

Glycemic and Satiety Index of Some Degree of Milling of Indonesian Adlay (*Coix Lachryma-Jobi Var Ma-Yuen*) Indigenous Genotype

Tensiska¹, Imas Siti Setiasih¹, O. Suprijana², Warid Ali Qosim³, Yana Cahyana¹

¹ Department of Food Technology, Faculty of Agriculture Industrial Technology, Universitas Padjadjaran, Bandung 45363, Indonesia

²Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran Bandung 45363, Indonesia

³Department of Agrotechnology, Faculty of Agriculture, Universitas Padjadjaran, Bandung 45363, Indonesia

Abstract: *The aims of research was to determine the adlay milling degree which resulted cooked adlay with low Glycemic Index (GI) and high in Satiety Index. The result was compared with IR64 rice variety; The research treatments were three degrees of milling i.e. (1) local traditional milling (still contain aleuron layer) that added seven percent bran (mesocarp) which same as bran proportion in its origin, to produce whole grain; (2) local traditional milling that result the grain with still contain aleuron layer; and (3) milling with abration machine to produce polished grain. The grain which resulted by three degrees of milling were analyzed nutrition contain i.e moisture, crude fat, protein, ash and dietary fiber. The grain that resulted were cooked like rice. Proportion grain : water was 1 : 1,5 (v/v) as usually used in rice cooking. The product were analyzed its GI and Satiety Index. These treatments were compared with IR64 rice variety. According to research results were (1) degree of milling which had highest dietary fiber contain was whole grain; (2) The lowest GI (20,1) that include low category (< 55) was resulted by polished grain; (3) The satiety index of polished grain did'nt significant difference with its whole grain, but higher than rice IR64 (Setra Ramos) variety, according to Duncan Multiple Range Test. Consumption of cooked adlay could maintain satiety until 3.5 hours but IR64 cooked rice only 2.5 hours*

Keywords: adlay, degree of milling, Glycemic Index, Satiety Index .

1. Introduction

Adlay (*Coix lachryma-jobi var ma-yuen*) is a minor cereal that has not been widely utilized in Indonesia. The main compounds of adlay grain are carbohydrate, protein and fat. Minor components consisted of dietary fiber, phytosterol, and minerals. Starch and protein are found in the endosperm, while fats and phytosterols in the germ. Dietary fiber is found in the bran fraction [1]. The number of chemical components of adlay grain is influenced by the post-harvest handling, especially the degree of milling [2]. The degree of milling (DOM) is the amount of bran left on the grain after the milling process. The lower milling degrees leaves more bran on the grain and vice versa [3].

The potential of adlay as a source of carbohydrates for diabetics has not been widely studied. Most researches on adlay focused on its potential as an anti-cancer [4]-[5]-[6]. People with type 2 diabetes need carbohydrates with low Glycemic Index (GI) and slow digestion. Rapidly digested starch increases the risk of type 2 diabetes. Meanwhile consumption of starch-rich foods rich in slowly digested (low GI) and resistant starch or high dietary fiber, decreases the risk of developing type 2 diabetes [7]. The concept of the GI was proposed by Jenkin in 1981 as a method for ranking carbohydrates based on the increased blood response to glucose produced. For people with type 2 diabetes, the supply of carbohydrates in the form of polysaccharides especially those containing fiber is better than simple sugars because of slower digestion so that blood glucose levels increase more slowly [8]. Thus, adlay containing bran (rich in dietary fiber) may be slowly digested so that the GI may be

also low and gives a longer satiety. The presence of soluble dietary fibers such as guar, pectin and β -glucan causes a decrease in gastric emptying and glucose uptake as well as the speed of the digestion in digestive tract thus giving a longer satiety [9].

Generally during milling, the grains are dehulled and the bran is separated. Meanwhile epidemiological studies show that consumption of whole grains and their products are consistently associated with decreased risk of chronic diseases such as heart disease, type 2 diabetes, obesity and certain types of cancer [10]. Whole grains can be either whole, mashed, cracked, or flaked grains which are principally endosperm, germ and bran / bran components in an amount proportional to those in intact cariopsis [11].

The research team from Padjadjaran University have identified 41 genotypes of adlay from West Java, Indonesia [12]. Based on the study, the highest productivity genotype was #G 44, so this genotype was used in this study. This genotype was glutinous with high viscosity so it was expected low Glycemic Index and high Satiety Index.

The objective of this study was to determine the degree of milling of the #G44 genotype adlay grain which produces cooked adlay with low GI and high satiety index. As a comparison used rice IR 64 varieties.

2. Materials and Methods

2.1. Materials

The materials used and subjects involved in this study were genotype # G 44 adlay seeds from breeding of superior local genotypes from West Java, Indonesia, Wistar male rats, 5 women aged 19 to 20 years (body mass index 19 - 21), and chemicals for proximat analysis.

2.2. Methods

2.2.1. Adlay Milling

The milling was aimed to produce three types of milling degrees, namely polished grain, aleuron grain and adlay grain containing bran (mesocarp and aleuron) called whole grains. Polished grain was prepared using abrasion machine to scrape the hull. Meanwhile, aleuron grain was produced by pounding the grain in a mortar with pestle to separate the bran from its grain. To produce whole grains, the grain was pounded in a mortar with the addition of bran or around 7 percent as proportion of bran in whole seeds.

2.2.2. Chemical Composition Analysis

Water content was determined by thermogravimetric method (AOAC 925.10, 2005) [13], ashes with heating in furnace 600°C for 6 hours (AOAC 923.03 2005) [13], fat content by solvent extraction method using soxhlet equipment (AOAC 963.15 2005) [13] and protein by micro Kjeldahl method (AOAC 960.52, 2005) [13], and the fiber content was by AOAC method 32.1.17. 1995 [13].

2.2.3. Glycemic Index Analysis [14]

White wistar male rats as many as 5 for each treatment, 6-8 weeks old with weight \pm 200 g were obtained from Inter University Center ITB, Bandung West Java, Indonesia. Prior to treatment, the rat was adapted for 7 days by standard feeding on ad libitum, after which it was fasting (except water) for 12 hours. Blood glucose level of rat was measured by glucometer (measurement of 0th minute). The rat used should have fasting blood glucose <110mg /dl indicating healthy rat. A blood glucose measurement of 2 ml of rat blood was taken from the tail by injury and then inserted in a pre-installed strip test on glucometer (Easy Touch brand). In ten seconds, blood glucose levels was read on the screen.

After the measurement at minute 0, the rats were fed with cooked adlay samples, namely (1) polished grain; (2) aleuron grain; and (3) whole grain and ; (4) cooked IR64 rice. The samples were first smoothed and then added aquadest until the total amount of 5 ml (rat's stomach holds a maximum of 5 ml of solution). Samples contained 50 grams available carbohydrate multiplied by conversion factor for rats (0,018). The sample was administered using gastric sonde. Then Blood glucose levels were measured at 30th, 60th, 90th and 120th minutes. Rats given pure glucose with a dose of 50 g x 0.018 were used as control. Blood glucose levels were plotted as a function of observation time (0th, 30th, 60th, 90th and 120th minutes). Area under the curve was calculated using the trapezoid formula. The Glycemic Index was

determined by comparing the area under curve of sample with that of pure glucose (control).

$$\text{Glycemic Index of Food} = \frac{\text{Total area of sample} \times 100 \%}{\text{Total area of pure glucose}}$$

2.2.4. Satiety Index Analysis [15]

The subjects of this study were 5 healthy women aged 19 to 21 years old with a body mass index of 19-21 kg / m². The subjects came to the laboratory at 8.am in fasting as long as 10 hours. They were asked to consume test foods until they were satisfied (ad libitum). They were then asked to fill in a questionnaire in the form of Visual Analog Scale (VAS). It was a horizontal long straight line of 100 mm with marked words at each end indicating a very positive level (100) and a very negative level (0). Each VAS was test of hunger, satiety, desire to eat (appetite) and the prospective consumption of food. Subjects were not allowed to discuss with other subjects. The subject activity during the test period, was mild activity like writing, reading lightly, watching videos, chatting and they were not allowed to consume food or drink. Test food were cooked adlay polished grain, adlay whole grain, rice polished grain (local variety IR64). Rice served with one kind of dish made with chicken, and vegetables. Mineral water was given in equal amounts.

3. Results and Discussion

3.1. The Effect of Degrees of Milling on Chemical Composition of Adlay Seed

Resulted of chemical composition of adlay grain following different degree of milling can be seen in Table 1. The result

Table 1: The Effect of Degree of Milling on Chemical Content of Adlay Grains

Chemical Content (%)	Treatments		
	Whole Grains	Grains with aleuron	Polished grains
Dietary fiber	12,533 \pm 0,07 ^a	11,982 \pm 0,03 ^b	9,945 \pm 0,14 ^c
Moisture	12,504 \pm 0,18 ^a	12,417 \pm 0,12 ^a	9,600 \pm 0,11 ^b
Ash	3,101 \pm 0,15 ^a	2,180 \pm 0,08 ^b	1,527 \pm 0,06 ^c
Crude fat	7,171 \pm 0,73 ^a	6,611 \pm 0,67 ^b	5,122 \pm 0,50 ^c
Protein	14,637 \pm 0,84 ^a	14,038 \pm 0,67 ^a	15,625 \pm 0,31 ^a

Remark: Different letters in the same column are significantly different among treatments (α = 5%) according to Duncan Test.

of statistical test (ANOVA) showed that the difference of milling degree resulted in different adlay grains chemical content. Whole grain contained significantly higher levels of dietary fiber than the other two milling degrees. The more intensive milling, the lower fiber content. This was because the fiber is concentrated on the outside part of the grain [16].

Duncan test results showed that whole-grain and aleuron grain had significantly higher moisture content than polished grain. This was due to their higher fiber content than the polished grain, where the fiber can bind water from the environment and that naturally bound when the seed was harvested. The reason for this was proved by the moisture content of whole seeds before the milling was 13.71%, whereas in whole grain and aleuron grain decreased to about 12.5%, so on the polished grain was 9,6 %.

Whole grain has higher ash and crude fat contain than aleuron and polished grain. This was because minerals or inorganic compounds were concentrated on the outside of the seeds [16] – [17]. Meanwhile almost fat was in germ [18] which was separated in milling proces, especially in polished grain. Consumption of adlay grain in the form of whole grains can increase significantly mineral intake. The main types of minerals in adlay grain are calcium, and iron [19].

The result of ANOVA test showed that the difference of degree of milling did not affect protein content of adlay grain. Different degree of milling resulted in differences in the outer seed component i.e bran and germ, while the endosperm was found in relatively equal amounts. The proteins in cereals are concentrated in the endosperm [16] so that different degrees of milling did not produce significantly different levels of grains protein. Starch granules are adhered to the protein matrix in the endosperm [18].

3.2. The Effect of Degree of Milling on the Glycemic Index

The result of statistical (ANOVA) test showed that the different degrees of milling resulted in significantly different effect on the GI of cooked adlay grain (Table 2).

Table 2: The Effect of Degree of Milling on Glycemic Index of Cooked Adlay

Treatments	Glycemic Index	Viscosity (mPas)
Whole grain	60,3±3,11 ^a	33.060 ^a
Aleuron grain	47,5±10,36 ^a	33.830 ^a
Polished grain	20,1±2,06 ^b	49.770 ^b
Polished rice IR64	53,3±4,28 ^a	54.450 ^b

Remark: Different letters in the same column are significantly different among treatments ($\alpha=5\%$) according to Duncan Test.

Although dietary fiber was expected could contribute to lower GI, but as can be seen in Table 2, GI of polished adlay grain was significantly lower than aleuron or whole grains. This was because the aleuron and whole grain adlay fiber components are insoluble fiber (cellulose, hemicellulose) thereby little contribution to the water holding capacity. The lower water holding capacity may result in low viscosity during digestion, leading to the higher GI. On the other hand, starch high in soluble fiber may decrease GI [7]. The presence of soluble dietary fibers such as guar, pectin and β -glucan leads to a decrease in the rate of glucose uptake following starch hydrolysis [9]. When the fiber forms a viscous gel in the small intestine, it inhibits enzyme hydrolysis of nutrients such as starch.

When compared GI of adlay polished grain with IR 64 rice polished grain, GI of adlay grain was lower, although the viscosity of IR64 rice was higher. The difference was because of adlay was more sticky (higher amylopectin) than IR64 rice, so it more difficult to digest. Adlay amylopectin was 92.83 %, meanwhile IR64 was 75,5 %. Amylopectin is a glucose polymer having branches of α -1,6 glycosidic, while amylose is a straight chain glucose polymer with α -1,4 glycosidic bond. Generally the bonds in the α -1,6 glycosidic branches are more difficult to hydrolyse by enzymes than α -

1,4 bonds [20]. Based on the GI classification, the GI value of aleuron grain and polish grain were categorised as low GI (<55) while the whole grain adlay was moderate.

In addition, higher adlay fat content increases the chances of the formation of amylose-lipid complex structures during gelatinization, which was digested more slowly by α -amylase enzymes [21]-[22].

3.3. The Effect of Degree of Milling on the Blood Glucose Profile

Blood glucose profile of male Wistar rat before and after consuming adlay grain from different degree of milling and IR 64 rice can be seen in Figure 1.

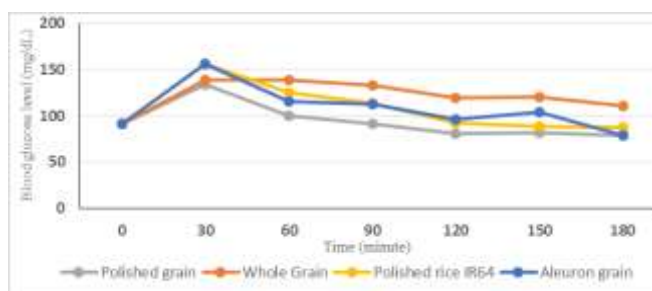


Figure 1: Rats Blood Glucose Level after Feed of Cooked Adlay and Cooked Rice of IR64

After 60 minute consumption, blood glucose level of rat that consumed whole grain adlay were higher than that consumed the other milling degrees and IR64 rice. Whole grain glucose supply was relatively stable and remained higher until the 180th minute after consumption. This proved that the whole grain adlay produced slowly digested starch. Glucose level until 180 minutes produced by this product was in the range of normal glucose levels ranging from 50-135 mg/dL [23].

Blood glucose level of those consumed polished grain decreased to the initial level within 90 minutes and no futher increase was observed. It was suggested that some polished adlay's starch was resistant starch. Resistant starch is an undigested starch (indicated no increase in blood glucose) after 2 hours of consuming it [24]. The mechanism of polished adlay starch change be resistant starch is not fully understood, presumably due to its high viscosity. Meanwhile, following the consumption of aleuron grain, blood glucose level reached base line level at minute 120th. The starch which digested between 20 to 120 minutes is classified as Slowly Digestible Starch [24], while the Goni method [25] is between 30 and 120 minutes. Based on this, some of adlay starch may categorised as slow digestible starch. Aleuron grain of adlay is a complex carbohydrate like other cereal starch and still contains aleuron layers that contribute to the slow digestibility.

The same blood glucose profile was showed by IR64 digestion results. This means that some IR64 rice starch was also slowly digestible starch. This was because of cereal starch is a complex of carbohydrates that are more slowly digested than simple sugars.

3.4. Satiety Index

3.4.1. Hunger

The result of statistical test showed that the difference of milling degree produced significantly different effect on subject hunger score after consuming adlay (Table 3).

Table 3: The Effect of Degree of Milling on Hunger of Subject After Consuming Cooked Adlay

Treatments	Hunger Score (0 – 100)				
	Minute 0 th	Minute 30 th	Minute 90 th	Minute 150 th	Minute 210 th
Whole grain	82±9 ^a	9±6 ^a	20±4 ^a	31±7 ^a	51±8 ^a
Polished grain	75±12 ^a	12±7 ^a	22±5 ^a	36±13 ^a	52±10 ^a
Polished rice IR64	73±12 ^a	21±11 ^a	28±13 ^a	60±10 ^b	77±16 ^b

Remark : Different letters in the same column are significantly different among treatments ($\alpha=5\%$) according to Duncan Test.

The subject hunger score was not significantly different at minute 0th i.e. just before consuming test food, meaning that in all test samples, subject conditions were relatively the same. Similarly, the subjects' hunger scores after 30th and 90th minutes consumed whole adlay grain, polished adlay grain and IR 64 rice.

After 150 and 210 minutes, the score of hunger of IR 64 rice was significantly higher than adlay whole grain or adlay polished grain. It may be due to the fact that the adlay whole grain supplied higher glucose level than IR 64 rice, while the adlay polished produced resistant starch whose role was similar to dietary fiber that gave full effect on the stomach so that hunger appears more slowly.

Rapidly Digestible Starch provides short-term satiety (about 1 hour), whereas Slowly Digestible Starch or low GI carbohydrates provide a slower satiety effect at 2 to 3 hours [26]. In this case it was more accurately called rapidly carbohydrate digestibility instead of the high GI term and slowly carbohydrate digestibility for low GI because it is not always low GI carbohydrates that are slowly digested and some high GI foods are also slow to digest [27]. In relation to this study, both whole grain and polished grain of adlay provided longer satiety due to slower digestibility, although GI of adlay whole grain was higher than IR 64 rice.

The cascade from satiety to hunger state occurs when the demand for metabolism of an organism that has run out of nutrient availability after absorption process. Low blood glucose and glucose entry rate to body tissues initiate a desire to eat [28]. Therefore adlay grain either whole grain or polished was slowly digested so that the blood glucose availability lasted longer than after consuming IR 64 rice, hence the score of subject hunger at minute 150th and 210th for adlay grain was significantly lower than hunger score of IR64.

3.4.2. Satiety

The result on milling degree effect on satiety is shown in Table 4. Following cooked adlay consumption, there was no

Table 4: The Effect of Degree of Milling on Satiety of Subject After Consuming Cooked Adlay

Treatments	Satiety Score (0 – 100)				
	Minute 0 th	Minute 30 th	Minute 90 th	Minute 150 th	Minute 210 th
Whole grain	16±8 ^a	91±4 ^a	84±3 ^a	76±4 ^a	54±7 ^a
Polished grain	22±7 ^a	90±4 ^a	83±3 ^a	77±9 ^a	56±9 ^a
Polished rice IR64	24±14 ^a	80±12 ^a	74±14 ^a	40±12 ^b	25±14 ^b

Remark : Different letters in the same column are significantly different among treatments ($\alpha=5\%$) according to Duncan Test.

significant difference in satiety until 150th minute. The satiety was then significantly higher at the subjects consumed adlay grain compared to IR64 rice at minute 150. This was presumably because before the 150th minute both adlay rice and IR64 rice provided similar glucose supply amount so that the satiety was similar. From the 150th minute, glucose supply from adlay was higher than the IR64 rice. It may be caused by higher amylopectin content in adlay grain, where α -1.6 glycosidic bonds were more difficult to hydrolyse so that starch digestion become slower [20]. Foods containing slowly digestible starch extend the satiety [29].

Satiety is also influenced by the rate of emptying the stomach, the slower the emptying of the stomach, the longer satiety persist. One of the factors affecting the rate of gastric emptying is the viscosity and the content of dietary fiber. Liquid phase food is faster in gastric emptying than in solid phase. In addition, fat content also reducing the rate of emptying the stomach [9]. Satiety after eating adlay grain lasted longer than IR 64 rice because of adlay was more viscous and sticky and also had higher fat content. In addition, satiety after eating adlay was also supported by protein content which was higher than rice. In isoenergy conditions the order of macro nutrients for satiety is protein > carbohydrate > fat [30].

3.4.3. Desire to Eat (Appetite)

The effect of milling degree on the desire to eat can be seen in Table 5. The desire to eat (appetite) is affected by low blood glucose levels and is manifested by hunger. The score of desire to eat before the 150th minute was relatively low at all treatments although the score for IR64 rice was significantly higher than either whole grain or polish grain of adlay. Starting at the 150th minute, score of desire to eat after

Table 5: The Effect of Degree of Milling on Appetite of Subject After Consuming Cooked Adlay

Treatments	Appetite Score (0 – 100)				
	Minute 0 th	Minute 30 th	Minute 90 th	Minute 150 th	Minute 210 th
Whole grain	81±7 ^a	10±3 ^a	19±4 ^a	33±5 ^a	51±10 ^a
Polished grain	76±10 ^a	12±3 ^a	21±6 ^a	39±14 ^a	51±12 ^a
Polished rice IR64	77±14 ^a	26±14 ^b	36±15 ^b	71±7 ^b	79±14 ^b

Remark : Different letters in the same column are significantly different among treatments ($\alpha=5\%$) according to Duncan Test.

IR64 rice consumption increased sharply. This indicated that glucose supply of IR64 rice has dropped dramatically, while

the digestion of adlay was still able to maintain a sense of satiety so that the desire to eat was still relatively low.

3.4.4. Prospective Consumption

The purpose of prospective consumption was to predict how much food the subject may be consuming at the time. The subject put a mark on a horizontal length scale of 100 mm marked on the left end of a very negative statement that is "nothing at all" and at the far right of the very positive statement "very much". The statistical test of the effect of milling degree on prospective consumption can be seen in Table 6. The significant difference in prospective consumption of adlay and IR64 rice began at the 150th minute. This suggested that glucose supply starts to decrease dramatically in 150 minutes or 2.5 hours after consuming IR64 rice, while adlay rice was still relatively capable of maintaining satiety so that its prospective consumption was significantly lower.

Table 6: The Effect of Degree of Milling on Prospective Consumption of Subject After Consuming Cooked Adlay

Treatments	Prospective Consumption Score (0 – 100)				
	Minute 0 th	Minute 30 th	Minute 90 th	Minute 150 th	Minute 210 th
Whole grain	76±9 ^a	10±7 ^a	28±8 ^a	31±7 ^a	50±11 ^a
Polished grain	70±8 ^a	14±11 ^a	25±4 ^a	42±16 ^a	52±8 ^a
Polished rice IR64	66±15 ^a	22±13 ^a	35±15 ^a	58±6 ^b	72±15 ^b

Remark : Different letters in the same column are significantly different among treatments ($\alpha = 5\%$) according to Duncan Test.

4. Conclusions

The content of dietary fiber of adlay whole grain was not significantly different with aleuron grain, but higher than polished grain. GI of the three treatment degrees of milling were 20.1 (adlay polished grain), 47.5 (adlay aleuron grain), 60.3 (whole grain). Both polished and aleuron adlay grain were classified as low GI food while whole grain as medium one. The satiety index of polished adlay grain was not significantly different with the adlay whole grain, but better than IR64 rice. Adlay grain consumption could withstand hunger up to 3.5 hours while IR64 rice was able to withstand hunger up to 2.5 hours.

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Author Profile



Tensiska received the B.S. degrees in Agricultural Industrial Technology, Bogor Agricultural University in 1992 and M.S. degrees in Food Science from Bogor Agricultural University in 2001. She is a Doctoral Candidate, continues her education at Padjadjaran University, at Postgraduate Program Doctoral Agricultural Science during 2014-now. From 1994 until now, she is a lecturer at Department of Food Technology, Faculty of Agriculture Industrial Technology, Padjadjaran University, Ministry of Research, Technology and Higher Education of the Republic of Indonesia