Glycemic Index of Flakes Made from Mocaf-Black Rice and Bean Flour as Alternative Snacks for People with Type 2 Diabetes Mellitus

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ABSTRACT

This study aimed to analyze the glycemic index and glycemic load of mocaf-black rice flakes. The study used a single-factor completely randomized design in which the type of bean flour added were black soybean flour and jack bean flour. The glycemic index was analyzed using the incremental area under the blood glucose response curve (IAUC) method. The glycemic index and glycemic load data were analyzed using paired T-test. The results showed that mocaf-black rice flakes with the addition of black soybean flour and jack bean flour had glycemic indexes of 50.19±21.57; 52.59±22.93 and glycemic loads of 13.75±5.91; 14.60±6.37, respectively. Both flakes can be recommended as snacks for people with type 2 diabetes.

Keywords: black rice, flakes, glycemic index, glycemic load, mocaf


INTRODUCTION

Diabetes mellitus (DM) is a disease characterized by hyperglycemia that occurs due to abnormal insulin secretion, abnormal insulin action, or both (1). Type 2 DM is progressive; thus, blood glucose control is needed as an effort to prevent the risk of complications(2). Besides pharmacological therapy, non-pharmacological therapy through dietary adjustment is effective to control blood glucose levels, lipid profile, and blood pressure in people with type 2 DM. The dietary adjustments using a small portion size and frequent eating are needed to maintain blood glucose stability(3). Therefore, besides the main dishes, snacks are needed to meet nutritional requirements and control blood glucose.
response after eating (4). The GI value of a product will be affected by factors such as fiber content, amylose-amylopectin ratio, fat, and protein (5). Consumption of high-fiber, high-amylase, and low-GI foods can improve insulin sensitivity, reduce the rate of glucose absorption, and it is useful for blood glucose control; thereby, reducing the risk of complications in people with type 2 DM(6). Diets low in GI and glycemic load (GL) were relevant to the prevention and management of diabetes and coronary heart disease, and probably obesity(7). Mocaf is a local food that has the potential to be developed as a substitute ingredient for wheat flour. Many studies on various types of mocaf-based foods have been conducted such as biscuit products (8), noodles (9), Indonesian pinch cakes (10), and cake (11). One of the popular and preferred snacks is flakes because of the practical properties and delicious taste. The formulation of mocaf and black rice with the addition of black soybean flour and jack bean flour that are made into high protein and dietary fiber flakes (12). Black rice has a GI of 64 and a GL of 32 (13). Soybean flour has high protein content, antioxidants, and low GI. It can also improve the product’s texture. Flakes made from local foods that have a low GI, fiber content, good fat, and protein can be an alternative snack for people with type 2 DM(14). Based on the previous study on the formulation of flakes from mocaf and black rice with the addition of black soybean flour, the water, ash, total protein, total fat, carbohydrate by difference, and dietary fiber contents of the flakes were 3.78%, 2.75%, 9.65%, 5.51%, 78.31%, and 16.10%, respectively (12) while the contents of the ones with the addition of jack bean flour were 3.17%, 1.88%, 4.65%, 3.27%, 87.03%, and 14.82%, respectively(14). This research was a follow-up study that aimed to determine the GI values and calculate the GL of mocaf-black rice flakes with the addition of black soybean flour and jack bean flour.

METHODS

Study Design, Location, and Duration
This was an observational study, which calculated the GI of flakes by observing the increase in blood glucose among healthy subjects and calculated the GL values. The study was conducted from May to July 2019 in the scope of Nutrition Science Study Program, Faculty of Health Sciences of Jenderal Soedirman University.

Materials and Tools
The flakes were made from the following raw ingredients: mocaf that was obtained from Banjarnegara, jack beans that were obtained from Bogor, and the black soybeans, black rice, refined sugar, tapioca, salt, and sodium bicarbonate that were obtained from modern bakeries in Purwokerto. According(14), the tools used in the production of flakes were analytical balance (Ohaus, China), electric ovens, ovens (Memmert, Germany), 60
and 80 mesh stainless steel sieves, noodle maker (Atlas, Indonesia), blender, household-scale kitchen utensils,
and some glassware for chemical analysis such as micropipettes, porcelain dishes, kiln, volumetric flasks,
clamps, glass desiccators, Soxhlet extractor (Iwaki, Indonesia), Kjeldahl flasks, distillation apparatus,
Erlenmeyer flasks, measuring cups, MSI vortex, and burettes.

**Research phases**

**Production of flakes**

The production of flakes began with the production of black rice flour, jack bean flour, and black soybean flour. All ingredients were mixed using a mixer, and the dough was then stirred until homogenous. The dough was steamed for 15 minutes, molded with noodle maker with a scale of 3 (with ± 1 mm thickness) and flat shape with a size of 1.5x1.5 cm, and baked in an oven at 130°C for ± 20 minutes.

**Glycemic index test**

The initial step of the test was to obtain ethical approval from the Ethics Committee of the Faculty of Medicine, Jenderal Soedirman University with a reference number: 2087/KEPK/V/2019. The GI calculation used the incremental area under the blood glucose response curve (IAUC) method. The test used 11 subjects, who were previously asked to fast (except plain water) for 10-12 hours the night before the test. The fasting blood glucose (FBG) was then measured. The subjects were then asked to consume the test foods (pure glucose, mocaf-black rice flakes + black soybean flour, and mocaf-black rice flakes + jack bean flour) equivalent to 50 g of carbohydrate by difference. The interval between treatments was three to four days to avoid bias from each food tested. The subjects’ blood samples (1-2 µL) were taken every 30 minutes (at 30, 60, 90, and 120 minutes) using a finger-prick capillary blood sampling method(15). The blood sampling used a blood glucose test device with a brand Gluco Dr Blood Glucose Monitoring System (AGM-2100 model) produced by All Medicus Co., Ltd. The blood glucose data were then spread as time (minutes) on the X-axis and blood glucose levels on the Y-axis.

The GI was calculated by comparing the area under the curve of the test foods (mocaf-black rice flakes + black soybean flour and mocaf-black rice flakes + jack bean flour) to a standard food (pure glucose), and the results were then averaged. The area under the curve was then calculated by the following formula [16]:

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

\[
GI = \frac{\text{Area under the curve of the test foods}}{\text{Area under the curve of a standard food}} \times 100\%
\]

L = area under the curve
Data from previous research, mocaf-black rice flakes + black soybean flour has total calories 401.3 cal, while mocaf-black rice flakes + jack bean flour has total calories 396.02 cal(14). Flakes as a snack has potency to fulfills 10 percent (200 calories) of 2000 calories as recommend by Indonesian Recommended Dietary Allowance (RDA). Amount of one serving of mocaf-black rice flakes + black soybean flour was 49.83 (200/401.3 x 100 g), and amount of carbohydrate per one serving was 27.40 (49.83 x 55%). While amount of one serving of mocaf-black rice flakes + jack bean flour was 50.5 (200/396.02 x 100 g), and amount of carbohydrate per one serving was 27.77 (50.5 x 55%).

The GL is obtained by multiplying the GI by total carbohydrates of one serving of the test food and then dividing the results by 100 (16);(17).

Data Analysis

The data regarding GI and GL tests collected were then analyzed using paired T-test (18).

RESULTS

Subjects’ Characteristics

The prospective subjects were recruited by purposive random sampling through verbal socialization (announcement) to ask willingness from the prospective research subjects. The prospective research subjects were students of Nutrition Science Study Program at the Jenderal Soedirman University who were willing to take part in the study by previously signing the informed consent. The selected subjects had met the inclusion criteria as determined in the research methods as follows: normal nutritional status (BMI of 18.5-22.9 kg/m²), FBG between 70 mg/dL and 100 mg/dL, and age range of 19-23 years (15). The characteristics of research subjects can be seen in Table 1.
Table 1. Characteristics of Research Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI* (kg/m²)</th>
<th>FBG (mg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>20</td>
<td>50.9</td>
<td>160</td>
<td>19.88</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>21</td>
<td>49.6</td>
<td>147.5</td>
<td>22.79</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>21</td>
<td>47.2</td>
<td>149</td>
<td>21.26</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>21</td>
<td>54.6</td>
<td>164.5</td>
<td>20.17</td>
<td>88</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>20</td>
<td>61.5</td>
<td>167.5</td>
<td>21.92</td>
<td>81</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>21</td>
<td>43.2</td>
<td>151.2</td>
<td>18.89</td>
<td>89</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>22</td>
<td>68</td>
<td>168</td>
<td>24.09</td>
<td>85</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>23</td>
<td>65.3</td>
<td>170.5</td>
<td>22.46</td>
<td>78</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>19</td>
<td>48.4</td>
<td>160</td>
<td>18.90</td>
<td>92</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>19</td>
<td>51</td>
<td>165</td>
<td>18.73</td>
<td>99</td>
</tr>
</tbody>
</table>

Mean: 20.07±1.25 59.5±12.02 160.4±7.23 20.91±1.88 87.8±5.85

*Body mass index (BMI) is the body weight (kg) divided by the square of body height (m²)

Determination of the Amount of Test Foods

The foods assessed for the glycemic index were mocaf-black rice flakes with the addition of black soybean flour and jack bean flour while the standard food used as a comparison was pure glucose. Each ingredient should contain 50 g of available carbohydrate, which could be known from the analysis results of carbohydrate by difference. According to (19), the total amount of the standard food given was 50 g because the standard food used was pure glucose while the total amount of the test foods can be seen in Table 2.

Table 2. Determination of the Amount of Test Foods Equivalent to 50 g of Available Carbohydrate

<table>
<thead>
<tr>
<th>Mocaf-black rice flakes</th>
<th>Carbohydrate by difference</th>
<th>Amount of the test foods*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added with black soybean flour</td>
<td>78.3 g</td>
<td>63.8 g</td>
</tr>
<tr>
<td>Added with jack bean flour</td>
<td>87.02 g</td>
<td>57.4 g</td>
</tr>
</tbody>
</table>

*50/carbohydrate by difference x 100

Blood Glucose Levels

The difference in bean flour (soybean flour and jack bean flour) added to mocaf-black rice flakes provided different glucose responses in the healthy subjects. The data regarding the results of the average response of blood glucose level in the healthy subjects to the standard food and test foods can be seen in Table 3.
Table 3. The Results of the Average Response of Blood Glucose Levels in the Healthy Subjects to the Standard Food and Test Foods

<table>
<thead>
<tr>
<th>Foods</th>
<th>Time (minutes)</th>
<th>0'</th>
<th>30'</th>
<th>60'</th>
<th>90'</th>
<th>120'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose*</td>
<td></td>
<td>90.20±</td>
<td>181.70±</td>
<td>163.20±</td>
<td>116.40±</td>
<td>91.90±</td>
</tr>
<tr>
<td>Mocaf-black rice flakes + black soybean flour**</td>
<td>5.98</td>
<td>34.94</td>
<td>30.26</td>
<td>22.18</td>
<td>17.24</td>
<td></td>
</tr>
<tr>
<td>Mocaf-black rice flakes + jack bean flour**</td>
<td>3.81</td>
<td>23.52</td>
<td>14.39</td>
<td>10.64</td>
<td>9.93</td>
<td></td>
</tr>
<tr>
<td>Mocaf-black rice flakes + jack bean flour**</td>
<td>95.1±</td>
<td>152.3±</td>
<td>116.4±</td>
<td>107±</td>
<td>92.2±</td>
<td></td>
</tr>
<tr>
<td>Mocaf-black rice flakes + jack bean flour**</td>
<td>4.59</td>
<td>10.44</td>
<td>17.18</td>
<td>10.67</td>
<td>9.10</td>
<td></td>
</tr>
</tbody>
</table>

*standard food, **test foods

Based on Table 3, it can be known that, on average, there was an increase in blood glucose levels of the healthy subjects in the 30th minutes after eating, and then the blood glucose levels decreased in the 60th, 90th, and 120th minutes. The high standard deviation shows heterogeneous data even though the study subjects fit the inclusion and exclusion criteria. The blood glucose data obtained from the measurement results of the research subjects’ blood glucose responses to each food given were then spread as time (minutes) on the X-axis and blood glucose levels (mg/dL) on the Y-axis in the form of scatter plot using Microsoft Excel software. Changes in the curve of the increase and decrease in blood glucose levels can be seen in Figure 1.

Figure 1. Changes in the curve of the increase and decrease in blood glucose levels

Based on the curve in Figure 1, it is known that the consumption of mocaf-black rice flakes with the addition of black soybean flour and jack bean flour has the same high increase in blood glucose response. Glycemic Index. The GI test used pure glucose as a standard food and mocaf-black rice flakes with the addition of black soybean flour and jack bean flour as the test foods. The flakes analyzed were equivalent to 50 g of carbohydrates based on the available carbohydrate content obtained from the analysis results of carbohydrate by difference. The
available carbohydrate described the total content digested, absorbed, and metabolized by the body. The results of flakes’ GI analysis can be seen in Table 4.

Table 4. The Results of GI Analysis of Mocaf-Black Rice Flakes with the Addition of Different Bean Flour

<table>
<thead>
<tr>
<th>Types of Treatment</th>
<th>GI</th>
<th>Category*</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mocaf-black rice flakes + black soybean flour</td>
<td>50.19±21.57</td>
<td>Low</td>
<td>0.812</td>
</tr>
<tr>
<td>Mocaf-black rice flakes + jack bean flour</td>
<td>52.59±22.93</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

*Category: low GI (<55), moderate GI (55-70), and high GI (>70)

Glycemic Load

The consumption of low-GI foods aims to reduce the GL of foods. GL is defined as food’s GI multiplied by the carbohydrate content of the food (20). The calculation results of flakes’ GL can be seen in Table 5.

Table 5. Results of Flakes’ Glycemic Loads

<table>
<thead>
<tr>
<th>Foods</th>
<th>GI</th>
<th>Amount of serving</th>
<th>Carbohydrates per serving</th>
<th>GL</th>
<th>Category*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mocaf-black rice flakes + black soybean flour</td>
<td>50.19</td>
<td>49.83</td>
<td>27.40</td>
<td>13.75±5.91</td>
<td>moderate</td>
<td>0.760</td>
</tr>
<tr>
<td>Mocaf-black rice flakes + jack bean flour</td>
<td>52.59</td>
<td>50.5</td>
<td>27.77</td>
<td>14.60±6.37</td>
<td>moderate</td>
<td></td>
</tr>
</tbody>
</table>

*Category: low GL (<11), moderate GL (11-19), high GL (>20)

GL = (GI x amount of carbohydrates per serving)/100

DISCUSSION

Based on Table 4, comparative analysis of glycemic index value between two treatment showed no significant difference (p=0.812), mocaf-black rice flakes with the addition of black soybean flour have a low GI value than the flakes with the addition of jack bean flour. The results of the study are in line with (21) that research analog rice made from corn flour, sago, soy flour and rice bran had a glycemic index of 54, while analog rice from white corn flour with the addition of 10% soy flour had a glycemic index value of 50(22). Cookies from black rice and black soybeans (65:35 %) has a glycemic index of 39.74; while the glycemic index of the red bean snack bar and arrowroot flour is 25(23).GI is useful in determining the amount and types of food sources of carbohydrates to control blood glucose(24). Carbohydrates are digested and absorbed at different speeds; thereby, they give different effects on blood glucose levels. Low-GI foods are optimal for controlling blood glucose levels of people with type 2 DM because they do not cause a spike in the blood glucose increase. The food GI can be grouped into low GI (<55), moderate GI (55-70), and high GI (70). The previous study indicated that the consumption of high-GI foods (>70) triggered rapid insulin secretion, resulting in increased insulin resistance (25). The GI and GL values can be influenced by several factors such as amylose-amylopectin ratio, resistant starch (26), and food processing (27); (17). The ingredients used in the production of flakes (e.g.,
mocaf, black rice, black soybeans, and jack beans) had been previously heated before being processed into flakes. Food processing in the form of heating and parboiling could reduce the GI of rice (28). Mocaf has a low GI value and carbohydrate (starch) content of 88.61-91.50% (29) while black rice contains complex carbohydrates and has high fiber content (30). The consumption of complex carbohydrates 50% of total calories can increase and improve glucose combustion in peripheral tissues and improve pancreatic β cells (31). Soybean was a source of vegetable protein with a protein content of 35-40%, low in saturated fats, and it did not contain cholesterol (32). The previous study showed that soybean consumption habits had a protective risk for type 2 DM because black soybeans not only had a low GI (31) but they also contained isoflavones and anthocyanins, which were antioxidants that neutralized free radicals due to hyperglycemia in type 2 DM (33). Food processing can change the structure and chemical composition of foods (e.g., particle size and gelatinization level) that can subsequently change nutrient absorption and influence the GI of foods (34); (35). The production of flakes used steaming and baking processes. The heating caused the gelatinization process. The gelatinized foods have higher GI values because the detached and swollen granules have a wider surface, which makes them easily hydrolized by digestive enzymes (5). However, the results of the current study showed that both flakes were classified into a low-GI category (<55). The previous study showed that the consumption of low-GI foods could improve insulin sensitivity, reduce the rate of glucose absorption, and it was useful in controlling blood glucose; thereby, it could reduce the risk of complications in people with type 2 DM (2); (3). Tabel 5. showed that comparative analysis of glycemic loads value between two treatment showed no significant difference (p=0.760). GL can be categorized into low (<11), moderate (11-19), and high (>20). Both mocaf-black rice flakes had moderate GLs. The mocaf-black rice flakes with the addition of black soybean flour had a lower GL than the mocaf-black rice flakes with the addition of jack bean flour. This result showed that mocaf-black rice flakes with the addition of black soybean flour caused a smaller increase in blood glucose levels. The result of the previous study on nutrient contents of mocaf-black rice flakes indicated that flakes with the addition of black soybean flour had a higher fiber content than the flakes with the addition of jack bean flour, which was in line with the flakes’ lower GI and GL values (14). The research results showed that the GL value was directly proportional to GI. Another study indicated that long-term consumption of high-GL foods could be associated with a risk of type 2 DM (20). Foods with lower GI and GL values will trigger a slow increase in blood glucose levels and also give a lower peak of blood glucose response, thereby not increasing the risk of hyperglycemia (3). Both flakes have low GI values and moderate GL values, thereby the flakes can be recommended as snacks for people with type DM, but we still need to pay attention to the portion size.
CONCLUSION

The mocaf-black rice flakes with the addition of black soybean flour had lower GI values than mocaf-black rice flakes with addition of jack bean flour. Both flakes can be recommended as snacks for people with type 2 DM, which are then expected to help control blood glucose. Further studies are needed regarding the direct effects of these flakes on people with type 2 DM.

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