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Local red rice genotypes with low glycemic index for people with diabetes Mellitus

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ABSTRACT

The prevalence of diabetes mellitus in the world continues to increase and poses high risk towards the society. This disease is incurable; however the quality of life of the patients could be improved if they eat the foods with low glycemic index (GI). This study aims to investigate the local red rice genotypes that are suitable for people diagnosed with diabetes mellitus. The study was conducted using six genotypes of local red rice, namely Bukittinggi, Taratak Baru, Jawi-Jawi, Pasaman Barat, Cubadak and Sungai Aur. GI was analyzed at the Laboratory of Animal Development and Structure of the Department of Biology, Universitas Negeri Padang. For each treatment, four mice were used as experimental objects with four replications. The results showed that the GI of the local red genotypes varies from low to high. Only Sungai Aur genotypes have a low glycemic index (54). Three other genotypes namely Jawi-Jawi, Bukittinggi and Cubadak has a glycemic index value 61, 65 and 67 respectively. This value is included into the category of medium GI. While the two other genotypes of the Taratak Baru and Pasaman Barat with values of 71 and 81 are categorized high glycemic index.

***Key words** : Glycemic index, Red rice, Local genotype, Diabetes mellitus*

Introduction

Diabetes mellitus (DM) is a metabolic disorder that is dangerous and widely spread among many developing countries around the world. IDF (2014) reported that one out of every twelve of the world population is a diabetic patient. Fifty percent of patients with DM did not know that they were a diabetic patient. It is estimated that, every second, one diabetic patient died. Ironically, 77% of people with diabetes live in low-income countries and in developing countries. The same trend is also found in people living in the developed countries (Fitzgerald *et al*., 2011). IDF (2013) reported that in 2012 patients with DM in Indonesia reached 7.6 million people. The figure rose to 10 million people by 2015 (IDF, 2015).

Diabetes mellitus is determined by genetic factors and also influenced by the consumption of particular foods that have a high glycemic index (GI). According to Fitzgerald (2011), the GI is a relative measure of the ability of carbohydrates in foods to raise blood sugar levels after eating. Food that has high GI raise blood glucose levels rapidly and vice versa

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(Rimbawan and Siagian, 2004). Conversely, foods that have a low GI are digested and absorbed much longer so that blood sugar levels and insulin secreted more slowly. Foods with a low glycemic index have been shown to improve glucose and fat levels in patients with diabetes mellitus and improve insulin resistance. In addition, foods with a low glycemic index also helps control appetite, slows the emergence of hunger that can help control the patient's weight.

Rice is the staple food of nearly half of the world's population. According to Mohanty (2013), more than 90% of the Asian population consumed rice daily. Indonesia's population makes rice as a staple food however, rice glycemic index varies widely. Fitzgerald *et al.*, (2011) reported that the GI of rice ranges from 48 to 92, with an average of 64. Anhar *et al.*, (2016) reported that the GI of six genotypes of rice plant originating from West Sumatra ranged from 63 to 77.

Information on GI of rice is very important for consumers, especially for people with diabetes. According to Foster-Powell (2002), the GI cannot be estimated based on grain size (long or short) or how to cook it. Results by Indrasari *et al.*, (2008) showed a tendency of amylose rice that has a high glycemic index (74-79), amylose rice having moderate GI (59-64), and upland amylose rice has a low glycemic index (34-50). According to Fitzgerald *et al.* (2011), GI is highly determined by the gene of the plant itself. The statement was supported by the results of research Purwani *et al.*, (2007) reported that the GI value of several rice varieties i.e., IR36 rice variety, Taj Mahal, Batang Piaman, and Mekongga were recorded 45, 60, 86 and 96 respectively. The Swarna variety that is widely cultivated in India has a low GI, whereas Doongara and Basmati varieties from Australia have medium value IG (Fitzgerald *et al.*, 2011). Thus, it turns out the GI rice is highly varied. Therefore, it needs to be determined locally (Foster-Powell, 2002).

In West Sumatra, Indonesia, the cultivated rice genotypes is in the form of national and local superior genotypes, however they were known to have a bad taste. Anhar (1996) reported that the preservation of local genotypes of rice plant is caused partly because the rice tastes better than the national superior genotypes. Until now, the GI value information is only limited to rice genotypes classified as white rice. In contrast, the Western Sumatra local genotypes classified as brown rice has not been reported. It certainly is not favorable for people with diabetes to choose the type of rice that is safe for their consumption as brown rice is a food source that is healthier than white rice. GI testing can be done directly on humans, however, controlling humans as test subjects are difficult. Therefore, the use of animal testing can also be performed. According Widowati *et al.*, (2006), animals such as mice are often used in research because it is cheap and easy to handle. Mice have been used for in-vivo screening of anti-diabetic (Soemardji, 2004).

Glycemic index of rice plant is genetically controlled. However, the expression of a gene is influenced by the environment. Bryant and Georgia (2000) state that the role of the environment and the rice crop cultivation practices are larger than genetic. The results of the study by Anhar *et al.*, (2009) showed that the results of several varieties of rice plant crops are affected by location. Thus, unstable genotype will adapt specifically according to the locality, so it will only display the optimal properties if they grow in a specific location. Conversely, stable genotype will produce the same phenotype in various environments so that it can be planted at various locations without significant phenotype changes. Therefore, this study aims to determine the GI of local red rice genotypes of rice in West Sumatra.

Materials and Methods

The study was conducted in two stages. In the first stage, data collection begins by collecting locally dominant brown rice genotypes grown in West Pasaman, Bukittinggi and Solok in West Sumatra, Indonesia. Based on observations made on the note that the genotype of the most popular and dominant cultivated at each location by name in accordance with the area where it is being cultivated. The genotypes are Bukittinggi, Taratak Baru, Jawi-Jawi, Pasaman Barat, Cubadak and Sungai Aur. Red Rice from six local rice plant genotypes was also collected from the planting site. GI of the varieties collected was analyzed in the Laboratory of Animal Development and Structure of the Department of Biology, Universitas Negeri Padang. Prior to testing, preparatory test was first performed on animals such as mice and test materials, such as rice. For each treatment four mice was selected as objects with four replications. Preparation of the test material in the form of brown rice from six local genotypes done by preparing extracts from rice flour in accordance with the procedure performed Widowati *et al.* (2006).

Samples of rice was grounded into flour and sieved using a sieve size of 80 mm. Rice flour weighed at 100 g and then mixed with distilled water. The mixture was then filtered with two layers of gauze and squeezed by hand. The residue that was left in the filter cloth rinsed again and filtered. The solution was stirred and precipitated. The supernatant was discarded and then wind dried. The mice used for the study was male mice weighing at 150-200 g. The experimental designed used a randomized block design with six treatments, one control (glucose) and four replications. Before treatment, the mice were fasted for the night (but still able to drink). In the morning, the blood glucose levels in mice were measured using a Gluco DR. Mice were fed with the rice flour with a rate of 4.5 kg/kg of body weight. Mice blood glucose were measured at 2, 4 and 6 hours after treatment. While for rice amylose, protein and fiber contents were analyzed according to standard method by AOAC (2005).

Results and Discussion

Protein content

Lowest brown rice protein found on the Pasaman Barat genotype (6.27%) and the highest was found in genotype Cubadak (8.14%). The protein content of all genotypes of rice is shown in Table 1. The protein content is relatively no different among six local rice genotypes of West Sumatra which was ranged from 5.9% to 7.4% (Anhar *et al.,* 2016) but higher than protein content of black rice from Toraja 1.04% (Mangiri *et al.,* 2016). The protein content of Cubadak genotype almost identical to the results of research by Indrasari *et al.* (2010), while for Batang Lembang genotype was recorded at 8.68%, but this result was still lower than Aek Sibondong genotype (10.55%) and Aek Tenggulang (10.4%). According to Juliano (1993), the average of the protein content of rice from various countries in Asia ranges from 6.3 to 9.2%.

The variety of protein content between the different genotypes cannot be separated from genetic and environmental factors. According Hillerislambers *et al.,* (1972), the protein content correlated with the genotype, phenotype and the environment. The protein content is influenced of soil type, temperature during ripening and growth duration (Juliano, 1993). In addition, soil organic matter, nitrogen calcium, copper, and molybdenum also affect the protein content of rice (Juliano, 1993). The protein content of rice is also significant if the same genotype with the same cultivation techniques were planted in different areas (Juliano, 1993).

According to Badawi *et al.* (1997), the protein content of rice plant in Egypt ranges from 6.2% - 8.3%. Wider spacing or reducing the number of plant population also increases the protein content of rice plant (Badawi *et al.,* 1997). Although genetic analysis has not been done, but it is believed that the six genotypes studied have a genetic difference. This happens because all of these genotypes are local genotypes originating from different areas. In addition, the diversity of plant locations on each genotype is very varied from the type of soil, climate and cultivation practices.

Crude fiber content

Crude fiber content of rice varied from 4.17 - 8.44 in Cubadak and Bukittinggi genotypes as shown in Table 1. The fiber content is higher than that of rice genotypes in Egypt which ranged from 0.20 to 0.65 (Badawi *et al.,* 1997). Even the fiber content was found was also higher than the results reported by Oko and Ugwu (2010). The fiber content of black rice cultivars pare ambo of Toraja in South Sulawesi recorded only 0.8% (Mangiri *et al.,* 2016). Black rice fiber content Southern Sulawesi reported by Ratnaningsih (2010) ranged from 1.09 to 1.28%.

Table 1. Protein Content and Crude Fiber of West Sumatera red rice genotype

Genotype	Protein (%)	Crude fiber (%)
Bukittinggi	6.36 ±0.12	8.44 ± 0.36
Taratak Baru	7.77 ±0.11	4.89 ± 0.23
Jawi-jawi	5.86 ±0.33	5.49 ± 0.20
Sungai Aur	7.08 ±0.17	4.59 ± 0.26
Cubadak	8.14 ±0.12	4.17 ± 0.19
Pasaman Barat	6.27 ±0.30	5.23 ± 0.13

The fiber content in rice was higher at 7.6 % reported (Malekian, 1992). High fiber content in rice also provides benefits for people with diabetes. A high fiber reduces the GI. According Lukitaningsih *et al.* (2012), higher fiber content in the rice contribute to the lower GI. The existence of possible fibers inhibits the absorption of nutrients, including carbohydrates, so that the blood glucose level does not rise high. Decrease in blood sugar due to the fiber content related to enzyme activity. According to AlEssa et al (2015), high-fiber food did not contain as much digestible carbohydrate, so it slows the rate of digestion and causes a more gradual and lower rice in blood sugar.

Based on these descriptions can be concluded that the fiber content of the genotypes studied are relatively high. Thus, all the genotypes studied can be used as a type of rice that is good for diabetes mellitus. In addition, the genotype can also be used as one of the elders by plant breeders in order to assemble the rice genotypes with high fiber content.

Amylose content

Brown rice amylose content studied varied from 13.48 in Bukittinggi genotype to 20.44 in Cubadak genotype. Other rice amylose content can be seen in Table 2. Based on the amylose content, grouped into four, namely sticky rice with amylose content less than 10%, low amylose (10-20%), medium amylose (20-25%) and high amylose if implies more than 25% (Juliano, 1993). Thus, five genotypes namely Bukittinggi, Taratak Baru, Jawi-Jawi, Sungai Aur, and Pasaman Barat included low amylose rice group while Cubadak including medium amylase.

The difference amylose content according to Bao (2004) was influenced by genotype variations. Okagaki and Wessler (1988) states that the amylose in endosperm synthesized by granule bound starch synthase (GBSS) are encoded by the gene Wx. Heda and Reddy (1986) states that the amylose content is controlled by two pairs of genes that are high amylose dominant against low amylose. Lee *et al.* (2000) suggest that the three QTL for amylose content located on chromosome 1, 6 and 11. QTL located on chromosome 6 express 91.1% of the total variation (He *et al.*, 1990).

Besides genetic factors, the amylose is also influenced by the growing environment. Afriyanti (2013) reported that the amylose content of the rice is different in each location of the five rice genotype. Higher air temperatures will lower amylose content (Asaoka *et al.*, 1985; Resurrección *et al.* (1979). This was due to lower GBSS activity at a higher temperature (Jiang *et al.*, 2003). Differences in cultivation practices can also affect the amylose content such as water stress. Amylose content is also influenced by nitrogen fertilizer in which the amylose content is slightly reduced with the application of nitrogen but is not affected by the time of application (Paule *et al.*, 1979).

According to Liu (2010), water stress during the reproductive period and grain filling phase reduces amylose content of rice. Harvest time delay of 30 to 40 or 50 days after the heading will lower amylose content (Badawi *et al.*, 1997). The interaction of genotype and environment is an important factor determining the amylose content of rice (Liu, 2010). Thus, differences in amylose content between different rice genotypes are commonly found in a research.

Blood glucose

Observations in mice showed that low blood glucose content at 2 to 4 hours of observation was found in Sungai Aur genotype. As for the 6-hour observation, the lowest blood glucose levels found in genotype of Jawi-Jawi. In contrast, the highest blood glucose levels in the range 2-6 hours after eating found in Pasaman Barat genotype. Nevertheless, all genotypes tested produces blood glucose levels that remained lower compared with the control (sugar). When compared with controls, six genotypes showed the same pattern in terms of blood glucose content. All genotypes showed that blood sugar levels decreased after 2 hours. In contrast, blood sugar levels in control would continue to increase until the observation to 4 hours after eating. Thus, all genotypes tested continued to have a drop in blood sugar better compared with controls. The pattern of decrease in blood glucose after 2 hours as the study's findings also found in research results by Indrasari *et al.* (2011) at nine genotypes of rice in Indonesia, namely Aek Sibondong, Setail, Ketonggo, Air Tenggulang, Martapura, Cigeulis, Batang Lembang, Marga Sari and Cisokan. The influence of genotype red rice paddy on blood sugar level can be seen in Fig. 1.

The decrease pattern in blood sugar level is also reported by Widowati (2006). Research results show

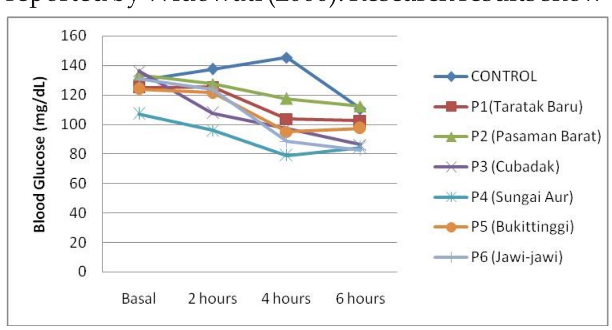

Fig. 1. Changes in blood glucose in mice after consumption of red rice

that lowering of blood sugar in animals that were fed 11 varieties of rice occurs after 30 minutes and reached the lowest value at the end of the observation after 2 hours. Among the five genotypes were tested, it is known that the genotype of Pasaman Barat, Cubadak and Jawi-Jawi showed the same decrease pattern in blood glucose.

The third genotype is able to maintain low glucose content at least until the last observation at 6 hours after consumption. In contrast, genotype Taratak Baru and Sungai Aur also showed the same pattern of blood glucose. A decrease in blood glucose occurred up to 4 hours of observation after consumption. Furthermore, blood glucose level showed a tendency to stagnate (Taratak Baru) or start rising again in Sungai Aur genotype.

Glycemic Index

The results showed that the GI of two local red rice genotypes is high and three genotypes were moderate. Only one genotype rice red has low GI that Sungai Aur (54). The GI some red rice genotypes can be seen in Table 2. High and low GI value is influenced by the type of rice (Zarrati *et al.,* 2008). Most researchers report that high amylose content which will produce low GI. Frei *et al.,* (2003) examined six different species and found that a low amylose content of rice can be used as a factor to predict a high GI. This happens because the high amylose resulted in slower digestion rate (Kabir *et al.,* 1998; Behalll and Scholfield, 2005). In addition, the enzyme amylase intestine has the effect of lower rice high amylose so that changes in blood glucose to be slow (Goddard *et al.,* 1984).

The results Widowati *et al.,* (2006) showed that rice genotypes Cisokan activity showed the highest among the top ten genotypes tested. The condition is supported by high levels of amylose. Guraya (1997) stateed that the rate of digestion is slower on rice with a high amylose may be due to the formation of complexes between amylose and lipid uponheating, thereby reducing the enzyme activity. In contrast, the molecule of amylopectin does not form a complex with most of the emulsifier. In addition, the glucose unit of amylose has more hydrogen bonding than glucose units in amylopectin, making them less accessible to digestive enzymes. Amylopectin also had larger than molecules of amylose, so it has a larger area for broken down by enzymes (Behall and Hallfrisch, 2002). Hu *et al.,* (2004) reported that the high rate of digestion in the content of low amylose or amylopectin level can be caused by the inability of molecules of amylopectin to form complexes with compounds such as fatty acids, thereby increasing access to the enzyme a-amylase of the molecule and cause easier and faster digestion. The results showed that low level of amylose does not produce high GI. All of the genotypes studied, five genotypes were recorded low content of amylose, the two genotypes produced a high glycemic index (Taratak Baru and Pasaman Barat), two genotype produce glycemic index medium (Bukittinggi and Jawi-Jawi) and Sungair Aua genotype would produce a low glycemic index. Thus, it can be concluded that that the amylose content were not always inversely proportional to the GI.

The results of the study Purwani *et al.,* (2007) also found inconsistent relationship between amylose content with the GI. The Batang piaman rice genotype was found containing high amount of amylose resulting in high GI. In contrast, rice with low GI was not only found in rice with low amylose, but also found in rice with a high amylose content (IR36) and also found in rice with medium amylose content. Indrasari (2009) also reported that the Ciliwung rice genotype and Batang Piaman genotype with high amylose also had a high GI. Other researchers also reported that the content of rice with a high amylose Doongara produce medium GI (Miller *et al.,* 1992).

There is still a difference of opinion among scientists about the rate of starch digestion is associated

Table 2. Glycemic Index values of local West Sumatera red rice genotypes

	Amylose	Category	Glycemic Index	Category
Bukittinggi	13.48 ±0.23	Low	65 ±1.8	Medium
Taratak Baru	18.16 ±0.20	Low	71 ±1.5	High
Jawi-Jawi	13.29 ±0.30	Low	61 ±1.4	Medium
Sungai Aur	14.18 ±0.21	Low	54 ±0.8	Low
Cubadak	20.44 ±0.42	Medium	67 ±1.7	Medium
Pasaman Barat	16.62 ±0.31	Low	81 ±1.4	High

with amylose or amylopectin content. Most argue that digestion of amylose is faster than with amylopectin because amylose is a simple sugar polymer with linear chain. Straight-chain amylose arrange bond so strong that it run into the gelatin. Thus, amylose is more difficult than the amylopectin described with simple sugar polymers, branched and open structure (Indrasari, 2009). Panlasigui *et al.,* (1991) reported that the amylose content of the rice is not a good predictor for the digestion of starch and glycemic response. Van *et al.,* (2015) also found that there was no correlation between amylose content and glycemic index. Besides amylose, glycemic index is also affected protein. According to Rimbawan and Siagian (2004), the metabolism of proteins in the body pass through a longer path, so it takes longer than carbohydrates. Therefore, protein tended to lower in the glycemic response.

Conclusion

It can be concluded that the GI of local red genotypes varying from low to high category. The only Sungai Aur genotypes have a low glycemic index (54). Three other genotypes namely Jawi-Jawi, Bukittinggi and Cubadak has a glycemic index value respectively 61, 65 and 67. This value is included into the category of medium glycemic index. While the two other genotypes of the Taratak Baru and Pasaman Barat with values 71 and 81 are categorized high glycemic. Based on this study, we recommend that patients with diabetes to consume Sungai Aur rice genotype for their daily diet.

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