Indonesian Journal of Agricultural Science 7(2), 2006: 57-66

HYPOGLYCEMIC ACTIVITY OF SOME INDONESIAN RICE VARIETIES AND THEIR PHYSICOCHEMICAL PROPERTIES

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ABSTRACT

Diabetes mellitus is a spectrum of inherited and acquired disorders characterized by elevating blood glucose levels. Diabetes is an abnormal carbohydrate metabolism, therefore, diet therapy for diabetics plays a key role in the management of the disease. Most Indonesian people consume rice as source of energy and protein. Generally, diabetics consume very limited rice because they believe that rice is the one of hyperglycemic food, even though different rice varieties have large range of glycemic index. The study aimed to evaluate hypoglycemic properties by using rat assay and chemical characteristics of 10 Indonesian rice varieties, i.e. Pandan Wangi, Rojolele, Bengawan Solo, Cenana Bali, Memberamo, Celebes, Ciherang, Batang Piaman, Cisokan, and Lusi. Taj Mahal, an herbal ponni imported rice, was used as a comparison. Male Sprague Dawley rats (150-200 g body weight) were used for hypoglycemic assay. The rats were fasted overnight before the blood glucose was measured in the morning. The rats were then feed with 4.5 g rice per kg body weight by oral administration, followed by 1 ml of 10% glucose solution in the next 30 minutes. The blood glucose was measured for the next 30, 60, 90, and 120 minutes. Changes in blood glucose concentrations (mg dl^{-1}) before and after the oral administrations were calculated for each rice variety tested. Results showed that Cisokan and Batang Piaman were categorized as low glycemic responses and Ciherang as high glycemic response, while the other varieties (Memberamo, Cenana Bali, Lusi, Bengawan Solo, Pandan Wangi, Celebes, and Rojo Lele) showed moderate glycemic responses. As the best hypoglycemic activity, Cisokan contained high amylose (27.6%), fat (0.87%), total dietary fiber (6.24%), resistant starch (2.02%), and lowest starch digestibility (52.2%), which are ideal for diabetic's consumption. Ciherang as the worst hypoglycemic activity had low resistant starch (1.78%), low total dietary fiber (4.52%), and medium amylose (23.0%). This study implies that Cisokan variety is suitable for diabetic's consumption.

[*Keywords*: Rice, hypoglycemic, chemicophysical properties, diabetes mellitus]

INTRODUCTION

Degenerative diseases such as diabetes mellitus become prevalence to the people' health due to the change in lifestyles such as more sedentary lifestyle, less physical activities, and change in food consumption patterns especially in the big city which follow western pattern (Tsujii and Kuzuya 2004). Diabetes is one of the major health problems of the world population of all ages, even though elderly people are more risky.

Diabetes mellitus is a spectrum of inherited and acquired disorders that is characterized by elevated circulating blood glucose levels due to an absolute or a relative deficiency of insulin and/or insulin action with a consequent deranged metabolisms of carbohydrate, fat, and protein (Sardesai 2003). Insulin is a hormon secreted by pancreatic β-cells that transports glucose from blood into cells as readily use energy. According to WHO survey, Indonesia placed the forth biggest diabetics in the world after India, China, and USA. Diabetes prevalence accounts 8.6% of Indonesian population, and it is predicted the number of diabetics around 12.4 million people in the year 2025. It is three times onset in 1995, i.e. 4.5 million people (Departemen Kesehatan Republik Indonesia 2005).

Diabetes is a serious condition that places people at risk for greater morbidity and mortality relative to the non-diabetic population, leading to blindness, amputation, renal failure, and a major cause of heart attacks as well as stroke (Sardesai 2003). Diabetes disease can be managed by controlling daily nutrition input. Lasimo *et al.* (2002) mentioned the diet therapy for diabetics as follows: (1) consume certain amount of calorie, depending on the nutrition status of the patients, (2) do selective diet, especially those have hypoglycemic effect or potent for inhibiting of related complication, and (3) tightly adopted meal program to avoid uncontrolled postprandial glucose load.

Glycemic activity is the effect of foods (especially carbohydrate) in elevating of blood glucose response after meal. Hypoglycemic activity means how low the food raises blood glucose level. Related to glycemic response, Jenkins *et al.* (1981) introduced a new concept of carbohydrate property, i.e. glycemic index (GI). The GI is the indexing of the glycemic response of a fixed amount of available carbohydrate from a test food to the same amount of available carbohydrate from a standard food consumed by the same people. The blood glucose area after consumption of the test food was expressed as a percentage of the standard food (Jenkins *et al.* 2002). Hypoglycemic food or food with high hypoglycemic activity breaks down slowly and releases glucose gradually into the blood stream. It is also called low GI food.

Diabetes is the abnormal condition of energy metabolism, therefore, diet management of diabetics is focused on diet load, especially carbohydrate. It is assumed that all types of carbohydrate at the same amount have the same effect on elevating blood glucose level. However, the late finding showed that different sources of carbohydrate will produce different effects on elevating blood glucose levels (Jenkins *et al.* 1981). A high GI food produces higher peak in postprandial blood glucose and a greater overall blood glucose response during the first two hours after consumption than that of a low GI food (Foster-Powell *et al.* 2002). Hypoglycemic food improved metabolic maintenance of type 2 diabetics. Miller (1994) reported that medium term of hypoglycemic diet for diabetics could maintain their blood glucose level.

Rice is consumed by more than 90% of Indonesian population (Damardjati *et al.* 2004) as a source of energy and protein. Generally, diabetes patients consume very limited cooked rice because they believe that rice is the one of hyperglycemic food which fastly and highly affects blood glucose responses.

Ministry of Agriculture Republic of Indonesia, has released more than 170 rice varieties, both local and national prime varieties (Fagi *et al.* 2003). However, scientific information on the varieties characteristics linked to GI properties is still limited. Foster-Powell *et al.* (2002) stated that rice varieties showed large ranges of GI values mainly due to genetic inherent differences such as the amylose content. Amylose is digested more slowly than that of amylopectin starch (Donduran *et al.* 1999). Glycemic response or GI food is also influenced by several factors such as processing methods (degree of starch gelatination and particle size), ratio of amylose and amylopectin, dietary fiber, fat, protein, and nutritional inhibitor content (Rimbawan and Siagian 2004). Animal models such as mouse is often used in pharmacology experiment because it is cheap and easily handling. Soemardji (2004) reported that mouse was used in screening of anti-diabetes *in vivo*.

The study aimed to evaluate hypoglycemic activities of some Indonesian rice varieties by using rat assay and their chemical properties. It is expected that the finding will be useful for diabetics as well as for healthy people to prevent the disease.

MATERIALS AND METHODS

The experiment was conducted at the Animal Laboratory, Department of Food Science and Technology, Bogor Agricultural University, and the Postharvest Laboratory of Indonesian Center for Agricultural Postharvest Research and Development. Ten Indonesian milled rice varieties obtained from the Indonesian Center for Rice Research were used such as Pandan Wangi, Rojolele, Bengawan Solo, Cenana Bali (a local red rice), low amylose varieties, i.e. Memberamo and Lusi (waxy rice), medium amylose varieties, i.e. Celebes and Ciherang, and high amylose varieties, i.e. Batang Piaman and Cisokan. An herbal ponni rice variety of India, i.e. Taj Mahal, was used as a comparison because the variety was claimed suitable for diabetics (Julianti 2003).

Extraction of Rice Starch

Rice samples of 90% milling degree were ground to flour and sieved using ± 80 mesh size. The flour (100 g) was mixed with 500 ml destilled water, screened with a double cheese cloth, and squeezed dry by hand. Residual pulp was washed again and re-screened. The starch suspension was combined and decanted. Supernatant was removed and prime starch was freeze-dried (Widowati 1990). The freeze-dried rice starch was analyzed for its hypoglycemic activity.

Hypoglycemic Assay

Male Sprague Dawley rats (150-200 g body weight) were used for hypoglycemic assay. The experiment consisted of 11 rice varieties, replicated 6 times (6 individual rats; n = 6). The rats were fasted overnight but still given water *ad libitum*. Fasting blood glucose level was measured in the morning. The rats were oral administrated with the rice starch samples at 4.5 g kg^{-1} body weight, followed by 1 ml of 10% glucose solution in the next 30 minutes. The blood glucose was then measured for the next 30, 60, 90, and 120 minutes following the oral administration. Changes in blood glucose concentrations (mg dl^{-1}) before and after the oral administrations were calculated for each rice variety tested (developed from Miller *et al.* 1996).

Blood Sampling and Analyses

Blood glucose level was measured by glucose oxidase biosensor method using One Touch Ultra blood glucose monitoring system (produced by Lifescan Johnson & Johnson Company 2002). For glucose measurement, capillary blood samples were taken from rat tails. The rat tail was cleaned and massaged carefully, then tip of the tail was pricked with Ultra lancet (Soemardji 2004). The test strip was inserted to turn on the meter automatically. The sample was applied by touch and hold blood drop to narrow channel in top edge of test strip. Blood glucose concentration was measured immediately (during 5 seconds).

Chemical Composition Analysis

Proximate compositions, starch and total sugar were measured by AOAC (1995) method. Amylose content was determined by using IRRI method (Khush 1986), dietary fiber was measured following Asp (1983), and resistant starch was assessed with Englyst and Cumming (1988) *in* Marsono (1993).

Data Analysis

The blood glucose response of rats for every point of time over 2 hours following the oral administration was used to calculate the incremental area under the curve. The data of chemical properties were subjected to repeate measure of ANOVA followed by Duncan multiple range test (DMRT). Differences were considered significant if $p < 0.05$. Each component was analysed for its correlation to glucose response (Pearson correlation two-tailed). The stastistical computations were performed using SPSS software, version 11.5.

RESULTS AND DISCUSSION

Blood Glucose Level

Average concentrations (n = 6) of fasting and postprandial blood glucose level were given in Table 1. Changes in the blood glucose concentrations varied depending on fasting concentration levels, therefore, the data could not be compared directly. To analyse the hypoglycemic activity of the tested rice varieties, the data were calculated for their changes in the blood glucose concentrations after oral administration. These values were plotted in a chart as presented in Figure 1.

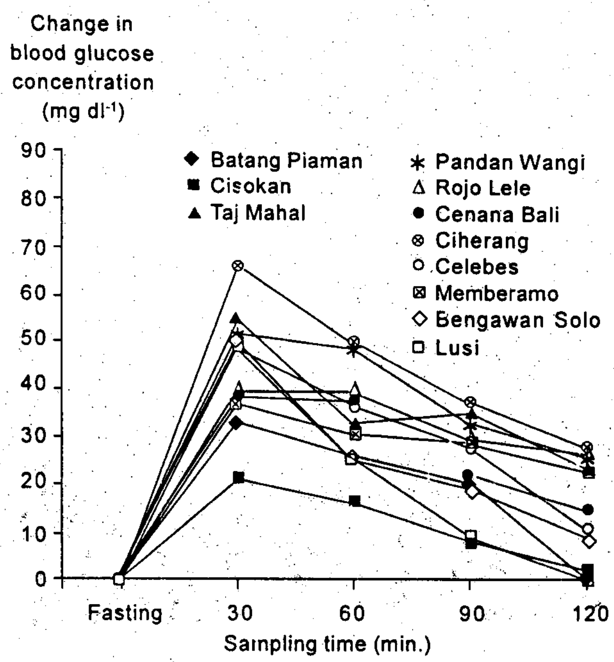

Fig. 1. Changes in blood glucose concentrations after oral administration of some Indonesian rice varieties in the rat assay.

Table 1. Blood glucose concentrations of the male Spargue Dawley rats after fasting and during 120-minute period after the oral administration with rice starch extracts (n = 6).

Variety	Blood glucose concentration (mg dl-1)				
	Fasting	30 min. AOA	60 min. AOA	90 min. AOA	120 min. AOA
Batang Piaman	80.2	113.0	106.2	100.3	80.2
Cisokan	100.0	121.0	116.0	108.2	101.8
Taj Mahal	78.0	132.7	111.0	113.5	101.3
Pandan Wangi	74.7	114.3	114.3	104.2	100.8
Rojolele	79.0	130.7	127.8	111.6	104.3
Cenana Bali	90.0	128.0	127.2	112.2	104.8
Ciherang	68.6	135.0	118.8	105.8	96.5
Celebes	81.8	130.8	118.3	109.8	92.2
Memberamo	78.6	115.5	109.0	107.3	101.2
Bengawan Solo	89.3	139.5	114.3	108.3	98.0
Lusi	82.2	131.2	107.3	91.3	82.0

AOA = After oral administration

All tested rice varieties reached a blood glucose concentration peak at 30 minutes following oral administration of the rats (Fig. 1). The peak illustrated the degrees of high and fast blood glucose concentrations in the tested rats. Glycemic response was indicated as area under the curve of each rice variety. The results showed that Cisokan variety performed the best hypoglycemic activity, followed by Batang Piaman, Memberamo, Cenana Bali, Lusi, Bengawan Solo, Pandan Wangi, Celebes, Rojo Lele, and Taj Mahal, whereas Ciherang variety was the worst.

Cisokan which was classified as the best hypoglycemic variety had smallest area under the curve and the lowest peak of its blood glucose concentration, which meant Cisokan variety increased blood glucose level slowly (low glycemic response). In the contrary, Ciherang performed the worst hypoglycemic variety because it elevated blood glucose level fastly (highest peak blood glucose level) and largest of its area under the curve. Other varieties were in between of these two extreme varieties. The finding showed that hypoglycemic response was influenced by the rice variety. The result supported the Foster-Powell *et al.* (2002) who stated that glycemic index values of rice varieties correlated with genetic inheritance.

The present study indicated that the blood glucose changes in the tested rats after 30-120 minutes of feeding with rice starch extracts varied (Fig. 1). Cisokan variety was the lowest (21-1.8 mg dl^{-1}, respectively), and the highest was Ciherang (66.4-27.9 mg dl^{-1}, respectively). This study suggests that glycemic response can be devided in three categories based on the blood glucose concentration peak at 30 minutes, i.e. low (≤ 35 mg dl^{-1}), moderate (35-55 mg dl^{-1}), and high (> 55 mg dl^{-1}). Based on this category, two varieties have low glycemic responses (Cisokan and Batang Piaman), seven varieties have moderate glycemic responses (Memberamo, Cenana Bali, Lusi, Bengawan Solo, Pandan Wangi, Celebes, Rojo Lele), and one variety produces high glycemic response (Ciherang). Interestingly, the blood glucose concentration changes of the Taj Mahal rice used as the recommended standard for diabetics was the second higher after Ciherang (54.7-23.3 mg dl^{-1}), even though still in moderate glycemic response but nearly high. Chemical composition and starch digestibility of Taj Mahal which will be discussed later may explain why this rice has moderate-high glycemic response. The result suggests that several Indonesian rice varieties, especially Cisokan and Batang Piaman, seem suitable for management diet for diabetics. The lower glycemic response of rice the better for dietary diabetics.

Chemical Composition

Amylose

Most of milled rice sold in the market have 90% milling degree, which means 90% of rice bran has already removed (Damardjati *et al.* 1989). The higher milling degree the higher glycemic response. Whereas, rice bran rich of dietary fiber slowly absorbs carbohydrate, included fiber, and produces lower blood glucose level or low glycemic response (Willet *et al.* 2002; Yusof *et al.* 2005).

Glycemic response is related to the chemical composition of foods, especially energy source. Table 2 shows carbohydrate, amylose, and total sugar content of Indonesian rice varieties tested. Among these three components, amylose was the highest related to the glycemic response ($r = 0.804$) (Table 3). It is stated that amylose is considered as the main parameter of cooking characteristics and eating quality of rice. The higher content of amylose results in non-sticky or hard cooked rice upon cooling, whereas lowest amylose rice produces soft and sticky cooked rice (Yusof *et al.* 2005). Therefore, in release of a new rice variety, amylose is one of component that should be analysed (Balai Penelitian Tanaman Padi 2004).

The amylose content influences digestibility and texture of the rice. Based on the amylose content, rice is classified into three categories, i.e. hard texture (>25-30% amylose), medium (20-25% amylose), and soft (10-<20% amylose) (Khush *et al.* 1986). Indonesian rice varieties tested are classified as hard texture (Batang Piaman, Cisokan, and Pandan Wangi), me-

Table 2. Carbohydrate, amylose, and sugar content of milled rice (milling degree 90%).

Variety	Amylose (%, db)	Sugar (%, db)	Carbohydrate (%, db)
Batang Piaman	29.90h	0.34a	92.18g
Cisokan	27.60g	0.39abc	91.37bc
Taj Mahal[1]	27.58g	0.39abc	91.18b
Pandan Wangi	25.90fg	0.43abc	91.95f
Rojolele	24.60ef	0.51bc	92.18g
Cenana Bali	23.40de	0.70de	90.34a
Ciherang	23.00de	0.43abc	91.72def
Celebes	21.80d	0.27a	91.68de
Memberamo	19.30c	0.56cd	91.43c
Bengawan Solo	16.90b	0.44abc	91.90ef
Lusi[2]	7.30a	0.83e	91.53cd

[1]Imported rice as a comparison; [2]Glutinuous rice.
Values in the same column followed by different letter (s) indicate significant difference on DMRT ($p < 0.05$).

Table 3. Correlation values of each chemical properties of rice with glycemic response.

Component	Corellation with glycemic response (r value)
Amylose	0.804
Sugar	0.733
Carbohydrate	0.690
Protein	0.499
Ash	0.236
Fat	0.223

dium texture (Rojolele, Cenana Bali, Ciherang, and Celebes), and soft texture (Memberamo, Bengawan Solo, and Lusi). It is surprising that the Taj Mahal rice variety showed high blood concentration because it contained high amylose (27.58%).

Digestability of amylose is still a controversial opinion among the scientists; most of them believe that amylose is slowly digested than amylopectin starch (Miller 1994; Behall and Hallfrisch 2002; Foster-Powell *et al.* 2002) because amylose is a polymer of simple sugar with no branch. The straight structure may construct a solid bond of amylose which is difficult to be gelatinized, therefore, amylose is relatively difficult to be digested. While amylopectin is a polymer of simple sugar having branch, bigger molecular size, and open structure, therefore it is easy to be gelatinized and digested. Based on those properties, glycemic response of high amylose foods is lower than that of the high amylopectin foods which increases glycemic activity (Foster-Powell *et al.* 2002). However, based on the enzymatic hydrolysis mechanism, amylose can be hydrolysed only by α-amylase, while amylopectin is firstly hydrolysed by α-amylase followed by α(1 → 6) glucosidase. Moreover, molecular weight of amylopectin is higher than that of amylose. Therefore, the amylopectin needs longer time to be hydrolysed (Lehninger 1982).

This research confirmed the previous finding that amylose content of rice affected its glycemic response in the tested rats. High amylose varieties, i.e. Cisokan (27.6%) and Batang Piaman (29.9%), had lower glycemic activity. However, Memberamo could also be categorized as hypoglycemic variety, although it had relatively low amylose content (19.3%). While Ciherang as a medium amylose (23%) seemed to be hyperglycemic variety. This may clarify that amylose is not a single factor affecting glycemic response. Wide differences in glycemic response of rice have been ascribed to various factors. These include ratio of amylose to amylopectin and the presence of lipid-amylose complexes (Hu *et al.* 2004), fiber content (Augustin *et al.* 2002), resistant starch (Astawan and Widowati 2005), and the botanical sources (Miller *et al.* 1992; Foster-Powell *et al.* 2002). Moreover, Miller *et al.* (1992) mentioned that rice with high amylose fraction of about 28% such as Basmati and Doongara brown rice have been shown to produce a lower blood glucose and insulin response. However, Paniasigui *et al.* (1991) concluded, after testing three high amylose rice varieties, that amylose content alone cannot predict the glycemic response and that gelatinization is also a factor.

Total Sugar

The second biggest correlation of energy source component with glycemic response was sugar (r = 0.733) (Table 3). Total sugar content of 11 rice varieties tested ranged from 0.27% (Celebes) to 0.83% (Lusi). Glycemic response of sugar is not always the same, depending on the type of sugar, e.g. glycemic response or glycemic index of glucose > sucrose > fructose (Foster-Powell *et al.* 2002). Most people thought that more sugar on the food resulted in higher GI. This opinion is not always right. Cisokan and Batang Piaman which showed the best hypoglycemic activity had relatively low sugar content, and Ciherang as the lowest hypoglycemic variety had medium sugar (0.43%, db). Probably, it was due to varied sugar type. Besides sugar component, some other characterictics of rice influenced glycemic response.

Carbohydrate

Carbohydrate is the main component of rice. As an energy source, carbohydrate content was related to glycemic response (Table 3, r = 0.690). Carbohydrate content of 11 rice varieties tested ranged from 90.34% (Cenana Bali) to 92.18% (Batang Piaman and Rojolele). It was a surprising result that Batang Piaman and Rojolele had the same carbohydrate content, but differed in hypoglycemic activity. It might be due to the difference in their physiology effects, such as starch digestibility. Table 4 shows that starch digestibility of Batang Piaman was 81.73%, while Rojolele was only 69.55%. Carbohydrates that break down quickly during digestion have a high GI. The blood glucose concentration raised fastly and high. While, carbohydrates that break down slowly, releasing glucose gradually into the blood stream, have low GI (Jenkins *et al.* 2002).

Protein

The second biggest component of rice is protein. The result showed that protein had moderate correlation with glycemic response (r = 0.499) (Table 3). Protein content of 10 Indonesian rice varieties ranged from 6.66% (Bengawan Solo) to 8.32% (Cenana Bali) (Table 5). Eckel (2003) and Rimbawan and Siagian (2004) mentioned that protein and fat are also contributing to glycemic response. Protein content in the diet influences the decrease of glycemic response (Foster-Powell *et al.* 2002). This component delayed the gastric emptying rate, so the digestion and absorption rate in the small intestine will be slowly. Based on this reason, food with higher protein content results in lower glycemic response. However, this research finding was not exactly confirmed the statement above. Cisokan which showed the highest hypoglycemic activity had relatively low protein (7.05%), while Ciherang, the lowest hypoglycemic activity, had higher protein (7.41%). Although Taj Mahal and Rojolele differed in amylose group, they had similar hypoglycemic activity and protein content.

Fat

Fat has similar metabolism to protein. It is digested and absorped in human intestine slowly, therefore, high fat foods result in lower GI. For example, fried potatoes have lower GI (54) than baked potatoes (Gi = 85) (Rimbawan and Siagian 2004). Moreover, Astawan and Widowati (2005) reported that fried, boiled, and baked sweet potatoes of BB 00105.10 cultivar have different GI, i.e. 47, 62, and 80, respectively. These implied that fat content in the diet contributed to lowering glycemic response.

Fat content of 10 Indonesian rice varieties was very low, ranging from 0.18% (Celebes) to 0.98% (Cenana Bali) and low related to glycemic response (r = 0.223). Therefore, it was not surprising that Cisokan showed highest hypoglycemic activity even though it contained relatively high fat (0.87%).

Ash

Ash content of rice was low (less than 1%). It was low correlation with glycemic response (r = 0.236). Table 3 shows that ash content of all rice varieties

Table 5. Protein, ash, and fat content of milled rice (milling degree 90%).

Variety	Protein (%, db)	Ash (%, db)	Fat (%, db)
Batang Piaman	6.83ab	0.34b	0.60d
Cisokan	7.05bc	0.66e	0.87f
Taj Mahal[1]	7.18cd	0.65e	0.98g
Pandan Wangi	7.24cde	0.44bc	0.38a
Rojo Lele	7.15cd	0.33b	0.35a
Cenana Bali	8.32g	0.35b	0.98g
Ciherang	7.41def	0.34b	0.55c
Celebes	7.48ef	0.18a	0.55d
Memberamo	7.61f	0.50cd	0.46b
Bengawan Solo	6.66a	0.62de	0.82e
Lusi[2]	7.18cd	0.47bc	0.80e

[1]Imported rice as a comparison; [2]Glutinuous rice.
Values in the same column followed by different letter indicate significant difference on DMRT ($p < 0.05$).

Table 4. Starch digestibility and dietary fiber of milled rice.

Variety	Soluble dietary fiber (%, db)	Insoluble dietary fiber (%, db)	Total dietary fiber (%, db)	Starch digestibility (%, db)
Batang Piaman	1.96bc	3.63bc	5.59d	81.73d
Cisokan	1.80abc	4.44def	6.24e	52.21a
Taj Mahal[1]	1.79abc	4.53ef	6.32e	99.08e
Pandan Wangi	0.82a	1.91a	2.73a	56.05a
Rojo Lele	2.40c	3.77bcd	6.17e	69.55bc
Cenana Bali	1.21a	3.01bc	4.22b	76.81d
Ciherang	1.55abc	2.97bc	4.52b	66.78bc
Celebes	1.48abc	3.71bcd	5.19c	78.29d
Memberamo	3.95d	2.97bc	6.92f	71.18c
Bengawan Solo	0.91a	4.62f	5.53cd	70.44bc
Lusi[2]	3.90d	2.61ab	6.51e	71.53c

[1]Imported rice as a comparison; [2]Glutinuous rice.
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ranged from 0.18% (Celebes) to 0.66% (Cisokan and Taj Mahal). This component has no directly correlation to glycemic response.

Resistant Starch

The old concept on nutritional science convinced that starch was able to be completely digested in the human intestine because saliva and pancreas produced amylase enzymes that was able to break down the starch. Nowadays, the postulate has already corrected since experiments both *in vitro* as well as *in vivo* found that starch intake was not completely digested. The starch fraction that cannot be digested called resistant starch (RS). The starch is resistant to enzymic degradation and digestion in the small intestine (Cairns *et al.* 1996). From physiological point of view, RS is the amount of starch resulted from starch digestion that cannot be absorped by healthy human intestine. Slowly digested and absorped carbohydrate will reduce postprandial metabolic response. Thus, carbohydrates that break down slowly, such as RS reduce glycemic response.

Table 6 shows that RS of 11 rice varieties significantly correlated with glycemic response (r = 0.973). This result confirmed Astawan and Widowati (2005) finding that RS was the main factor that affected GI of sweet potatoes. RS content in the diet produced lower glycemic response. Figure 2 shows that RS content of some Indonesian rice varieties ranged from 1.57% (Celebes) to 2.68% (Memberamo). Cisokan as the best hypoglycemic variety contained high RS (2.02%). On the contrary, Ciherang as the worst hypoglycemic variety had low RS (1.78%).

Dietary Fiber

The GI concept is an extension of the fiber hypothesis, suggesting that fiber consumption reduces the rate of nutrient influx from the gut (Jenkins *et al.* 2002). Dietary fiber plays a key role in maintaining human health. This component influences glucose assimilation and reduces serum cholesterol. Researches showed that certain plant fibers delay the absorption of carbohydrate and result in less post-prandial hyperglycemic. Increased fiber in the diet is associated with reduced insulin resistance. An increase in fiber from

Table 6. Correlation of resistant starch, dietary fiber, and starch digestibility with glycemic response of milled rice.

Component	Correlation to glycemic response (r value)
Resistant starch	0.973
Soluble dietary fiber	0.623
Insoluble dietary fiber	0.543
Total dietary fiber	0.387
Starch digestibility	0.424

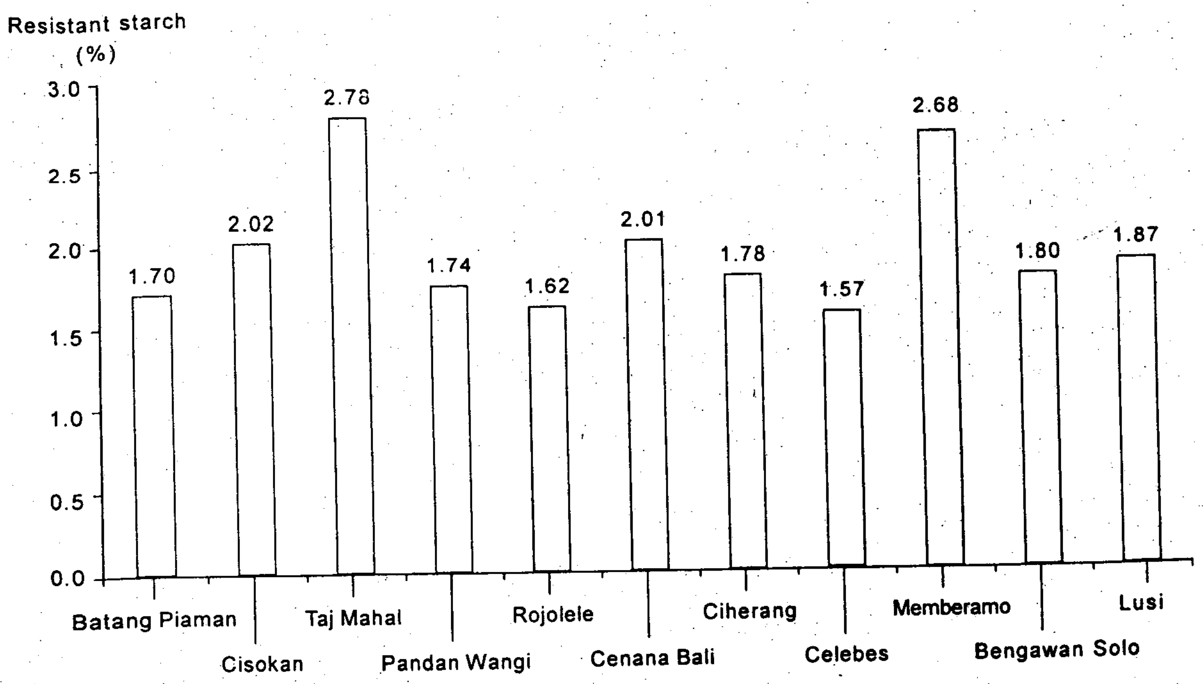

Fig. 2. Profile of resistant starch in milled rice.

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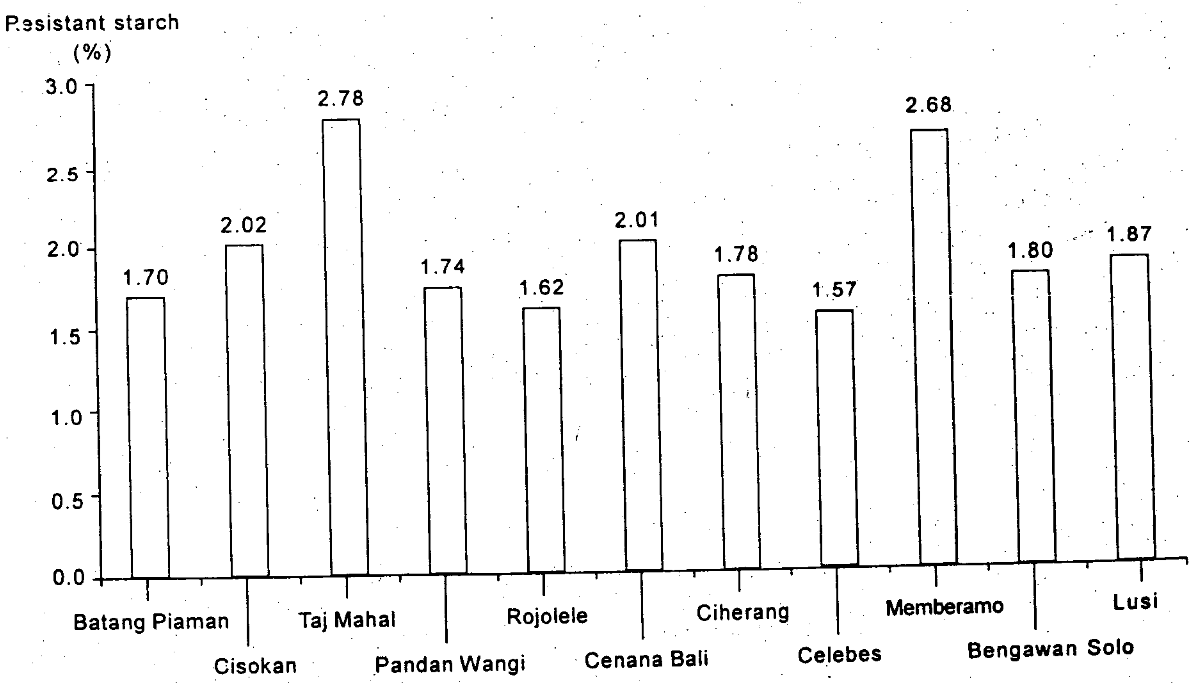

Fig. 2. Profile of resistant starch in milled rice.

whole grain, legumes and vegetables may appear to be beneficial for the diabetics (Sardesai 2003).

Total dietary fiber (TDF) consists of soluble dietary fiber (SDF) and insoluble dietary fiber (ISDF). Among those properties, SDF had the highest correlation with glycemic response (r = 0.623), followed by ISDF (r = 0.543) and TDF (r = 0.387) (Table 6). SDF affects blood glucose control. Direct effects of SDF decreases digestion rate by impedes access to digestive enzymes, and absorption rate by slows diffusion rate across unstirred layer. While indirect effects of SDF decreases absorption of dietary fat and regulates appetite. Behall and Hallfrisch (2002) mentioned that the gel forming of soluble fiber sources such as oats and barley has been proposed as the mechanism by which these grains reduce both cholesterol and glucose response. Table 4 shows that rice contains SDF, ISDF and TDF ranging from 0.82-3.95%, 1.91-4.62% and 2.73-6.92%, respectively. Dietary fiber contributes to prevent various diseases, mainly associated with digestion gutter such as constipation, diverticulosis, and colon cancer (Eckel 2003; Astawan and Wresdiyati 2004).

In general, dietary fiber reduces blood glucose levels. Cisokan variety as the best hypoglycemic activity was supported with high TDF (6.24%) and ISDF (4.44%). On the other hand, Ciherang as a hyperglycemic variety was supported by low dietary fiber (1.55% SDF, 2.97% ISDF, 4.52% TDF), while Taj Mahal contained low SDF (1.79%) and high ISDF (4.53%) as well as TDF (6.32%).

Starch Digestibility

According to Willet *et al.* (2002), slowly absorbed carbohydrate produced lower peaks in blood glucose level and appeared to be an advantage in maintaining glycemic response. Table 6 shows that starch digestibility of rice had moderate correlation with glycemic response (r = 0.424). Among the Indonesian rice varieties, the lowest starch digestibility was obtained from Cisokan (52.21%), therefore, the variety had the lowest glycemic response. It means that Cisokan confirms the statement above.

Foods that break down easily during digestion will immediately increase plasma glucose levels. Quick ascending of plasma glucose levels pushed the pancreas to produce and secrete more insulin. As a consequence, high plasma glucose levels will increase insulin response (Ostman *et al.* 2001). Ciherang as the worst hypoglycemic activity had medium starch digestibility (66.78%). In addition, Batang Piaman variety had the highest rate of starch digestion, but its glycemic response was the second lowest after Cisokan. Although Taj Mahal contained high amylose (27.58%) and high RS, the variety showed high glycemic response, probably due to high starch digestibility (Table 4). Generally, lower rate of starch digestion decreases its blood glucose response.

The overall data above illustrated that glycemic activity is a unique property. It could not be predicted only by certain chemical composition. Some factors mixed together to result in certain glycemic response. Jenkins *et al.* (2002) mentioned that despite inconsistencies in the data, positive findings have emerged to suggest that the dietary glycemic index is potential importance in the treatment and prevention of chronic diseases.

This research was not purposed to determine the glycemic index of rice, but evaluated glycemic response by rats assay to select hypoglycemic rice variety. Nevertheless, the result could be used as guidance for people to choose a rice veriety which suitable for their health status.

Result showed that Cisokan as the best hypoglycemic variety was supported with high amylose, high dietary fiber, high RS, highest fat, and low starch digestibility. Batang Piaman as the second best hypoglycemic variety was supported with highest amylose and lowest sugar content. Ciherang, a medium amylose variety, appeared to be hyperglycemic variety, probably due to low RS and low dietary fiber content. Although Memberamo contained low amylose (19.29%), the variety produced moderate glycemic response. It was supported with its highest TDF (6.92%), highest SDF (3.95%), highest RS (2.68%), and high protein (7.61%). Cenana Bali and Lusi had similar hypoglycemic response with Memberamo. However, Cenana Bali contained higher amylose than Memberamo resulted in harder rice texture and less taste. While Lusi is glutinuous rice, not usual as staple food. The property of Taj Mahal was beyond the expectation. Taj Mahal was the second worst hypoglycemic activity. It might be due to highest starch digestibility (99.08%) and low SDF (1.79%). Further study will be conducted to evaluate the effect of several processing methods on reducing GI of selected rice varieties, and also the effect of polyphenol containing-rice on controlling blood glucose level of diabetic rats model.

CONCLUSION

Among the Indonesian rice tested, Cisokan performed the best hypoglycemic activity and Ciherang was the worst one. Lowest glycemic response of Cisokan was supported with high amylose (27.60%), fat (0.87%), TDF (6.24%), and RS (2.02 %) contents, and low starch digestibility (52.21%), while Ciherang as the worst hypoglycemic variety was supported with low RS (1.78%) and low dietary fiber content (4.52%). This study suggested that Cisokan and Batang Pia-man were categorized as low glycemic responses and Ciherang as high glycemic response, while the other varieties (Memberamo, Cenana Bali, Lusi, Bengawan Solo, Pandan Wangi, Celebes, and Rojo Lele) showed moderate glycemic responses.

ACKNOWLEDGMENT

The authors wish to thank to Participatory Development of Agricultural Technology Project and also the Indonesian Center for Agricultural Postharvest Research and Development for the financial supports and facilities for this research.

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