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The Glycemic Index (GI) of Adlay (*Coix lachryma-jobi var-mayuen*) on Processed Products

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***Abstract*—Adlay or Job's tears (*Coix lachryma-jobi var ma-yuen*) is one of minor cereals that is not used widely in Indonesia. Research on Adlay as a source of carbohydrate for diabetes patient is rarely found. Diabetes patient needs low Glycemic Index (GI) carbohydrate. As a source of carbohydrate for diabetes, Adlay has not yet been explored. The objective of this research was to determine Adlay processing method, which resulted in low GI product. In this research, first of all, Adlay was processed in three different treatments: (1) cooked with excessive water, like cooking rice; (2) puffed; and (3) flaked. The GI and gelatinization degree of the three types of processed products were then analyzed. Second of all, the ratio of margarine and sucrose in the Adlay flour and the ratio of water and coconut milk in flake products were determined. Biscuits and flakes were then analyzed using hedonic test involving 20 panelists to determine the preferred taste, flavor, texture, and appearance. The GI was then analyzed on the best result gained based on this test. The result showed that the processing method which resulted in low GI was flake (GI 51.3), with gelatinization degree of 35.6 %. Also, based on hedonic test, biscuits which were made of Adlay flour with margarine and sucrose ratio of 1:0.75 was the best one. Meanwhile, the best water and coconut milk ratio was 1: 1. The GIs of both biscuits (GI 40) and flake (GI 36) was low (< 55).**

***Keywords*— glycemic index; adlay; processing; biscuits; flakes.**

I. INTRODUCTION

Adlay (*Coix lachrymal-jobi var ma-yuen*) is a perennial herb in the family of Gramineae. Its seed has now become one of the most popular Chinese herbal medicines used in the treatment of diseases such as cancer, hypertension, arthritis, asthma, and immunological disorders [1]. *Adlay* is one of minor cereals that is not used widely in Indonesia. The main compound of adlay is carbohydrate, and the rest are protein and fat [1]–[3]. As a source of carbohydrate for diabetes, *Adlay* has not yet been explored. Meanwhile, there were some studies on *Adlay* on anti-tumor activity [5]–[7], antioxidant activity [8], and protective effect on hypercholesterolemia [9].

Diabetes patient needs low Glycemic Index (GI) and slowly digestible carbohydrate. The GI is the indexing of the glycemic response of a fixed amount of available carbohydrate from test food to the same amount of available carbohydrate from standard food (glucose or white bread) consumed by the same subject [9]. Rapidly Digestible Starch can increase the risk of diabetes type 2. On the contrary, Slowly Digestible Starch (with low GI) and resistant starch or starch with high soluble dietary fiber decreases the risk of diabetes type 2 [10]. Slowly Digestible Starch (SDS) is slowly digested throughout the small intestine, resulting in slow release of glucose into the blood stream, which gives a low glycemic response. This type of starch may be helpful for controlling hyperglycemia diseases [11].

Some important factors on the formation of SDS are heat and water level [11]. Hydrothermal treatment induces structural changes in starch that significantly affects its digestibility [12]. Raw starch (especially the A-type) is an ideal SDS, and it can be substituted by cooked or processed starchy food. Retaining SDS can be done using incomplete gelatinization by lowering the temperature, decreasing the water amount, or shortening the processing time of the starch [11]. Food processing with full gelatinization can result to high GI product [13] such as dextrin, drum drier instant starch, and extruded starch (which is high in pressure and contains middle up to high level of moisture). Moisture level is a critical parameter here. High moisture level with high temperature (baking or *drum drying)* or high pressure and *shearing (*extrusion) can cause full gelatinization, resulting in a product with high GI. Food processing that limits the gelatinization of starch as in the making of flake and plain biscuits will produce low GI foods [14]. In many starchy foods, a portion of residual starch is not fully gelatinized during the process, and it is usually due to the limited water amount or insufficient heating [15]. Partially gelatinized starch is more resistant to enzymatic digestion than retro gradation starch [16]. Based on the explanation, it is therefore necessary to conduct a research on the effect of processed *Adlay* products on GI.

II. Material and Method

A. Materials

The materials used were *Adlay* genotype #G44 and white male *Wistar* rats. The *Adlay* genotype #G44 used was retrieved from local varieties of West Java *Adlay* which was planted in the farming laboratory of Universitas Padjadjaran (Figure 1 and 2).

Fig. 1 Adlay Plant of Genotype #G44

Fig. 2 Polished Adlay of Genotype #G44 Grain

B. Methods

1) Adlay Processing: In this study, the *Adlay* grain was processed in three different treatments: (1) cooked in excessive water, like cooking rice; (2) puffed and (3) flaked. The GI, the blood glucose profile, and the gelatinization levels of these three products were then measured.

2) Biscuits and Flake Formulation: Biscuits were made by limiting the addition of sucrose, i.e. margarine and sucrose ratio of 1:0.5; 1:0.75; and 1:1, while flake was made with coconut milk and water ratio of 1:0; 1:1; and 0:1. An analysis was done on organoleptic characteristics (using hedonic test) and on chemical content (using proximate analysis). The Glycemic Index (GI) of the best products gained based on hedonic test was then analyzed.

3) Glycemic Index Analysis: Glycemic Index (GI) analysis was conducted on as many as five white male *Wistar* rats for each treatment. The rats were 7-8 weeks old, weighing ± 200 g, and were obtained from Inter University Center, Bandung Institute of Technology, West Java. Prior to treatment, the rats were adapted for 7 days by standard feeding in ad libitum. After fasting (water consumption still included) for 12 hours, blood glucose levels were measured by glucometer (measurement of 0 min). The blood glucose level of these rats was <110 mg/dL, which indicates that the subjects do not suffer from diabetes.

The blood glucose level measurement was 2 μL. The blood was retrieved from the tail by injury. It was then inserted on a strip test on glucometer (*Easy Touch brand*). After ten seconds, the blood glucose levels were displayed on the screen. After minute 0 measurement, the rats were fed with samples namely: (1) cooked *Adlay* grain; (2) puffed *Adlay*; and (3) flaked *Adlay*. The samples were ground until fine, and were added with up to 5 ml aquadest (a rat's stomach holds a maximum of 5 ml of solution). The samples given contained 50 g available carbohydrate, which, if multiplied by conversion factor for rats was 0.018. The sample was administered *in vivo* using a gastric sonde. Blood glucose levels were measured after 30 minutes (30^{th} minute measurements). Measurements of the same glucose levels were performed at 60, 90, and 120 minutes. Control rats were administered with pure glucose with a dose of 50 g x 0.018, and in minutes 30, 60, 90, and 120 their blood glucose were then measured.

Blood glucose levels per observation time were plotted on the Y-axis, whereas observation time was plotted on the X-axis. The next thing that was calculated was the incremental area under the curve by using the trapezoid formula. Calculations were performed on the area under the curve of blood glucose (sample) and blood glucose of reference food (pure glucose). The GI was determined by comparing the incremental area under the sample curve (IAUC) with the incremental area under the curve of pure glucose, according to the method of Jenkins et.al. [17]–[9].

$$Glcemicindex = \frac{areaundersampeccurvex100\%}{areaunderglu\cos a} \quad (1)$$

4) Chemical Contain Analysis: Moisture level was determined by thermo gravimetric method [20], ashes [20], fat solvent extraction method using soxhlet apparatus [20], and protein by micro Kjeldahl method [20].

5) *Gelatinization Degree Analysis [21]:* Determination of degree of gelatinization began by making a standard curve that describes the relationship between the degree of gelatinization and absorbance. The sample used for standard curves was 100% gelatinized, obtained by boiling 5 g of

Adlay flour in 100 ml of water until it became clear. The second sample used was non-gelatinized sample, obtained by suspending 5 g of *Adlay* flour in 100 ml of water. Subsequently, a mixture of both samples was prepared to obtain samples with 20%, 40%, 60%, and 80% starch gelatinization degrees. The ratio between 100% and 0% gelatinized starch is 20:80 for 20% gelatinized sample, 40:60 for 40% gelatinized sample, 60:40 for 60% gelatinized sample, and 80:20 for 80% gelatinized sample.

The next step was absorbance readings of each sample. The sample was weighed up to 0.5 g and was put into a 100 ml glass, and then was added with 47.5 ml of distilled water. The mixture was then shaken for one minute and was added with 2.5 ml of 0.2 N KOH, and it was further shaken for five minutes. This mixture was centrifuged for 15 minutes at 3500 rpm. Supernatant was then inserted into two test tubes A and B of 0.5 ml each, and was then added with 0.5 ml of HCl 0.5 N and 0.1 ml of iodine solution. Afterwards, 9 ml of *aquadest* was added into the A tube, and 8.9 ml of *aquadest* was added into the B tube. Both tubes were shaken, and the absorbance was afterwards read using Spectrophotometer at a wavelength of 625 nm. A tube solution is a blank reading for B tube. The standard curve was made by plotting the degree of gelatinization on the X-axis and the absorbance on the Y-axis. A linear equation was then calculated to get the relationship between absorbance and degree of gelatinization. Linear equation obtained was:

$$Y = a + bX \tag{2}$$

where Y was the absorbance and X was the degree of gelatinization, 'a' and 'b' were constant. The sample absorbed from some processing method of *Adlay* was measured the same way as the standard curve. The calculation of gelatinization degree of sample used linear equation which was obtained from standard curve.

6) Data Analysis: The results were expressed as mean ± standard deviation. The data from 3 repetitions were tested by ANOVA statistics, followed by Duncan multiple-range test (DMRT) at a significant level of α=0.05.

III. Result and Discussion

A. Glycemic Index

The ANOVA test results showed that different processing methods resulted in significantly different GI products according to DMRT as listed in Table 1. Based on Table 1, the GI of puffed *Adlay* was significantly higher than cooked *Adlay* and *Adlay* flakes.

TABLE I
THE EFFECTS OF THE PROCESSING METHOD ON THE GLYCEMIC INDEX OF *ADLAY* PRODUCT

Product	Glycemic Index	Gelatinization degree (%)
Puffed Adlay	83.2±15.52[a]	100±0.40[a]
Cooked Adlay	71.9±12.32[b]	81.3±0.80[b]
Flaked Adlay	51.3±1.45[c]	35.6±1.03[c]

Note: Means within each column followed by the same letter are not significantly different at p<0.05 according to DMRT

These differences were influenced by the degree of gelatinization during the food processing; the higher the degree of gelatinization, the higher the GI and *vice versa*. Food processing that limited starch swelling produced food with low GI [14]. This was also supported by the results of Holm et al. [22] which states that the higher the gelatinization degree, the higher the starch digestibility and the higher the glycemic response are.

Puffed products were made with high pressure even though the water measurement was relatively low to moderate (10-30%). But due to high pressure, it led to perfect gelatinization [14]. Meanwhile, cooked products were cooked with high water level (150% x grain weight) in high heat with high degree of gelatinization, but still lower than puffed products. Flaked products had the lowest GI as well as degree of gelatinization, as they were made with 50% water measurement restriction, normal atmospheric pressure, and shorter heating. Gelatinized starch granules are easily digested. The degree of gelatinization is influenced by water level, processing temperature, heating duration, and pressure. Food processing which leads to gelatinization, high viscosity, and dissolved starch will produce food with high GI [23].

B. Blood Glucose Profile

Blood glucose profile of white male *Wistar* rats before and after consuming processed *Adlay* products can be seen in Figure 3. Based on Figure 3, the blood glucose level increased in the 30th minute after consumption for all of processed *Adlay* products. In the 60th minute, blood glucose levels of rats consuming flakes continued to decline and returned to baseline after 180 minutes. This suggests that some starch in the flakes were slow in digestion (digested between 30 to 120 minutes) and some were resistant starch, indicating lower blood glucose levels than cooked or puffed *Adlays*.

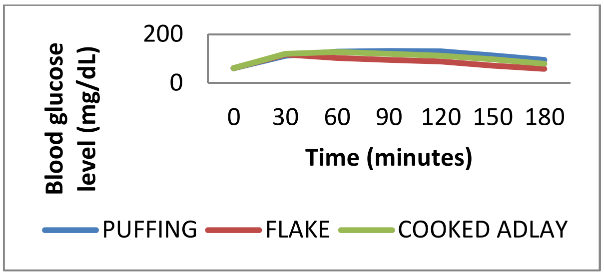

Fig. 3 Blood Glucose Profile after Consuming Processed Adlay Products

Meanwhile, puffed *Adlay* had a higher digestible starch than cooked and flaked *Adlay*, and almost all could be digested. This was supported by the degree of gelatinization of puffed products which was 100%, and was significantly higher than the degree of gelatinization in cooked and flaked *Adlays*. Blood glucose level up to 180 minutes (3 hours) after consumption was directly proportional to the degree of starch gelatinization. Based on the data in Figure 3, products with low GI were some of the resistant starch, whereas products with high GI was closer to rapidly digestible starch and slowly digestible starch.

C. Hedonic Test Results of Biscuits

The result of ANOVA statistic test showed that the ratio of margarine and sucrose had a significant effect on some hedonic parameters of *Adlay* biscuits according to DMRT, as shown in Table 2.

TABLE II
THE EFFECT OF MARGARINE AND SUCROSE RATIO ON ADLAY BISCUITS PREFERENCE

Treatment (margarine : sucrose)	Hedonic score			
	Taste	**Texture**	**Flavor**	**Appearance**
(1: 0.5)	4.8±0.65[a]	5.0±1.30[a]	5.0±1.28[a]	5.3±1.36[a]
(1:0.75)	5.7±1.03[b]	5.6±0.78[a]	5.4±1.12[a]	5.6±1.03[a]
(1: 1)	5.6±1.30[b]	5.1±1.28[a]	5.0±1.58[a]	5.2±1.07[a]

Note: Means within each column followed by the same letter are not significantly different at p<0.05 according to DMRT.

The treatment in the processing of these biscuits was to reduce the sucrose ratio, compared to the standard recipe i.e. margarine and sucrose ratio of 1:1. According to Table 2, only the taste of the biscuits was significantly different. A lower score for taste was in margarine and sucrose ratio of 1:0.5 because of the salty taste of the margarine. In addition, from the technical point of manufacture, there was also a difficulty, because the dough was flakey. Based on the results of the hedonic test, the best treatment for *Adlay* biscuits formulation was margarine and sucrose ratio of 1:0.75, followed by the measurement of GI.

D. Chemical Characteristics of Biscuits

The effect of the margarine and sucrose ratio on the chemical composition of *Adlay* biscuits can be seen in Table 3.

TABLE III
THE EFFECT OF MARGARINE AND SUCROSE RATIO ON CHEMICAL COMPOSITION OF ADLAY BISCUITS

Treatment margarine: sucrose)	1: 0.5	1: 0.75	1: 1
Moisture (%)	5.67±0.19[a]	5.33±0.09[a]	5.10±0.04[a]
Ash (%)	4.42±0.29[a]	6.08±0.06[a]	7.13±0.20[a]
Crude Fat (%)	25.66±0.09[a]	23.36±0.13[b]	22.70±0.03[c]
Protein (%)	6.98±0.16[a]	7.21±0.61[a]	6.42±0.29[a]
Carbohydrate (%)	57.28±0.38[a]	58.02±0.54[b]	58.66±0.38[c]

Note: Means within each column followed by the same letter are not significantly different at p<0.05 according to DMRT.

Based on the results in Table 3, the difference in the ratio on margarine and sucrose produced biscuits with significantly different ash content. The greater the addition of sucrose, the higher the ash content is. This may be because the sucrose used still contains minerals derived from cane juice. The fat contained in biscuits increased as the proportion of sucrose decreased. This was possible because by reducing the proportion of sucrose, the total dough decreased. While the amount of added fat remained, the percentage of fat increased.

Increasing the proportion of sucrose in the dough did not produce significantly different effects on moisture level and protein because the sucrose did not contribute to either chemical component. The carbohydrate contained in biscuits increased with the increase in sucrose addition, but the increase in the proportion of sucrose 0.25 and 0.5 did not produce significantly different carbohydrate levels.

E. Hedonic Test Results of Flakes

The result of the ANOVA test showed that the difference in water and coconut milk ratio had no significant effect on some of the hedonic parameters of flaked *Adlay*, as can be seen in Table 4.

TABLE IV
THE EFFECTS OF WATER AND COCONUT MILK RATIO ON HEDONIC SCORE OF FLAKED *ADLAY*

Treat-ment (water: coconut milk)	Hedonic Score			
	Taste	**Texture**	**Flavor**	**Appearance**
0 :1	3.7±1.57[a]	3.7 ±1.38[a]	4.1±1.02[a]	4.0±0.99[a]
1 : 1	4.0±0.86[a]	3.8±1.04[a]	3.9±0.99[a]	3.4±1.09[a]
1: 0	3.6±1.29[a]	3.3±1.66[a]	4.0±0.86[a]	3.7±1.13[a]

Note: Means within each column followed by the same letter are not significantly different at p<0.05 according to DMRT.

Although the hedonic test results for water and coconut milk ratio was 0:1 and 1:1, both had the two highest values. But the best-selected treatment was water and coconut milk ratio of 1:1 because the taste and texture parameters were more important than the flavor and appearance. The flavor will be overpowered by the milk that was consumed with the flakes. Similarly, the appearance of flakes was mixed in liquid milk, causing the shape to change due to absorption of water. Based on the scores given by the panelists, flakes ratio of water and coconut milk was 1:1, with taste, texture, and flavor parameters were included in the "accepted" category, while the overall appearance was included in the "dislike" category. In terms of appearance, panelists liked the flakes ratio of water and coconut milk which was 0:1, even though this product was lower in quality than the others because it was more fragile and effortless to powder.

F. Chemical Characteristics of Flakes

The result of the ANOVA test showed that the difference between water and coconut milk ratio resulted in a significantly different effect on the chemical composition of *Adlay* flakes, according to DMRT, as shown in Table 5.

TABLE V
THE EFFECT OF WATER AND COCONUT MILK RATIO ON CHEMICAL COMPOSITION OF ADLAY FLAKES

Treatment (water: coconut milk)	0: 1	1: 1	1 : 0
Moisture (%)	4.58±0.40[a]	4.05±0.23[a]	4.58±0.06[a]
Ash (%)	2.14±0.09[a]	2.43±0.13[a]	2.29±0.13[a]
Crude Fat (%)	16.05±0.06[a]	12.66±1.27[b]	8.86±0.03[c]
Protein (%)	13.02±0.03[a]	13.31±0.39[a]	12.98±1.35[a]
Carbohydrate (%)	64.21±0.23[a]	67.54±1.80[b]	71.63±1.32[c]

Note: Means within each column followed by the same letter are not significantly different at p<0.05 according to DMRT.

Differences in the ratio of water and coconut milk caused significantly different fat content. The higher the coconut milk proportion, the higher the fat content of flake because the coconut milk contains oil/fat. Meanwhile, other nutritional components were not affected by the proportion of coconut milk. The flakes's water measurement has been eligible for dry product under 5%. Therefore, this product had much higher protein content and it was one of its superiority.

G. Glycemic Index of Processed Adlay Products

GI was analyzed on the best products of biscuits and flakes. The result of the statistical test with t-student shows that the difference of processing method gave no significant effect on the GI values of flakes or biscuits. As can be seen in Table 6, the GI values of both products are low (IG <55).

TABLE VI
THE EFFECT OF PROCESSING METHODS ON GLYCEMIC INDEX OF ADLAY PRODUCT

Product	**Glycemic Index**
Biscuit	39.99±12.88[a]
Flake	36.10±9.29[a]

Note: Means within each column followed by the same letter are not significantly different at $p<0.05$ according to the t-student test.

This was possible because even though in the processing of biscuits sucrose was added, in relatively low amounts (75% of the weight of margarine) the presence of fat plays a role in lowering the GI by forming the amylose-lipid complex. Meanwhile, in the manufacture of flakes, there was a limitation of gelatinization by limiting the moisture level (40% dough), and there were no added carbohydrates that support the increase in GI.

IV. CONCLUSION

Adlay processing method can produce low GI by limiting starch gelatinization (GI 51.3) and limiting the degree of starch gelatinization of 35.6%. Biscuits made with margarine and sucrose ratio of 1:0.75 was the most preferred product of panelists in terms of taste, texture, aroma, and appearance, and they were included in the "like" category. Flakes made with water and coconut milk ratio of 1:1 was the most preferred product of panelists in terms of taste and texture, and they were included in the "accepted" category. The Glycemic Index of biscuits and flakes were included in the low GI (<55) where biscuits GI was 40, while flake GI was 36.

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