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Glycemic index of a breakfast food from black rice, konjac, jack beans, and red dragon fruit in rats with type 2 diabetes

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ABSTRAK

Latar Belakang: *Penderita DM tipe 2 memerlukan sarapan yang tepat sehingga tidak meningkatkan kadar gula darah, yang harus terbuat dari bahan-bahan dengan indeks glikemik rendah. Beras hitam, porang, kacang koro pedang dan buah naga merah memiliki komposisi bahan dengan indeks glikemik rendah sehingga pengolahannya menjadi sereal sarapan dapat menjadi alternatif yang dapat dikonsumsi penderita DM2 dengan aman.*
Tujuan: *Penelitian bertujuan untuk mempelajari indeks glikemik sereal sarapan beras hitam, porang, kacang koro pedang, dan buah naga merah, dan membandingkannya dengan sereal sarapan yang sudah komersial.*
Metode: *Penelitian ini bersifat eksperimen dengan desain post test. Indeks glikemik dianalisis menggunakan metode incremental area under the blood glucose response curve (IAUC). Data indeks glikemik dianalisis menggunakan uji one way ANOVA yang dilanjutkan dengan uji Duncan.*
Hasil: *Hasil penelitian menunjukkan bahwa sereal sarapan pagi mengandung total gula 13,72%, total serat pangan 33,98%, dan antosianin 35,2%, serta nilai indeks glikemik 49,75. Kadar serat pangan, antosianin pada produk hasil penelitian ini lebih tinggi dibandingkan produk komersial, sedangkan energi lebih rendah.*
Kesimpulan: *Produk sereal sarapan memiliki kandungan serat makanan dan antosianin yang tinggi, serta kandungan gula total dan indeks glikemik yang rendah; dapat digunakan sebagai pengganti sarapan bagi penderita diabetes melitus. Perlu dilakukan penelitian lebih lanjut untuk mengetahui keefektifan produk ini dalam mengontrol glukosa darah puasa pada individu dengan diabetes melitus.*

KATA KUNCI: *antosianin; beras hitam; indeks glikemik; sereal sarapan; serat pangan*

ABSTRACT

Background: *Patients with type 2 diabetes need the correct meal that has low glycemic index components in order to prevent blood sugar levels from rising. Due to the low glycemic index of black rice, konjac, jack bean and red dragon fruit, their processing into morning cereals can be a safe choice for DM2 patients.*
Objectives: *The aim of this study was to study the glycemic index of breakfast cereals of black rice, konjac, jack bean, and red dragon fruit, and compare them with commercial breakfast cereals.*
Methods: *This research is experimental with a posttest design. The glycemic index was analyzed using the incremental area under the blood glucose response curve (IAUC) method. Glycemic index data were analyzed using a one-way ANOVA test followed by Duncan's test.*

Results: *The results showed that breakfast cereals contained 13.72% total sugar, 33.98% total dietary fiber, and 35.2% anthocyanins, and a glycemic index value of 49.75. The levels of dietary fiber and anthocyanins in the products of this study were higher than those of commercial products, while the energy levels were lower.*
Conclusions: *Breakfast cereal products have a high content of dietary fiber and anthocyanins, as well as a low total sugar content and glycemic index; can be used as a substitute for breakfast for people with diabetes mellitus. Further research is needed to determine the effectiveness of this product in controlling fasting blood glucose in individuals with diabetes mellitus.*

KEYWORDS: *anthocyanin; black rice; glycemic index; breakfast cereal; dietary fiber*

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INTRODUCTION

Laboratory rats are mammals often used as test animals in various scientific research projects because they have physiological similarities to humans, a relatively short life cycle, a relatively small body shape, and good adaptability. White rats (*Rattus sp*) are widely used as experimental animals because they respond rapidly, can provide data on processes that may occur in humans and other animals (1), and have a physiological system similar to that of humans. Diabetes mellitus (DM) is a chronic metabolic disorder disease caused by many factors and characterized by high blood glucose levels due to abnormalities in insulin secretion, insulin action, or both (2). Type 2 diabetes mellitus (T2DM) is a lifelong disease in which the body cannot produce or use insulin correctly. Approximately 27 million people in the US have T2DM.

In Indonesia, the incidence or prevalence of T2DM increased from 2013 to 2018, from 6.9% to 8.5% of the total population of Indonesia. Diet has a very important role in T2DM management. In addition to pharmacological therapy, non-pharmacological therapy through dietary adjustment can effectively control blood glucose levels, lipid profile, and blood pressure in people with T2DM. The dietary adjustments include using a small portion size and frequent eating to maintain blood glucose stability (3). The principles of the diabetic diet are a balanced diet according to the type and number of caloric needs, as well as a regular eating schedule. One of the dietary therapies to prevent and treat T2DM is the use of a variety of foods that have low glycemic indexes (GIs), are rich in antioxidants, and provide functional properties (4). Low GI foods that have been made, for example cupcakes from wheat flour and corn flour sweetened with Stevia rebaudiana (5). An investigation towards making dietary Sohan-Pilaki for people with diabetes and celiac disease by completely swapping out wheat flour for rice-corn flour and replacing sucrose with Stevia-Isomalt (6)

Food from konjac and black rice can be an alternative breakfast for people with DMT2 because konjac and black rice have hypoglycemic effect (7), (8). Konjac has a low GI due to its high glucomannan content (9). After purification, the levels of glucomannan contained in konjac flour ranged from 36.6 - 64.2% (10). High-carbohydrate supplementation containing glucomannan in T2DM patients for 3 weeks has been shown to reduce blood glucose levels and lipid profiles (11).

In Indonesia, there are many black rices that have high levels of anthocyanins as antioxidants, including Sirampog black rice which contains 4368 mg/g of anthocyanins (12). Black rice contains more fiber than brown and white rice, while reducing sugar is lower. The decrease in fasting blood glucose levels in the group of diabetic rats was greater in the group of diabetic rats given black rice compared to brown rice because black rice has a higher fiber and anthocyanin content and a lower GI when compared to brown rice (13). Until now, there has been no research on the manufacture of konjac and black rice breakfast cereal and its effect on blood sugar, so this research was carried out. Konjac and black rice have high protein content so that in the preparation of breakfast cereals are added jack bean.

Jack beans (*Canavalia ensiformis*) have a fairly high protein content, 28.6% (14). Jack beans extracted with methanol have shown high levels of free phenolic compounds, which can act as antioxidants and inhibit the action of α-amylase and α-glucosidase enzymes in vitro (15). Phytopharmacognostic studies have concluded that the flavonoid and triterpenoid fractions obtained from jack beans can lower blood glucose levels in diabetic subjects (16).

Red dragon fruit lowers blood glucose levels because dragon fruit contains flavonoids that protect against damage to pancreatic cells, which are insulin producers and can increase insulin sensitivity (17). Dragon fruit flesh has been shown to contain 7.21 ± 0.02 mg flavonoids and 42.4 ± 0.04 mg phenolic compounds (18).

Based on our preliminary research on the development of breakfast food from black rice and konjac supplemented with jack beans and red dragon fruit, the moisture, ash, total protein, total fat, carbohydrates (determined by difference), and crude fiber contents of the flakes were 6.07%, 4.87%, 8.68%, 0.38%, 79.99%, and 43.49%, respectively. This research extended that work by examining the effect of breakfast cereal products on blood glucose in normal and diabetic rats and determining the GI values of black rice, konjac, jack beans, and red dragon fruit breakfast cereal.

MATERIALS AND METHODS

Sirampog black rice produced by UMK Maju Lestari, Brebes, Central Java, Indonesia; porang flour produced by Wikonjac, jack bean flour produced by the Bogor BUMR, red dragon fruit from a fruit seller in Purwokerto, crystal coconut sugar produced in Sumbang, salt produced by PT. Uni Chem Indonesia.

The production of breakfast cereal began with the production of black rice flour and red dragon fruit concentrate. Black rice flour, konjac flour, jack bean flour, and red

dragon fruit concentrate were mixed until homogenous and baked in an oven at 120°C for 40 minutes; crystal coconut sugar and salt were added and stirred until homogeneous.

The water and ash content were analyzed using the gravimetric method (19), while the protein levels were determined by the Kjeldahl method (19), the fat content was measured using the Soxhlet method (19), and the carbohydrate content was calculated by difference. Total sugar content was analyzed with the Nelson–Somogyi spectrophotometric method (20). The total anthocyanins were obtained with the pH difference method (21). Dietary fiber was analyzed with the enzymatic-gravimetric method (22).

This study on experimental animals has a post-test design on 30 male Rattus norvegicus rats divided into two groups (15 normal rats and 15 diabetic rats) aged 2 months. Animal management was carried out in accordance with the European Communities Council Directive 86/609/EEC guidelines for the care and use of experimental animals and the official Mexican Standard (NOM-062-ZOO-100-1999) technical specifications for the production, care, and use of laboratory animals (23). Similarly, the Ethics Commission of the Faculty of Medicine, Jenderal Soedirman University (No. 928/KEPK/XI/2022), approved the project.

This test was performed three times for each treatment. Each group has divided into smaller treatment groups, which were as mentioned bellow. The normal groups consisted of five treatment groups (n=3). First, AN group which is feed with 98% glucose solution at a dose of 0.4 g/200 g of body weight. Second, BN group which is feed with Havermout ® at a dose of 0.54 g/200 g of body weight. Third, CN group which is feed with Energen (corn flavor) ® at a dose of 0.54 g/200 g of body weight. The fourth is DN group which is feed with Oriflakes ® at a dose of 0.54 g/200 g of body weight; and EN is a group of normal rats given black rice, konjac, jack bean, and red dragon fruit (X) at a dose of 0.54 g/200 g of body weight.

The diabetic groups consisted of five treatment groups (n=3). First, AD group which is feed with 98% glucose solution at a dose of 0.4 g/200 g of body weight. Second is BD group which is feed with Havermout ® at a dose of 0.54 g/200 g of body weight. Third is CD group which is feed with Energen ® corn flavor at a dose of 0.54 g/200 g of body weight. Fourth group is DD which is feed with Oriflakes ® at a dose of 0.54 g/200 g of body weight. The last is ED group which is feed with black rice, konjac, jack bean, and red dragon fruit (X) at a dose of 0.54 g/200 g of body weight.

Experimental analysis on animals was carried out in three stages: adaptation, induction, and intervention. During the adaptation period, the rats were given AD II standard feed and allowed to drink ad libitum. Their body weights were recorded on the first and last day of the adaptation period as initial data before the induction period. The diabetic group was then treated with streptozotocin at a dose of 45 mg/kg of body weight (injected intraperitoneally) (24) to raise blood sugar levels to 200 mg/dL (25). The induction period lasted three days. At the end of the third day, blood sugar levels andbody weight were measured as baseline data. The glucose levels of the blood were measured by taking

the blood with the retro-orbital method into an EDTA vacutainer tube. Before blood sampling, the rats were fasted for 10 hours (except for mineral water). After fasting, blood was taken to measure blood glucose levels at minute 0 (fasting). Furthermore, the rats were given food according to each group, and then their blood was taken 15, 30, 60, 90, and 120 minutes after feeding.

The blood was then tested using the glucose oxidase–aminoantypyrin peroxidase (GOD-PAP) method using a spectrophotometer read at a wavelength of 500 nm (23). The Glycemix Index (GI) calculation was calculated from the incremental area under the blood glucose response curve (IAUC) (26). The area was determined using the formula:

$$L = \frac{\Delta 30t}{2} + \Delta 60t + \frac{(\Delta 30-\Delta 60)t}{2} + \Delta 90t + \frac{(\Delta 60-\Delta 90)t}{2} + \Delta 120t + \frac{(\Delta 90-\Delta 120)t}{2}$$

where

L : area under the curve

t : time interval for blood collection (30 minutes)

Δ30 : difference in blood glucose levels 30 minutes after fasting

Δ60 : difference in blood glucose levels 60 minutes after fasting

Δ90 : difference in blood glucose levels 90 minutes after fasting

Δ120 : difference in blood glucose levels 120 minutes after fasting

The GI values were calculated with the formula:

$$\frac{\textit{Area under the curve of the test food}}{\textit{Area under the curve of standart food (glucose solution)}} \textit{ x 100}$$

Data Analysis

The proximate, anthocyanin, dietary fiber, and total sugar contents of the foods were statistically analyzed using analysis of variance (ANOVA) at a significance level of $p<0.05$ to determine the effect of treatment. If significant at level 0.05, it follows by The Duncan's Multiple Range Test (DMRT). The blood glucose values were statistically analyzed using ANOVA at a significance level of $p<0.05$ to understand the effect of treatment. The DMRT follow-up test was carried out at the same significance level ($p <0.05$) to observe the resulting differences between treatments. The GI data were analyzed using the one-way ANOVA test at a significance level of $p<0.05$.

RESULTS AND DISCUSSION

Characteristics of breakfast cereal

Breakfast cereal developed with the proportion of composite flour (black rice : konjac : jack bean) 60% : 30% : 10% and 35% addition of red dragon fruit concentrate (T1B3). There is no difference in the ash content in the three commercial breakfast cereal products, but there is a significant difference between the best breakfast cereal (T1B3) and three commercial breakfast cereals. In **Table 1** it can be seen that the ash content of commercial breakfast cereals has an ash content in the SNI range for cereal products, while T1B3 has higher ash content set by SNI 01-4270-1996 (maximum 4.0%) (27). This is because the ash content of the

ingredients used in the best breakfast cereal (T1B3) are black rice, konjac, jack bean, and red dragon fruit, have an ash content 1,20%, 9,22%, 2,36%, and 0,57% respectively (9), (12), '(14),(28) where this content is greater than oat, wheat flour, and arrowroot starch (29),(30). High ash content in T1B3 breakfast cereal indicates high mineral content in T1B3 breakfast cereal.

Table 1. Characteristics of breakfast cereal compared with commercial and Indonesian National Standard

Charateristics	T1B3*	Havermout	Energen	Oriflakes	Indonesia National Standard (SNI 01-4270-1996) (27)
Ash (%)	4.98±0.15^{a}	2.68±0.14^{b}	2.72±0.00^{b}	2.83±0,01^{b}	max. 4%
Moisture (%)	5.41±0.94^{a}	5.95±0.07^{a}	2.28±0.00^{b}	2.00±0.00^{b}	max. 3%
Total protein (%)	9.51±1.17^{a}	12.70±0.85^{a}	4.58±1.62^{b}	2.67±0.94^{b}	min. 5%
Fat (%)	0.37±0.01^{b}	9.95±0.64^{a}	10.03±0.44^{a}	9.85±0.21^{a}	min. 7%
Carbohydrate (%)	79.72±0.37^{a}	69.71±0.42^{b}	81.16±2.26^{a}	81.73± 2.45^{a}	min. 60.7%
Energy (kcal)	224.38±2.57^{c}	382.39±3.04^{b}	400.38±3.05^{a}	408.6±1.01^{ab}	-
Anthocyanin (mg)	35.16±0.39^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	-
Dietary fiber (%)	33.98±0.52^{a}	9.21±0.11^{b}	8.22±0.11^{c}	4.41±0.07^{d}	max. 0.7%
Soluble dietary fiber (%)	2.89±0.14^{a}	0.54±0.02^{b}	0.41±0.01^{c}	0.35±0.02^{c}	-
Insoluble dietary fiber(%)	31.09±0.37^{a}	8.67±0.08^{b}	7.82±0.12^{c}	4.07±0.10^{d}	-
Total sugar (%)	13.72±0.03^{c}	14.53±0.03^{c}	28.29±0.18^{b}	32.69±0.15^{a}	

Note :

*T1B3 = Breakfast cereal developed with the proportion of composite flour (black rice : konjac : jack bean) 60% : 30% : 10% and 35% addition of red dragon fruit concentrate

**The same letters in a row are not significantly different at 5%

With the exception of havermout, the moisture content of commercial morning cereals and T1B3 differed significantly. (**Table 1**). Energen and oriflakes has moisture content tha are within the SNI (maximum 3.0%) (27). Meanwhile, havermout and T1B3 both have a higher moisture content than SNI. The high moisture content in T1B3 is due to the addition of red dragon fruit concentrate, because the water content in red dragon fruit is 94,05% , so the water content in T1B3 has a high value.

There was a significant difference between commercial breakfast cereal (except Oatmeal) and the T1B3 in the protein content **(Table 1).** Protein content in oatmeal and T1B3 fulfill the SNI, while energen and oriflakes have protein levels below the SNI. The difference in protein levels is caused by the main ingredients. T1B3 consisting jack

bean as the protein source with protein content 32,18% '(14). Havermout consisting oat have a protein content of 15-18% (31). Meanwhile, the main ingredient in Energen was wheat flour that contain protein content 9,46% (32), and Oriflakes consisting arrowroot starch with protein content 0,24% (30). T1B3 and oat protein levels meet BPOM standards for diabetics, while Energen and Oriflakes do not (**Table 2**).

There was a significant difference between the commercial cereal products and T1B3 in the fat content (**Table 1**). The fat content in commercial breakfast cereal products fulfill the minimum requirements of SNI i.e. at least 7.0% (27), while T1B3 contain fat below the SNI.

There was no significant difference in the carbohydrate content of T1B3 with commercial cereal products except Havermout. The use of oats as an ingredient for havermout which has higher protein content resulted in lower carbohydrate content than the other (**Table1**). Nonetheless, the carbohydrate content of all types of breakfast cereal fulfill the SNI, at least 60,0% (27). T1B3 protein levels do not meet BPOM recommendations for diabetic products as well as commercial breakfast cereals, because the carbohydrate too high (**Table 2**).

T1B3 has the lowest energy when compared to commercial products, followed by havermout, oriflakes and energen (**Table 1).** For normal people, energy requirement per day is 2000 kcal (33). To fulfill the daily nutritional rate, the amount of energy intake needed at breakfast is estimated between 400-500 kcal. For healthy individuals, 100 grams of T1B3 is insufficient to meet their morning energy needs. However, with the low energy content, it can be utilized as a functional food intended for individuals with certain health problems, such as type 2 diabetes mellitus (T2DM). Anthocyanin were only detect in T1B3 at 35,2% (**Table 1**). T1B3 contained black rice and red dragon fruit which contained anthocyanin compounds. The total anthocyanin in black rice and red dragon fruit ranges from 159,31-359,51% and 43,15%, respectively (12), (35). Meanwhile, commercial products do not contain anthocyanins because the raw materials used are food ingredients that do not contain anthocyanins. Anthocyanins are one of the bioactive compounds of the flavonoid class that provide various health benefits with antioxidant activity which can provide electrons to unstable free radicals, so they become stable (36). Anthocyanins have a role as an antidiabetic by protecting pancreatic β cells from oxidative stress due to glucose induction (37). Research on black rice bran showed antidiabetic activity due to the content of anthocyanin compounds which have a mechanism of action by regenerating pancreatic β cells and allowing them to increase insulin release, thereby increasing Ca^{2+} (calcium ions) in Langerhans islet cells (8). Anthocyanins in black rice also show antidiabetic activity such as lowering blood glucose by reducing insulin resistance, protecting pancreatic β cells, increasing insulin secretion and reducing glucose digestion in the small intestine (38). So consuming T1B3 with anthocyanin content can reduce the risk of diabetes complication in individuals with diabetes.

There are significant differences in the

Table 2. Characteristics of breakfast cereal products in 100 kcal compared to food and drug control agency (BPOM) indonesian recommendations for products for diabetic

Charateristics	T1B3	Havermout	Energen corn flavour	Oriflakes	Food and drug control agency indonesian standards for diabetes (34)
Ash (g)	2.23±0.01[a]	0.70±0.01[b]	0.68±0.00[b]	0.69±0,00[b]	
Moisture (g)	2.41±0.18[a]	1.55±0.02[a]	0.57±0.00[b]	0.49±0.00[b]	
Total protein (g)	4.24±0.21[a]	3.32±0.08[a]	1.15±0.28[b]	0.65±0.12[b]	2.5-5 g
Fat (g)	0.16±0.01[b]	2.60±0.01[a]	2.51±0.04[a]	2.36±0.04[a]	2.22-2.78 g
Carbohydrate (g)	35.53±0.49[a]	18.23±0.09[b]	20.27±0.13[a]	20.00±0.21[a]	11.25-16.25 g
Anthocyanin (mg)	15.67±0.09[a]	2.41±0.03[b]	2.05±0.00[c]	1.08±0.00[d]	
Dietary fiber (g)	1.29±0.05[a]	0.14±0.00[b]	0.10±0.00[c]	1.00±0.01[c]	1-1.7 g
Soluble dietary fiber (g)	13.85±0.24[a]	2.27±0.03[b]	1.95±0.00[c]	8.00±0.02[d]	
Insoluble dietary fiber (g)	6.11±0.06[c]	3.80±0.03[c]	7.06±0.08[b]	7.67±0.03[a]	

Note :

*T1B3 = Breakfast cereal developed with the proportion of composite flour (black rice : konjac : jack bean) 60% : 30% : 10% and 35% addition of red dragon fruit concentrate

**The same letters in a row are not significantly different at 5%

levels of total dietary fiber, soluble dietary fiber, and insoluble dietary fiber for each product tested, except for soluble dietary fiber for energen and oriflakes (**Table 1).** Based on the data, T1B3 can be categorized as a high fiber food product according to the standards set by the European Commission and Codex Alimentarius. The two standard commissions works in the food sector set rules for claims on high fiber food products if the fiber content of the food at least 6 g/100 g of material(22).

High fiber content in breakfast can provide benefits that can reduce the risk of children getting type 2 diabetes mellitus (39). High dietary fiber intake also has a significant effect on reducing the incidence of diabetes from a cohort perspective in epidemiological studies (40). Dietary fiber does not contribute energy or has no caloric value if consumed, but dietary fiber can provide many beneficial benefits for human health such as controlling weight or preventing obesity, moisture-soluble fiber contained in food can retain moisture and form a viscous liquid in the gastrointestinal tract so the food will be digested longer and give a longer feeling of fullness. Dietary fiber can provide benefits for the management of type 2 diabetes mellitus, dietary fiber in foods is able to absorb moisture and bind glucose to reduce the

availability of glucose. In addition, sufficient consumption of dietary fiber causes complex carbohydrates and fiber, so that the digestibility of carbohydrates decreases. Decreasing the digestibility of carbohydrates is able to prevent an increase in blood glucose and keep blood glucose under control(41).

Although dietary fiber has positives impact on health, excess dietary fiber intake can cause negative effects. Excessive dietary fiber intake can lead to the unavailability of some of the nutrients the body needs, such as fat-soluble vitamins (especially vitamins D and E), and can affect the activity of protease enzymes (42). In addition, to reducing the absorption of nutrients, excessive intake of dietary fiber can cause flatulence and have a considerable influence on mineral absorption so that it can cause mineral deficiencies which increase the risk of osteoporosis in the elderly(43). As a reference, it is recommended that both adult women and men consume 25-30 grams of fiber a day(44).

There was a significant difference between T1B3 and commercial breakfast cereals except for havermout in total sugar (**Table 1**). Sugar is a type of carbohydrate that is naturally contained in most foods. The recommended daily sugar intake according to Permenkes No. 30 of 2013 is <10% total energy intake or equivalent to 50 grams of sugar/day with an RDA of 2000 kcal/day. Based on the WHO recommendation, daily consumption of sugar is <10% of total energy intake or <25 grams/day(45).

Total sugar is absorbed by the body through the small intestine, the speed at which sugar is absorbed is related to the speed at which blood glucose levels increase in the body. The faster the absorption, the faster the blood glucose level will increase. High total sugar content in a food ingredient will have a high energy content.

An uncontrolled increase in blood glucose levels can cause hyperglycemia is the beginning of type 2 diabetes mellitus (46). The maximum amount of simple sugars that can be consumed by individuals with T2DM is 5% of the total daily intake (47). Even though the total sugar contained in T1B3 breakfast cereal has a value of 13.72%, T1B3 can still be consumed by individuals with T2DM. It's because the type of sugar added to the T1B3 is crystalline coconut sugar which has a relatively low GI value of 52 (48). So that the sugar in T1B3 will be absorbed and metabolized more slowly in the body to produce energy and does not raise blood glucose levels quickly.

Body weight of rats

The body weight of the normal group appeared to gain weight at the end of the treatment (**Table 3**). This weight gain is due to the state of the organs in rat's body that are still normal, so the absorption of glucose and other nutrients can still be absorbed optimally by the body and stored in the form of fat body stores. The results of statistical analysis performed on the normal and diabetic group body weight showed that there was a significant difference in body weight after the adaptation period and STZ induction of the normal and diabetic groups.

The body weight of the diabetic group before and after treatment experienced was decreased (Table 3). This is because STZ induction damages pancreatic β cells which

Table 3. Body weight change in normal and diabetic rats

Products	Normal group			Diabetic group			Significance
	Before adaptation	After adaptation	Difference (after-before)	Before induction	After induction	Difference (after-before)	
T1B3)	183.67±3.51	187.33±2.52	3.67	182.67±2.52	175.67±4.04	-7	0.013
Havermout	185.33±3.51	189.33±4.04	4	182.67±2.08	175.33±1.53	-7.33	0.005
Energen	187.00±1.00	190.33±0.58	3.33	181.00±3.00	173.33±3.51	-7.67	0.001
Oriflakes	180.67±2.08	185.00±3.00	4.33	184.33±3.21	177.00±2.65	-7.33	0.026
98% glucose	182.33±2.52	186.67±1.53	4.33	184.67±3. 51	177.33±2.52	-7.33	0.042

the body is unable to absorb glucose optimally and triggers glycogenolysis (49). Glycogenolysis is the opposite of glycogenesis in which glycogen in the body undergoes a breakdown reaction by enzymes to produce glucose (50). Continuous glycogenolysis events in the diabetes group cause weight loss.

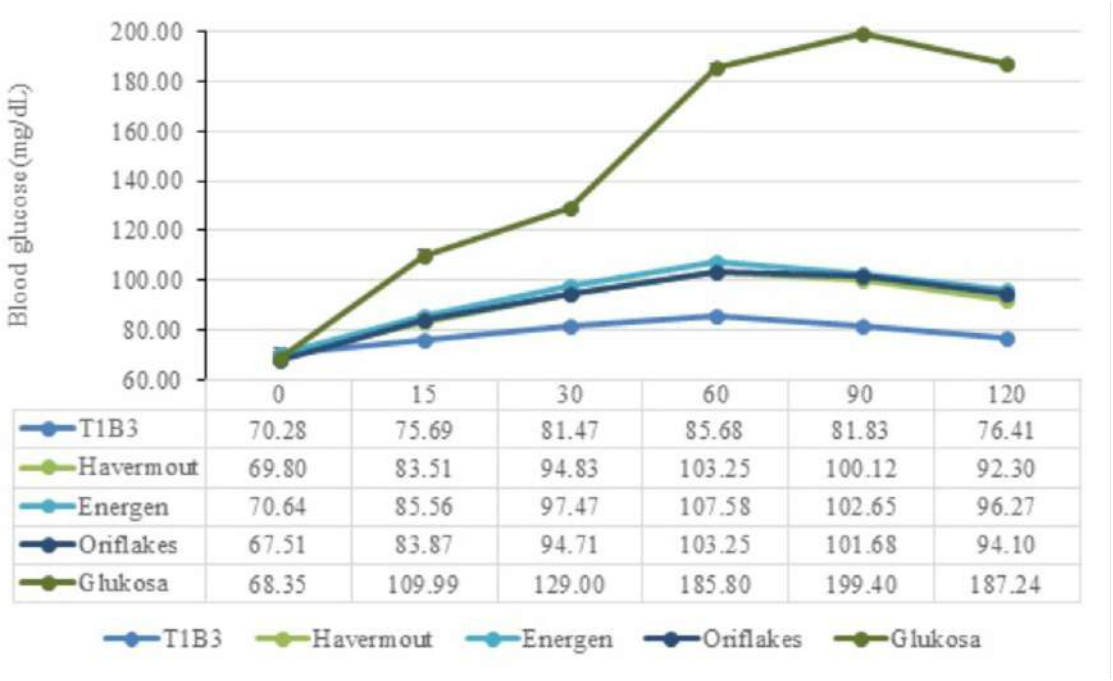
In people with diabetes mellitus there are also problems in the work of insulin to metabolize glucose into imperfect cells so that blood glucose will remain high. This situation can poison and cause a feeling of weakness and unhealthy and cause disturbances in other metabolism. If the body is unable to get enough energy from glucose, the body will process other substances to be converted into energy such as fat and protein in the body. Continuous use of fat and protein stored in the body will lead to weight loss (51).

Blood glucose of rats

The peak blood glucose levels in T1B3 or commercial breakfast cereals in the normal group occurred in the 60th minute, and in the diabetic group the peak blood glucose levels in the commercial breakfast cereals also occurred in the 60th minute, while the peak blood glucose levels in T1B3 occurred in 30th minute (**Figure 1 and 2**). For standard food (glucose solution) it's peak glucose levels in both normal and diabetic occurred in the 90th minute. Blood glucose levels in glucose solutions in both groups has higher levels compared to all types of breakfast cereal.

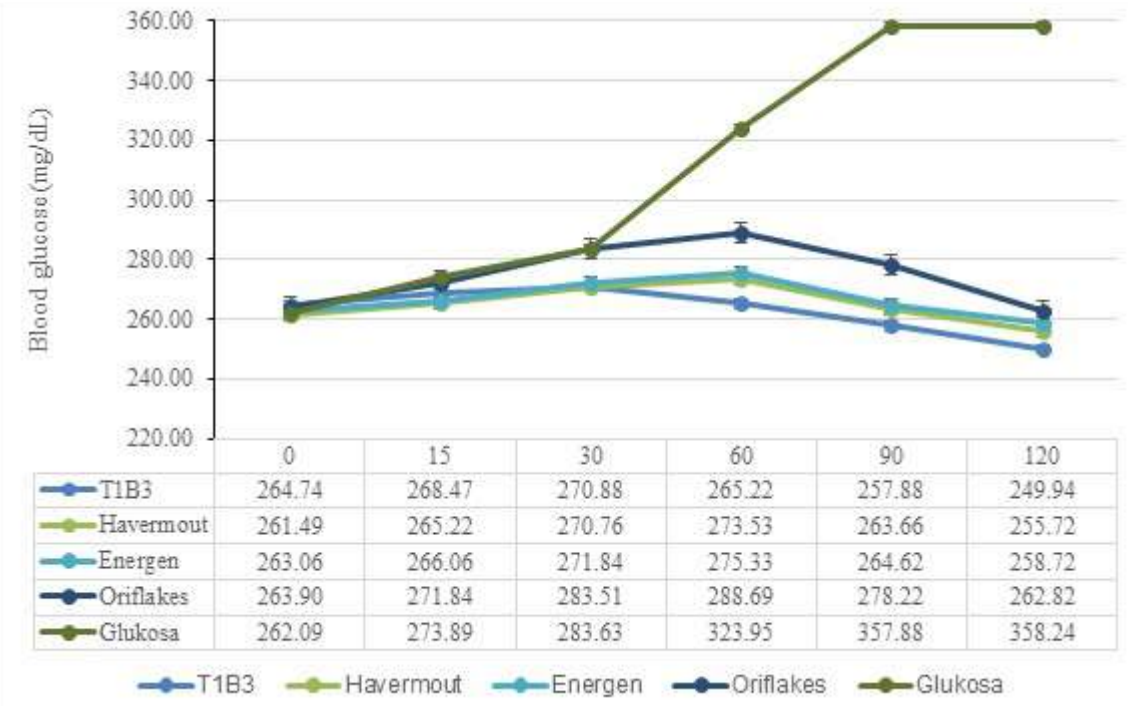
The rate of blood sugar rise levels is determined by the rate of carbohydrates breakage and its absorption by the body. The breakage and absorption of carbohydrates in the body must be converted into glucose. The occurrence of blood glucose peak depends on the digestion and absorption rate of carbohydrates in the human body (52). The blood glucose levels of normal and diabetic which consumed glucose solution are higher than the groups who consumed breakfast cereal, it is because the glucose solution had a more liquid consistency than others and the glucose solution contained more simple carbohydrates so the digestion and absorption processes is faster (53).

Due to the dietary fiber present in each product, blood glucose levels in T1B3 and commercial breakfast cereals were both lower than those of conventional foods. The fiber in cereals can significantly reduce the



	0	15	30	60	90	120
T1B3	70.28	75.69	81.47	85.68	81.83	76.41
Havermout	69.80	83.51	94.83	103.25	100.12	92.30
Energen	70.64	85.56	97.47	107.58	102.65	96.27
Oriflakes	67.51	83.87	94.71	103.25	101.68	94.10
Glukosa	68.35	109.99	129.00	185.80	199.40	187.24

Figure 1. Blood glucose of normal rat group



	0	15	30	60	90	120
T1B3	264.74	268.47	270.88	265.22	257.88	249.94
Havermout	261.49	265.22	270.76	273.53	263.66	255.72
Energen	263.06	266.06	271.84	275.33	264.62	258.72
Oriflakes	263.90	271.84	283.51	288.69	278.22	262.82
Glukosa	262.09	273.89	283.63	323.95	357.88	358.24

Figure 2. Blood glucose of diabetic rat group

increase of blood glucose levels that occurs in both normal individuals and individuals with diabetes. This dietary fiber will form a viscous solution in the small intestine which can reduce macronutrient metabolism with digestive system enzymes thereby reducing glucose absorption and delaying the increase of post-prandial plasma glucose and insulin levels released by pancreatic β cells (41). Blood glucose levels return to normal after two or three hours. Replacing the types of carbohydrates that have a high GI with low GI

in mixed foods has significant advantages for controlling blood sugar in people with type 1 and type 2 diabetes mellitus (8).

Glycemic Index of Breakfast Cereal Products

The glycemic index (GI) value of the breakfast cereals of T1B3 and the commercial breakfast cereals were range in 49,75-60,51 (**Figure 3**). The results of statistical analysis showed a significant difference between T1B3 and commercial breakfast cereals. The GI value in a food is caused by several factors present in the food such as fiber content, amylose and amylopectin ratio, starch digestibility, fat and protein content, and food processing methods (54). Each component in the food contributes and influences each other to produce a certain glycemic response. The GI value of T1B3 had the lowest value of 49,75 which was classified as a food group with a low GI value, while all breakfast cereals belonged to a food group with an average GI (55)(56).

T1B3 has a low GI value due to the nutritional and non-nutritional chemical components contained. The chemical components analyzed in this study were anthocyanins and dietary fiber. The athocyanin compound contained in the tested food cereal product was 35,2% (**Table 1**), whereas in the commercial breakfast cereal the anthocyanin compound was not detected. The anthocyanin compounds contained in the T1B3 test cereals are able to maintain normal blood glucose levels in the human body (57). Anthocyanins derived from this plant work by significantly inhibiting the activity of the α-amylase and α-glucosidase enzymes, both enzymes are the enzymes responsible for the digestion of starch in the intestine. Thus, with the inhibition of the action of the α-glucosidase enzyme from anthocyanins, it provides a lower blood glucose response in the body and the GI value of these foods becomes lower (58).

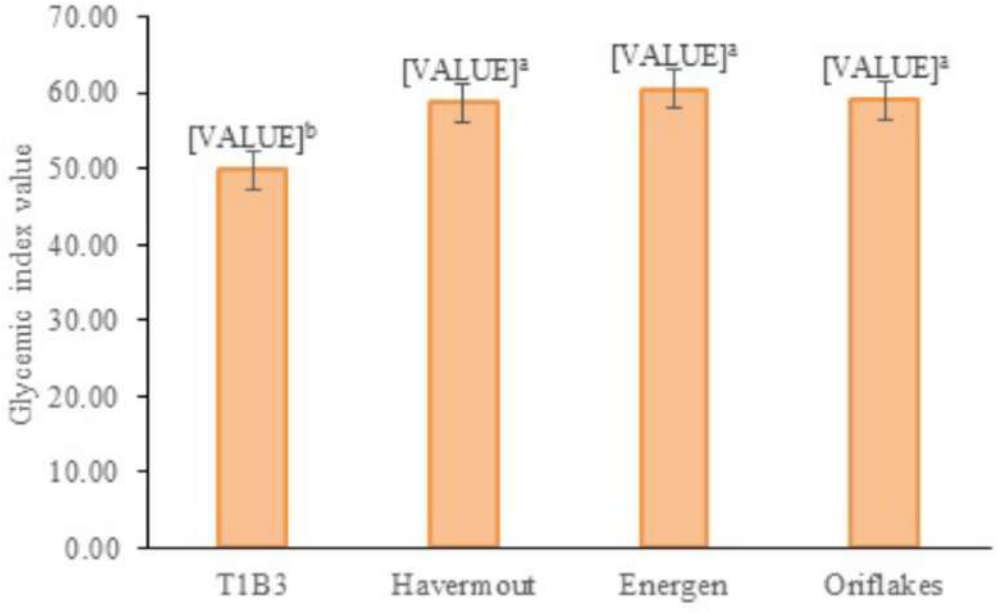


Figure 3. Glycemic index value of food product

The level of dietary fiber in a food also determines the GI value of a food. The food fiber content of T1B3 has the highest levels compared to other commercial breakfast cereals, namely 33,98% **(Table 1).** The higher the fiber content, the lower the GI value in a food (59). Dietary fiber in its intact form can work as an inhibitor in the digestive system. Dietary fiber will slow down the rate of food in the gastrointestinal tract and inhibit enzyme activity, so that the digestive process, especially starch, will be slower and the response from blood glucose will be lower, this slow response from blood glucose indicates that the GI value of the food has a higher value low(60).

Dietary fiber in reducing GI values is related to the physiological function of its components consisting of soluble and insoluble fiber. Soluble dietary fiber will slow down digestion in the intestine, provide a longer feeling of satiety, and will slow down the rate of increase in blood glucose, so the insulin needed by the body to carry glucose into the body's cells and convert it into energy will be less (61). Insoluble dietary fiber can prevent diseases related to the digestive tract by forming a rigid food structure that slows down digestion thereby inhibiting the release of sugar from cells and reducing absorption.

Foods with high GI values are foods that cause high blood glucose concentrations and increase insulin demand, thus contributing to a higher incidence of T2DM. The main goal of managing the diet in individuals with diabetes is to reduce hyperglycemia, prevent hypoglycemia in individuals who use insulin, and reduce the risk of complications. Consumption of food that is absorbed by the body will slowly inhibit the increase in blood glucose. So that individuals with T2DM are advised to replace their food from high GI value food to low GI value food because they can improve glycemic control and reduce hypoglycemic events in individuals who use insulin(62). Therefore, with a low GI value with a GI value of 49,75, T1B3 can be a breakfast substitute for individuals with T2DM.

CONCLUSION AND RECOMMENDATIONS

T1B3 breakfast cereal has total sugar, total dietary fiber, and anthocyanin levels of 13.72%, 33.98%, and 35.2%, respectively. Consuming T1B3 did not increase blood glucose quickly in either the normal rat group or the diabetic rat group. The GI value of T1B3 is 49.75, making it a low-GI food. Therefore, the breakfast cereal T1B3 can be a substitute breakfast food for individuals with DMT2.

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