Comparison of chemical properties, glycemic index, and glycemic load, between arrowroot (*Maranta arundinaceae*) cookies containing glucomannan extract with palm sugar addition

Dewa Baskara Gama[1], *Eni* Harmayani[2*], *Lily* Arsanti Lestari[1], and *Emy* Huriyati[1]

[1]Department of Health Nutrition, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Jl. Farmako, Sekip Utara, Yogyakarta, 55281, Indonesia.
[2]Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora 1, Yogyakarta, 55281, Indonesia

Abstract. Diabetes Mellitus (DM) is a degenerative disease mainly caused by high carbohydrate and high glycemic index (GI) diet. Meanwhile, Indonesia has large source of low GI food, such as arrowroot, *porang* tuber, and palm sugar that has not developed well. Cookie, as a well-known snack in Indonesia, will be made from the combination of arrowroot flour, *porang* glucomannan extract, and palm sugar is expected could be an alternative snack for diabetic people. The aim of research is to investigate the difference of chemical properties (proximate, total starch, total dietary fiber, total sugar, and resistant starch), GI, and glycemic load (GL) between arrowroot cookies containing glucomannan extract with palm sugar and cane sugar addition. The research was conducted using analytical observation method with cross-sectional design. Chemical properties will be compared using unpaired t-test. GI of cookies with palm sugar is 19.6, while GI of cookies with cane sugar is 25.6. GL of cookies with palm sugar is 13.71, while GL of cookies with cane sugar is 17.6. There is no significant difference in chemical properties, except in total dietary fiber (p<0.05). Both cookies classified into low GI and moderate GL food.

1 Introduction

In 2017, Indonesia became the top 6 ranked country for highest number of people with Diabetes Mellitus (DM) in the world, which 90 % of them are type 2 DM [1]. According to Indonesia Basic Health Research data, the prevalence of diabetic people is always increasing. In 2007, the prevalence of DM was 5.7 %, increased to 6.9 % in 2013, and increased again to 8.5 % in 2018 [2].

The increment of diabetes prevalence in Indonesia is caused by multi-factors, one of them is irregular eating habits. More people are more frequent to eat high-sugary and high in GI food. High GI food is absorbed faster in the intestines, causing much higher blood glucose and compared to low GI food. This condition is called hyperinsulinemia which could lead into long-term chronic hyperglycemia [3]. Several studies had shown that choosing low GI food as daily consumption could reduce the risk of suffering from DM. Low GI food have high total fiber so it is digested slower in the intestine and help to stabilize the post-prandial blood glucose fluctuation [4].

Arrowroot tuber had been proven as low GI food [5]. A study showed b that GI score of steamed arrowroot tuber was 14 which made arrowroot classified as low GI food (GI<55) [6]. Roasting is a way of cooking arrowroot tuber and its product which had been known has the effect to maintain its GI score. This is due to an increase in resistant starch during the roasting process also less water is added hence prevent the gelatinization process. Arrowroot can be produced into delicious yet healthy cookies, which is well-known snack and widely accepted by society [7].

Beside arrowroot, there is another component that had been studied could help stabilize blood glucose fluctuations, namely glucomannan. Glucomannan is a fiber component in the form of polysaccharides consisting of β-1-4 chain, glucose, and mannose bonds [8]. Glucomannan is extracted from *porang* tubers (*Amorphophallus oncophylus*) that grows in tropical countries such as Indonesia.

A study investigated that glucomannan has the effect of stabilizing glucose homeostasis, fat metabolism, and calorie intake. Glucomannan has the ability to induce a longer feeling of satiety through viscosity changing of food bolus in gaster so it slows down digestion process. This phenomenon could happen because glucomannan has the ability to bind with water up to 200 times its initial weight therefore it could prolong satiety [9].

Cane sugar is the most commonly used natural sweeteners for baking cookies. Sugar is important ingredients for baking cookies since it will help increase the taste. Formulating cookies for diabetic people should use different kind of sugar therefore could produce a good taste and low-GI cookies. Study found palm sugar as an alternative sugar that could substitute cane sugar

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* Corresponding author: eniharmayani@yahoo.com

in many cooking activites. This kind of sugar even a bit more expensive but have a relatively low in GI compared to cane sugar. Palm sugar has distinctive pale until dark brown color because it did not go through rafination and whitening process [9].

Several studies that carried out arrowroot cookies associated with GI had been conducted. A study stated that modified arrowroot starch cookies has GI score of 31. Another study tried to substitute arrowroot cookies with red bean flour (35 %) and resulted in GI score of 11.42 [7]. The difference of this research from the other published studies is the usage of glucomannan in making the cookie dough, investigation of glycemic load, and comparison of chemical properties, GI, and GL of cookies using two different kind of sweeteners (cane sugar and palm sugar).

2 Materials and methods

2.1 Study design

The research was conducted with analytic-observational study with a cross-sectional design. The glycemic index (GI) was obtained by calculating the incremental area under the curve (iAUC) for blood glucose after consumption of a test food divided by the iAUC of a reference food containing the same amount of available carbohydrate. There were two variables studied: the independent variable was the use of palm sugar and cane sugar, meanwhile the dependent variables were the chemical properties (proximate content, total dietary fiber, total sugar, total starch content, and starch), glycemic index, and glycemic load.

2.2 Cookies production phase

The research began with the production of arrowroot cookies at the Food Engineering Laboratory, Center for Food and Nutrition Studies, Universitas Gadjah Mada (UGM). Arrowroot flour was provided by Kusuka home industry in Bantul, Special Region of Yogyakarta. Arrowroot starch was provided by Mekarsari home industry in Kulon Progo, Yogyakarta. Glucomannan was provided by Incubator Laboratory in Faculty of Agricultural Technology, UGM. The cookies production itself was under the supervision of Gama Food, a subsidiary of Gama Multi company, which has received legal hyigene permission number 206340401497-21 from local health department. Arrowroot flour and starch used was 60:40 in ratio. Glucomannan usage was 1 % from total dough weight. The usage of both palm and cane sugar was 9.3 % from total dough weight.

2.3 Chemical properties testing phase

Chemical properties testing was carried out in the Nutrition Analysis Laboratory, Center for Food and Nutrition Studies, UGM. The chemical properties tested including proximate (water, ash, protein, fat), total starch, resistant starch, total dietary fiber (water-soluble fiber and water-insoluble fiber), and total sugar content. The test was conducted for 60 d period.

2.4 Subjects criteria

The procedure for GI testing refered to ISO 26642: 2010 and National Agency of Drug and Food Control (NADFC) Guidelines on GI testing (2011). The procedure began with subjects recruitment which was conducted with consecutive sampling according to inclusion and exclusion criterias. The inclusion criterias were students of Universitas Gadjah Mada (UGM) aged 18 yr old to 23 yr old, BMI 18.5 to 22.9 $kg\,m^{-2}$, normal fasting blood glucose (70 to 110 $mg\,dL^{-1}$), and above all that must be in a good-health condition indicated by health certificate from nearby primary health care facility. Exclusion criterias were ever had a history of diabetes and/or other metabolic syndromes, digestive disorders such as diarrhea, and pregnant or breastfeeding during blood glucose sampling period.

2.5 Blood sampling phase

Blood glucose measurement were carried out by health analyst at Health and Nutrition Department Building, Faculty of Medicine, Public Health, and Nursing, UGM. Glucometer was using Therasense@Freestyle brand, lancet, and test strips. The blood sampling step was carried out for 3 wk. The first week was testing for solution of 200 mL water with 25 g of anhydrous glucose. The second week was testing for cookies with sugar cane (Formulation B). The third week were testing for cookies with palm sugar (Formulation A). The data then used to calculate GI and GL score. This research was safe and obeying standard procedure approved by Ethics Commission of Faculty of Medicine, Public Health and Nursing with reference number KE/FK/1231/EC/2018 on November 22nd, 2018.

2.6 Data analysis

The chemical properties data were analyzed with quantitative method. The normality of the data was tested with Shapiro Wilk test. The data distribution was tested with unpaired t-test. The data from GI and GL testing were analyzed with quantitative test.

3 Results

3.1 Subjects recruitment and characteristics

Glycemic Index (GI) and Glycemic Load (GL) testing of the cookies began with subject recruitment. At the beginning, 13 subjects were obtained. After briefing session, 2 subjects were withdrawn due to fear of syringes. Health status of all agreed subjects were then checked before blood sampling begin. During blood sampling, 1 subject withdrew because subject missed one blood sampling session. The flow of subject recruitment can be seen in Figure 1. From all the subjects recruited, it can be inferred that there are seven

females and three males with average years 21.2±0.92 years old, average BMI 20.57±0.97 kg m^{-2}, and average of fasting blood glucose 80.75±1.74 mg dL^{-1}. The information can be seen in Table 1.

Table 1. Demographic and clinical characteristics of subjects

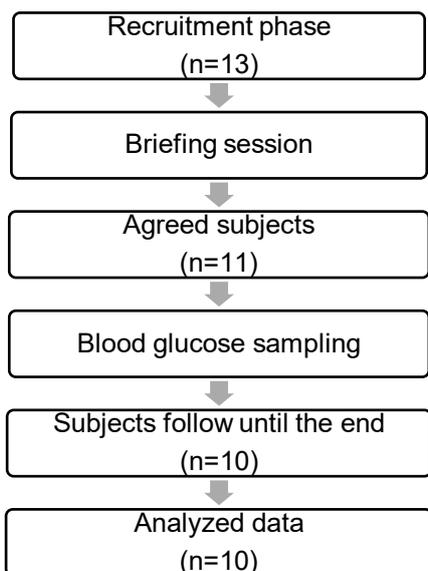| Characteristic	Value
Total subjects	10
Female(s)	7
Male(s)	3
Average of age (years)	21.2±0.92
Average of BMI (kg m^{-2})	20.57±0.97
Average of Fasting Blood Glucose (mg dL^{-1})	80.75±1.74

Fig. 1. Subjects recruitment flow

3.2 Chemical properties testing

Components analyzed including proximate (water, ash, fat, and protein), total starch, total dietary fiber, resistant starch, and total sugar for both cookies. Proximate analysis was used as a base to calculate the amount of energy from cookies. Total starch, total dietary fiber, and resistant starch was used to determine which one is better for alternative snack for diabetic people. Snack with high of these components are more suitable for them because they help to control hunger and blood glucose fluctuation. Total starch and total sugar were used to calculate the available GI and GL of the cookies.

Based on the result of statistic tests in Table 2, it was known that there is no significant difference between mean of water, ash, protein, and fat levels of the two cookies variants (p< 0.05). Based on the result of the tests in Table 3 and Table 4, it was known that there is no significant difference between sugar levels, water-soluble fiber, water-insoluble fiber, and resistant starch from the two variants of the cookies (p< 0.05).

Table 2. Proximate test

Variant	Water	Ash	Protein	Fat
Cookies A	5.48 ± 0.44	2.48 ± 0.29	6.73 ± 0.21	24.62 ± 0.43
Cookies B	5.67 ± 0.12	2.51 ± 0.04	7.57 ± 0.02	25.21 ± 0.8
p	0.64	0.91	0.11	0.48

Table 3. Carbohydrate content test

Variant	Starch	Total sugar	Total dietary fiber*	Resistent Starch
Cookies A	21.08 ± 0.9	46.76 ± 0.48	15.29 ± 0.02	1.81 ± 0.00
Cookies B	21.37 ± 0.41	48.24 ± 0.12	16.88 ± 0.13	2.55 ± 0.4
p	0.73	0.12	0.03	0.23

Table 4. Fiber content test

Variant	Average value (%)	
	Total dietary fiber	
	*water-soluble fiber	*water-insoluble fiber
Cookies A	0.39 ± 0.04	14.89 ± 0.07
Cookies B	0.50 ± 0.14	15.43 ± 0.16
p	0.47	0.08

Cookies A: Arrowroot cookies with glucomannan + palm sugar
Cookies B: Arrowroot cookies with glucomannan + white sugar
water-soluble fiber and water-insoluble fiber are part of total dietary fiber

3.3 Calculation of available carbohydrate

Reference food used for GI and GL testing was 25 g of anhydrous glucose dissolved in 200 mL of water. Amount of each cookies used for testing must be equivalent to 25 g of available carbohydrate in one-time consumption. Calculating available carbohydrate for each cookies was using formula by using total sugar added with starch component [10]. Based on result in Table 5, amount of cookies used was 35.75 g for cookies A; 36.35 g for cookies B; and 25 g of anhydrous glucose dissolved in 200 mL of water.

Table 5. Amount of standard food and cookies given equivalent to 25 g available carbohydrate

No	Sample	Sugar (%)	Starch (%)	Available Carbohydrate* (%)	Total portion** (g)
1	Anhydrate glucose			100	25
2	Cookies A	46.77	21.08	69.95	35.75
3	Cookies B	48.25	21.37	71.75	34.84

Information:
Available carbohydrate = total sugar + 1.1 (starch)
*Amount of servings = 25/*available carbohydrate* x 100

3.4 Glycemic index (GI) and glycemic load (GL)

The GI score was obtained by calculating the incremental area under the curve (iAUC) for blood glucose after consumption of a test food divided by the iAUC of a reference food containing the same amount of available carbohydrate. The result of GI score showed that cookies A has score of 19.6 while cookies B has score 25.6. Both cookies is still considered into low GI food [10].

Glycemic Load (GL) can be calculated by knowing the GI score of both cookies. The formula used is by calculating the number of carbohydrates available in one portion of test food multiplied by GI score of the test food then multiplied by 100. The calculation of available carbohydrates requires total sugar and starch values. Based on the calculation result, GL of cookies A is 13.71 while cookies B is 17.6. It can be concluded that GL of cookies A is lower than cookies B, but both of them included into medium category [10]. GL of food divided into three groups, they are low (1 to 10), moderate (11 to 19), and high (>20) [13].

3.5 Cookies calorie and dietary recommendation

Arrowroot cookies can be applied as alternative snack for diabetic people. It is suitable as morning, afternoon, or evening snacks. Based on the result, it is known that the GI and GL of palm sugar cookies has lower score compared to cane sugar cookies hence cookies A is better option for diabetic people and could be processed into next step for calorie calculation. Based on the chemical testing of protein, fat, and carbohydrate (by difference), the total energy produced from 100 g of each cookies could be calculated [14].

4 Discussion

Subjects included in the study were subjects who had met the inclusion and exclusion criteria. Testing of IG values in different types of individuals and races was not shown significant differences in GI test results. The specific criteria for subjects is normal BMI. This case is important because BMI, both female and male will greatly affect the blood glucose response to food. Association of BMI class and difference within blood glucose response is proven by a research which stated that there is a significant relationship between overweight BMI and increased blood response in 253 subjects of women and men. Other specific criteria is age. As people grow older, their organs function especially beta pancreas that secrete insulin will degenerate. The degeneration continues to increase and meet its highest peak at age of 45 yr old [16, 17, 18].

Determination the amount of available carbohydrates as the initial step in determining the amount of standard food and test food is adjusted to the National Agency of Drug and Food Control (NA-DFC) and ISO 26642: 2010 concerning the determination of GI of food and its classification. Based on data from Table 7, it could be concluded that both cookies belong to low GI food with cookies A having score of 19.6 and cookies B having score of 25.6. The difference in GI score provides a reference to society about a better option of natural sugar types that can help stabilize blood glucose response. Palm sugar consists not only disaccharide, but also polysaccharide dextran, which was found by a study when testing palm sugar using a liquid chromatography method [20]. This component cannot be found in commonly used cane sugar. Other study showed that palm sugar has lower GI than cane sugar, which stated that palm sugar has GI score of 35 (<55) [21]. Food classification based on GI score in this study is using reference from who group food based on GI score into three class. First, low (<55), moderate (55-69), and high (> 70) GI food. The GI score for both cookies in this research proved to be quite good compared to common cookies made from flour. Common cookies issued on the market are having GI score ranging from 60 to 80 depending on the basic and added ingredients [12].

The GI score of both cookies is considered low and it is caused by three main factors. First, the substitution of all purpose flour into arrowroot flour and starch. Second, the cookies is processed through roasting method. Third, the cookies has glucomannan. Basically, processing food through heat increases the GI score of food because many nutrients are degraded and way easier to be digested by digestive enzymes in the intestine. However, roasting process is one process that can keep GI score low because it was not added anymore water from the outside so minimalize the nutrient degradation process also roasting was a way of cooking that could increase resistant starch [7]. The addition glucomannan itself also help to maintain the GI score low. Glucomannan helps prolong the satiety because it increases the viscosity of bolus in gaster and slow down the rate of peristalsis in the intestine. That phenomenon is due to glucomannan ability which binds water molecule up to 200 times from the initial weight [9].

Glycemic load (GL) is also an important indicator for choosing a better food for daily diet for diabetic people. GL itself reflects how much digested carbohydrate is contained in food. GL is known to be more accurate in controlling blood glucose especially diabetic people which their blood glucose response is dramatically sensitive to sugar compared to normal person with the same age. This case happened because it accurately account the amount of digested carbohydrates that will enter the body [22]. Based on GL calculation, it is known that GL of cookies A is 13.71 while cookies of B is 17.6. The classification for both cookies belongs to food with moderate GL content.

Table 6. Proportion of protein, fat, carbohydrate, dan total energy per 100 g cookies

Cookies	Protein (%)	Fat (%)	Carbohydrate (%)	Total Energy (kCal)
A	6.73	24.62	60.69	491
Dietary requirements[*)]	10–15	20–25	60–70	Differ within each person

Based on the calculation of total energy in Table 6, it is known that the cookies has energy of 491 kcal per 100 g. The minimum dietary protein standard set by *Perkumpulan Endokrinologi Indonesia* is 12 % while palm sugar cookies has 6.7 % of protein. Arrowroot cookies has lower protein content based on fact that its basic ingredients are poor in protein too compared to all purpose flour. To meet the standard protein amount in cookies, it is necessary to add high protein ingredients such as skimmed milk or substitute some part of arrowroot flour with all purpose flour. Carbohydrate and fat levels have completely met the dietary criteria set by *Perkumpulan Endokrinologi Indonesia*. Based on the result, palm sugar cookies is proven has a lower GI (low) and GL (moderate) so it is suitable for diabetic people. If the energy needs of a person with diabetes for a day is 2 000 kcal (average calorie needs of an adult), and the calorie distribution given for one-time snack is 10 % (200 kcal), it is equivalent to 40.7 g or 3 pieces of palm sugar cookies.

5 Conclusion

Chemical properties tests showed there is no significant difference in water, ash, protein, fat, total sugar, starch, resistant starch, water-soluble fiber, and water-insoluble fiber content. However, significant difference was found

in dietary fiber content. The glycemic index (GI) test of cookies A has score of 19.6 while cookies B has score of 25.6. Both cookies belong to low GI food. Glycemic load (GL) of cookies A (13.71) is lower compared to cookies B (17.6). Both cookies are classified as moderate GL food. Cookies A is better choice for diabetic people because first it is low GI and the fat also carbohydrate content has met the standard need for one-time snack consumption. 3 pieces of palm sugar cookies is recommended as daily snack for diabetic people. Arrowroot cookies with *porang* glucomannan, both with the addition of palm sugar and cane sugar are suitable for people with DM because the IG and GL scores are low.

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