten Indonesian rice cultivars (Inpari 32, Sintanur, Inpago Unsoed 1, Sulutan Unsrat 2, Memberamo, Way Apo Buru, Bestari, Pepe, Situ Bagendit, and Logawa) were analysed for glycaemic index (GI). Wistar rats were randomly selected and after overnight fast were given a portion containing 0.44 g available carbohydrate of different cultivars cooked rice (test foods) or glucose (reference food) on separate occasions. Blood glucose responses were determined at fasting and during the postprandial periods over the next 2 h and we calculated the incremental area under the blood glucose response curve (IAUC). GI value was determined by dividing IAUC for test foods by IAUC for reference food and multiplying by 100. There were significant differences ($p < 0.001$) between GI values for Inpari 32 (74.54 ± 4.68), Sintanur (91.36 ± 1.28), Inpago Unsoed 1 (94.11 ± 5.93), Sulutan Unsrat 2 (83.56 ± 5.87), Memberamo (92.78 ± 3.69), Way Apo Buru (71.53 ± 7.71), Bestari (87.76 ± 12.69), Pepe (70.61 ± 10.69), and Situ Bagendit (81.81 ± 5.63) rice cultivars and all classified as high GI. However, Logawa (54.39 ± 1.49) cultivar was classified as low GI. Therefore, we have an urgent need to develop low GI rice cultivars via breeding technologies.

1. Introduction

Rice (*Oryza sativa*) remains one of the most commonly eaten staple foods in the world [1]. It is a rich source of carbohydrate in European, Africa and Asia, which provides 700 calories/day-person [2]. Since the mid 1960, many high-yielding cultivars of rice have since been developed in Asia [3], which rice cultivation technologies were developed continuously [4]. Different cultivars of rice seed vary in characteristics and can be identified based on their size, shape, color, and texture, or by determining the chemical attributes [5]. Thus, the cultivars can either be short-grain (< 5.5 mm), medium-grain (5.51-6.6 mm), long-grain (6.61-7.5 mm), or extra-long-grain (>7.51 mm), and bold-grain (<2), medium-grain (2-3), or slender-grain (>3) on the basis of length/width ratio [6], and superfine (> 3), fine (2-3), or coarse (< 2) on the basis of length/breadth ratio [7], and waxy (1-2 %), very low-amylose (2-12%), low-amylose (12-20%), intermediate-amylose (20-25 %) and high-amylose (25-33%) [8].

Higher consumption of white rice may lead to increased risk of developing type 2 diabetes mellitus in Asian populations [9 - 11]. The GI of rice renders it the main contributor to dietary glycemic load in many Asian countries [12]. However, the genetics of GI remain unclear so cultivars development targeting the dietary management and prevention of type 2 diabetes have not been emphasized in rice breeding programs [13]. The GI is a system of physiological carbohydrate-classification based on glycemic response after consumption of a carbohydrate-containing test food relative to the response to a reference food [14]. The GI values can be classified into low (≤ 55), medium (55-69) or high (≥ 70)

[15]. Different cultivars of rice may have different GI, apart from diverse cooking characteristics [16]. The GI of rice cultivars ranges from a low of 48 to a high of 92, with an average of 64 [17].

In Indonesia, diabetes affects more than 7 million people [18], despite the prevalence is relatively low of 5.7 % [19]. Indonesian thinks they have not really had meal before they eat rice, although they may have eaten some other foods [20]. Therefore, low GI rice have been reported to produce effects of beneficial on glycemic control, and hence could be able to help in the dietary management and prevention of diabetes [21]. However, there remains a paucity of information available on the GI of commercially rice cultivars in Indonesia and it is clearly needed to determine its GI. Health professionals will use this information to provide dietary advice, and a secondary objective of the research was to offer an insight as to whether programs of rice breeding have changed the GI of several rice cultivars commercially available and widely consumed in Indonesia.

2. Materials and methods

2.1. Subjects

Sixty six healthy, non-diabetic, male Wistar rats (*Rattus norvegicus* albino) (61.47 ± 9.44 g; aged 3-4 weeks) were then given *ad libitum* access to food and water and housed in metabolic cages. Body weight was recorded to the nearest readability 0.0001 g using the analytical balance (Ohaus Pioneer PA214, Ohaus Corp., NJ, USA). Subjects were excluded if they were overweight and their fasting blood glucose value was > 110 mg/dl. The period of adaptation was 7 days and were then experimental period began. Ethical approval was obtained from the Commission of Ethics of Medical and Public Health Research, Faculty of Public Health, Diponegoro University.

2.2. Test/reference foods

Ten commercial cultivars of Indonesian rice were selected as test foods for the study (Table 1). The chemical composition of test foods were performed for moisture (method 934.01), ash (method 942.05), crude protein (method 954.01), fat (method 920.39), and crude fiber (method 962.09) according to the methods of Association of Official Analytical Chemists [22]. Total carbohydrate content was determined by calculation using proximate difference [23]. The available carbohydrate content was total carbohydrate by difference minus crude fiber, and the test food size was calculated as (100/available carbohydrates) x dose [24]. Animal dose (mg/kg) = human equivalent dose (mg/kg) / (animal weight (kg) / human weight (kg)) $^{0.33}$ [25]. Food energy (kCal/g) = (crude protein x 4) + (fat x 9) + (carbohydrate x 4) [26]. All test foods were tested in dehusked form (non-parboiled). They were tested as 0.44 g equivalents available carbohydrate (Table II) and compared with a reference food. The reference food is 0.44 g of dextrose (D (+) Glucose monohydrate, Merck KGaA, Germany) dissolved in water (w/v). The test foods were cooked to completion in the same way using an electronic rice cooker (Miyako MCM-606A, PT. Kencana Gemilang, Tangerang, Indonesia). All directions provided in the rice cooker's instruction manual were followed including the amount of water to be added (1:6 w/v).

2.3. Study protocol

Experimental protocol was used in this research to determine the GI value adapted as described by [27]. During the adaptation and experimental periods, temperatures were always maintained at 21 ± 1 ^{0}C, and illumination was provided by alternating periods of 12 h of light and dark. After the seventh day of adaptation, the subjects were randomly assigned for the analysis of the postprandial blood glucose response and these animals were then excluded from the next assigned. The popular free internet-based random number generator was used in producing randomization (www.psychicscience.org/random.aspx). After a 10 – 12 h overnight fast, blood samples were taken from the tail vein at fasting before consumption of test/reference foods. Glucose levels were measured by blood glucose meter (GlucoDr, All Medicus Co., Ltd., Gyeonggi-do, Republic of Korea; maximal reading 600 mg/dl), and the method has been proved to be reliable for blood glucose determination in rats [28 – 30]. After the fasting blood glucose measurement, subject ingested the test food which was completely consumed in a period of 20 min, and the first blood sample was taken exactly 15, 30, 45, 60, 90, and 120 min afterward. Subjects were served equivalent available carbohydrate of ten test food once each and the reference food three times for a total of thirteen tests in random order on separate days, with a seven days gap among measurements for minimizing carryover effects.

Table 1. General characteristics of test foods

Rice cultivars	Thousand-Seed Weight (g)	Seed Size	Seed Shape	Whole-Rice Color	Cooked-Rice Texture
Inpari 32	27.10	Extra long	Slender	Brown	Smooth
Sintanur	27.40	Extra long	Medium	Brown	Smooth
Inpago Unsoed 1	27.70	Extra long	Slender	Brown	Smooth
Sulutan Unsrat 2	27.00	Extra long	Slender	Brown	Smooth
Memberamo	27.00	Extra long	Slender	Brown	Smooth
Way Apo Buru	27.00	Extra long	Slender	Brown	Smooth
Bestari	27.71	Extra long	Slender	Brown	Smooth
Pepe	27.00	Extra long	Slender	Brown	Smooth
Situ Bagendit	27.50	Extra long	Slender	Brown	Smooth
Logawa	27.00	Extra long	Slender	Brown	Hard

2.4. Determination of the glycaemic index
For each of the test food and the reference, the area under the curve has been determined as the incremental area under the blood glucose response curve (IAUC) and were calculated geometrically using the trapezoid rule, ignoring the area beneath the fasting baseline. The GI value was calculated by dividing IAUC for test food by IAUC for reference food and multiply the result by 100 [16].

2.5. Statistical analysis
Data were analyzed using Statistical Analysis System software (SAS University Edition, SAS Institute Inc., North Carolina, USA) [31]. Standard descriptive statistics were used to describe data as means and standard deviations (SD). The interindividual variability of the three reference foods were investigated by determining the coefficient variation (CV). The statistical differences in the IAUC and GI values were evaluated using the generalized linear model. Post hoc multiple pairwise comparisons using the Tukey test were carried out. A significance level of $p < 0.05$ was used for all tests.

3. Results
The nutrient composition of the ten rice cultivars (cooked rice) are presented in Table 2 and 3. The moisture content was 63.17 – 77.89 %. The rice contained of protein and fat were in the range of 2.02 – 5.56 and 0.10 – 0.24 %, respectively, whereas crude fiber varied between 0.43 – 1.83 %. The available carbohydrate were 17.67, 21.00, 19.91, 23.19, 32.73, 24.28, 30.73, 28.66, 27.30, 23.84 for Inpari 32, Sintanur, Inpago Unsoed 1, Sulutan Unsrat 2, Memberamo, Way Apo Buru, Bestari, Pepe, Situ Bagendit, and Logawa rice cultivars, as they provide food energy in the range of 87.6 – 146.99 kCal/g. The interindividual variation in glycaemic response to the reference food (glucose) was 9.73 %. There was no significant difference ($p=0.299$) among the ten cultivars of rice in the mean fasting blood glucose.

Table 4 and Figure 1 summarizes the results of the mean IAUC and GI values for all rice cultivars. The interindividual variation of the ten rice cultivars was 14.58 %. Statistical data analysis of the IAUC values indicate significant difference among the ten rice cultivars ($p < 0.001$). In addition, the ten rice cultivars exhibited GI values ranged from 54.28 (Logawa) to 94.11 (Inpago Unsoed 1). There was also significant difference in the GI values among the ten rice cultivars ($p < 0.001$). Tukey's post-hoc analysis showed that the GI of Inpago Unsoed 1 differed significantly from that of Inpari 32 ($p < 0.001$), Way Apo Buru ($p < 0.001$), Pepe ($p < 0.001$), and Logawa ($p < 0.001$). Significant differences were observed between Logawa and the other rice cultivars ($p < 0.001$ – $p = 0.006$). According to the three classifications of GI, the nine rice cultivars fell within the high-GI classification (≥ 70). However, Logawa is classified as low-GI cultivars of rice (≤ 55).

Table 2. Moisture, ash, crude protein, fat, and crude fiber of ten commercially Indonesian rice cultivars (g/100 g of cooked rice)

Rice cultivars	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)	Crude Fiber (%)
Inpari 32	77.89 ± 0.30	0.66 ± 0.01	3.42 ± 0.08	0.36 ± 0.01	0.43 ± 0.00
Sintanur	75.65 ± 0.77	0.36 ± 0.04	2.89 ± 0.16	0.10 ± 0.00	0.53 ± 0.00
Inpago Unsoed 1	77.58 ± 0.39	0.37 ± 0.05	2.02 ± 0.20	0.12 ± 0.00	0.57 ± 0.00
Sulutan Unsrat 2	73.74 ± 0.30	0.31 ± 0.05	2.61 ± 0.10	0.15 ± 0.01	0.51 ± 0.00
Memberamo	63.17 ± 0.18	0.57 ± 0.04	3.14 ± 0.08	0.39 ± 0.01	1.39 ± 0.00
Way Apo Buru	71.38 ± 0.50	1.05 ± 0.05	2.85 ± 0.10	0.44 ± 0.01	0.81 ± 0.00
Bestari	64.53 ± 0.21	0.56 ± 0.03	3.83 ± 0.14	0.35 ± 0.01	1.58 ± 0.00
Pepe	64.45 ± 0.19	0.92 ± 0.05	5.56 ± 0.05	0.41 ± 0.01	1.83 ± 0.01
Situ Bagendit	68.74 ± 0.12	0.48 ± 0.04	3.11 ± 0.10	0.37 ± 0.01	1.64 ± 0.00
Logawa	72.07 ± 0.39	0.89 ± 0.05	2.74 ± 0.10	0.46 ± 0.01	1.59 ± 0.00

4. Discussion

The research reports on the GI of rice are of great importance as the world's populations, particularly Indonesian, have associated with higher risk to develop type 2 diabetes [32]. Different rice cultivars may exhibit different physico-chemical characteristics and hence can have different GI values [12]. Chiu and Stewart [33] reported that white rice has a high GI and associates with the higher glycemic response to the lower amylose content. The other study performed that replacing the same amount of brown rice for white rice facilitated the prevention of type 2 diabetes [34]. However, rice cultivars showed the similar amylose content can differ in starch digestion rate and glycemic response due to different gelatinization [35].

Table 3. Total carbohydrate, available carbohydrate, food energy and portion size of ten commercially Indonesian rice cultivars (g/100 g of cooked rice)

Rice cultivars	Total Carbohydrate (%)	Available Carbohydrate (%)	Food Energy (kcal/g)	Portion Size (g)
Inpari 32	17.67 ± 0.40	17.24 ± 0.40	87.60 ± 1.19	2.55
Sintanur	21.00 ± 0.97	20.47 ± 0.97	96.46 ± 3.24	2.15
Inpago Unsoed 1	19.91 ± 0.64	19.34 ± 0.64	88.79 ± 1.74	2.27
Sulutan Unsrat 2	23.19 ± 0.46	22.68 ± 0.46	104.55 ± 1.35	1.94
Memberamo	32.73 ± 0.31	31.34 ± 0.31	146.99 ± 0.83	1.40
Way Apo Buru	24.28 ± 0.66	23.47 ± 0.66	112.48 ± 2.15	1.87
Bestari	30.73 ± 0.39	29.15 ± 0.39	141.39 ± 0.89	1.51
Pepe	28.66 ± 0.30	26.83 ± 0.31	140.57 ± 0.91	1.64
Situ Bagendit	27.30 ± 0.27	25.66 ± 0.27	124.97 ± 0.59	1.71
Logawa	23.84 ± 0.55	22.25 ± 0.55	110.46 ± 1.71	1.98

Total-carbohydrate = 100 – (moisture + ash + crude protein + fat);
Available-carbohydrate = total carbohydrate – crude fibre;
Food-energy = (total carbohydrate x 4) + (fat x 9) + (crude protein x 4);
Portion size expressed as raw test foods weight providing 0.44 g available carbohydrate = (100/available carbohydrate) x 0.44.

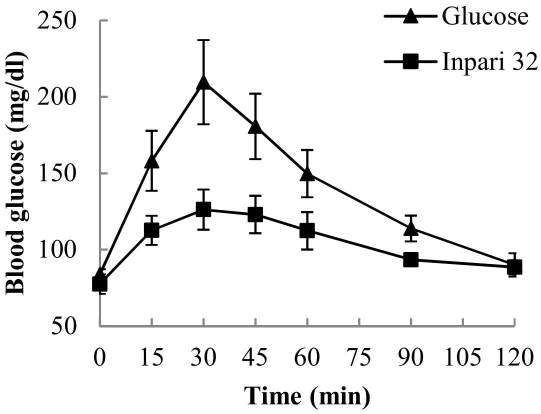
Recently, GIs for three Indian rice were evaluated for against glucose as the reference food [16]. Such GIs were slightly lower (70.2 – 77.0) than those reported in our study (70.61 – 94.11). Of greater interest that the same research found brown rice provide high GI values. To our knowledge this is the first prospective investigations conducted that have specifically evaluated brown rice of Indonesian rice cultivars in relation to GI value. Unfortunately, we were not determined the amylose content of the ten rice cultivars used in this research nor is it available in the literature. Further research is therefore may be help to gain a better understanding of its glycemic properties based on the starch molecular structure.

Table 4. Incremental area under the blood glucose response curve (IAUC) and glycemic index (GI) values of ten commercially Indonesian rice cultivars (cooked rice)

Rice cultivars	IAUC	GI	GI Classification*
Inpari 32	12663.75 ± 795.24	74.54 ± 4.68	High
Sintanur	15521.25 ± 217.46	91.36 ± 1.28	High
Inpago Unsoed 1	15990.00 ± 1007.26	94.11 ± 5.93	High
Sulutan Unsrat 2	14197.50 ± 997.04	83.56 ± 5.87	High
Memberamo	15762.50 ± 626.61	92.78 ± 3.69	High
Way Apo Buru	12152.50 ± 1310.44	71.53 ± 7.71	High
Bestari	14910.00 ± 2156.68	87.76 ± 12.69	High
Pepe	11996.25 ± 1816.59	70.61 ± 10.69	High
Situ Bagendit	13900.00 ± 956.77	81.81 ± 5.63	High
Logawa	9241.25 ± 252.36	54.39 ± 1.49	Low

*Based on classification by Mohan et al. [15]

Biochemically, amylose and amylopectin are starch, but starch can also be classified based on the length of time for digestion into rapidly digested starch (RDS), slowly digested starch (SDS) and resistant starch (RS) [36]. [37] have reported changes in the RDS, SDS, and RS may contribute to differences in GI values. Moreover, [38] have shown that inhibition of starch gelatinization and expansion, which caused by water absorption slow and little, it might be because that higher protein content meant more closely frain structure and smaller space between the starch grains. A very interesting finding from our results was that protein content classified low (≤ 8.9 %). In addition to protein content, the glycemic response is also influenced by fat content [39]. Our results also show that fat content classified low (< 1 %). On the other hand, some studies in line with our results, reported that most of the cooked rice from different cultivars were having lower protein and fat [40 – 42].



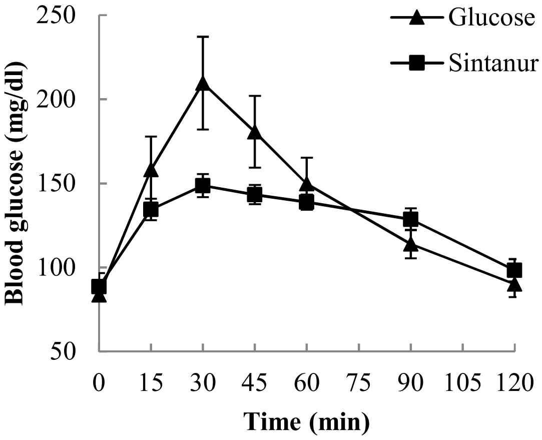


Figure 1 (*Continued*)

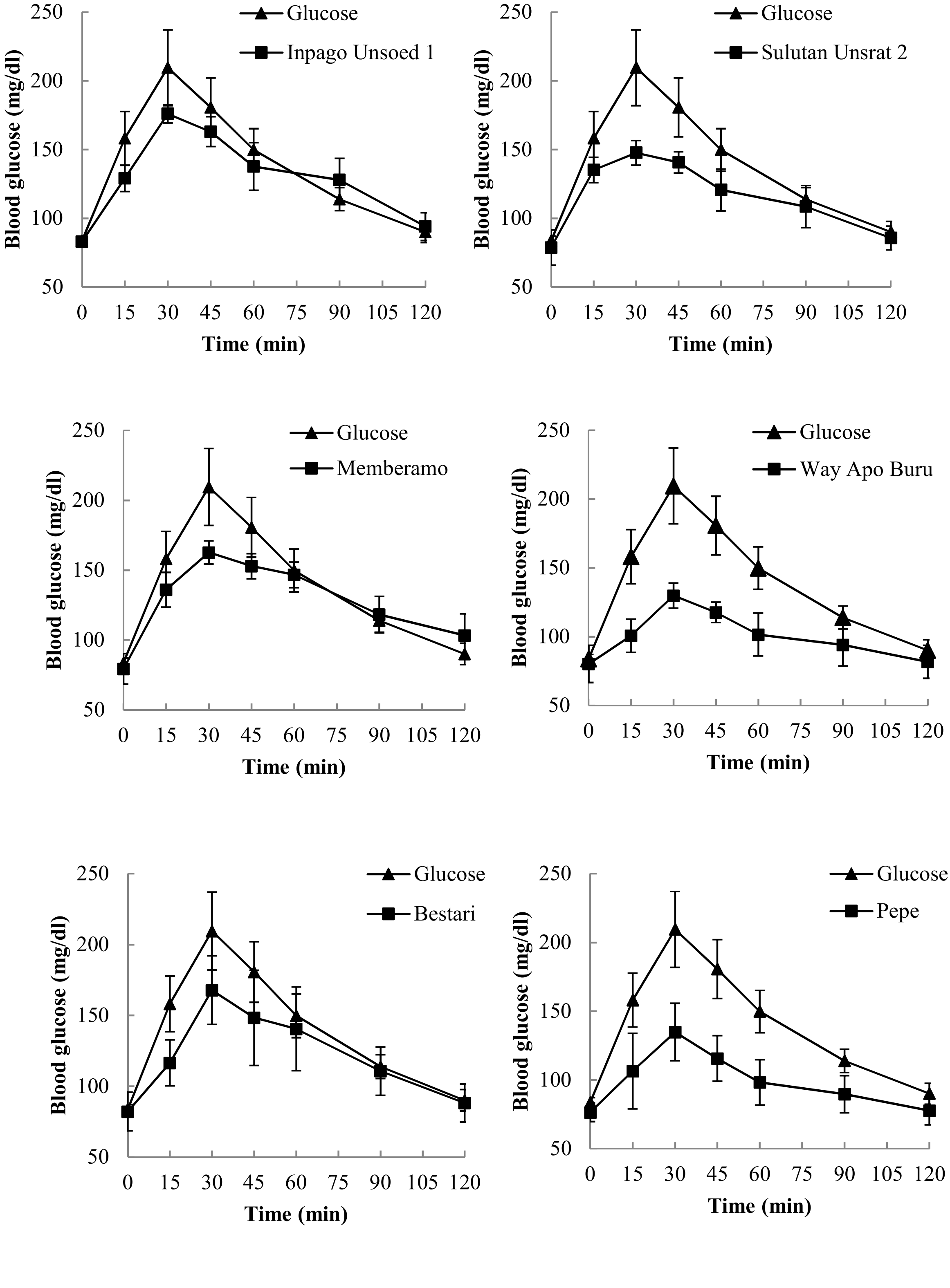


Figure 1 (*Continued*)

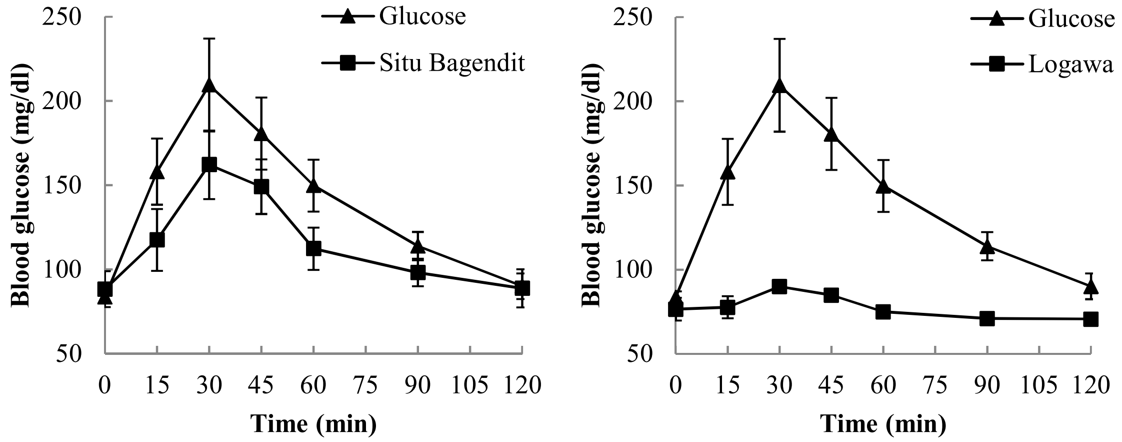


Figure 1. Incremental area under the blood glucose response curves (IAUC) values (■) for ten commercially Indonesian rice cultivars. (▲) Glucose. Data are shown as mean and standard deviation expressed by vertical bars (n = 6).

Information from this research can lead to more precise breeding strategy to incorporate characters for GI. In Indonesia, most widely grown commercially cultivars of rice had high GI values, indicating that they are not recommended for functional food use. Further testing would be recommended to determine how amylose content as well as other starch properties interact with glycemic response. The effort to lower the GI characteristic of rice using breeding technologies might improve the diet quality of rice-based diets and glycemic load in future.

5. Conclusions

The differences between the GI values for nine commercially Indonesian rice cultivars (Inpari 32, Sintanur, Inpago Unsoed 1, Sulutan Unsrat 2, Memberamo, Way Apo Buru, Bestari, Pepe, and Situ Bagendit) were significant and all classified as high GI. However, Logawa rice cultivar was classified as low GI. Hence, there is a great importance need to determine the GI of other rice cultivars so we can identify a lower GI and to make it available to the Indonesian population. These information are a valuable resource for the future rice improvement, which have to consider the development of cultivars targeting the dietary management and prevention of type 2 diabetes.

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