Glycemic Index of Biscuits from Pedada (*Sonneratia caseolaris*), Lindur (*Bruguiera gymnorrhiza*), with Gembili (*Discrorea esculenta L.*) and Gadung (*Dioscorea hispida densst*) Tubers

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Abstract. Glycemic index is the level of food according to its immediate effect on blood glucose levels. Foods that rapidly increase blood glucose have a high glycemic index; if absorbed more slowly, it indicates a low glycemic index. One way to control blood glucose is through dietary management. Pedada and lindur mangrove fruits and tuber flours (gadung and gembili) contain high dietary fiber and amylose, so often be used as raw materials in making biscuits. This study aims to produce biscuit products formulated from pedada and lindur fruit flour with gadung and gembili tubers with good physicochemical characteristics and to analyze the Glycemic Index in vivo with humans as respondents. This study used a one-factor, completely Randomized Design (CRD) with ten treatment levels, namely the proportion of pedada and lindur mangrove flour with gadung and gembili tubers flour formulations of 0:10, 10:90, and 20:80, respectively. The results showed that the best treatment was obtained from biscuit products with a formulation of pedada flour and gadung flour with a proportion of 20:80 which got 89.37% of yield, 3.69% of moisture, 2.25% of ash, 6.56% of protein, 8.46% of fat, 79.04% of carbohydrate, 70.44% of starch, and the score of organoleptic 3.7 of taste 3.2 of aroma, 3.5 of color, 3.6 of texture, 7.32% of dietary fiber, the value of glycemic index 54.33 and glycemic load 14.05.

Keywords: Biscuits, Mangrove, Gembili, Gadung, Glycemic Index.

1. Introduction

People's lifestyles are constantly changing as the time goes by. People with a high activity level indirectly change their diet to prefer instant foods high in carbohydrates and fat but low in fiber [1]. The prevalence of diabetes mellitus in Indonesia continues to increase, estimated to reach 28.57 million people in 2045 [2]. This rising number of diabetes mellitus must be prevented by consuming foods with a low glycemic index.

The glycemic index (GI) is a number that shows the state of a person's glucose levels after consuming a food. There are three classifications of food based on the glycemic index value, namely low (<55), medium (56-69), and high (>70). The

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glycemic index is often used as a reference for people with diabetes in choosing the right foods to control their blood glucose levels. Foods with a low glycemic index value produce an inadequate glucose response after consumption, and vice versa [3].

Factors that affect the GI in food include fiber, the ratio of amylose and amylopectin [4], starch digestibility, fat, protein, and processing methods [5]. Food glycemic index (GI) was measured by giving all research subjects test foods equivalent to 50 grams of carbohydrates [6]. Based on some research results, Glycemic index analysis can be done with human subjects.

[7] reported that pedada fruit flour has an insoluble fiber of 53.9% and soluble fiber of 9.8%, and also contains antioxidants, flavonoids, steroids, phenols (Jariyah et al., 2015), and has hypoglycemic and hypocholesterolemic properties [8]. Another type of mangrove that can be utilized is lindur fruit (Bruguiera gymnorrhiza). The advantage of lindur fruit flour is its carbohydrate content of 80.38% and 0.76% fiber [9]. Based on the description above, both flours have the potential to be used as raw materials for making non-gluten biscuits by adding flour from gembili and gadung tubers.

Gembili tubers contain dietary fiber and the bioactive compound inulin by 14.66% [10]. Inulin can reduce the risk of colon cancer, normalize blood glucose levels, help reduce heart health risks, and prevent colon cancer [11]. Meanwhile, gadung tubers help lower cholesterol [12] and have a low glycemic index of 14-22 [13].

This study evaluates the physicochemical characteristics and functional properties of biscuit products from pedada and lindur fruit flour substituted for gadung and gembili tuber flour.

2. Methods

2.1. Materials

Tuber's flour (gembili and gadung) was purchased from the Ladang Lima factory, while the pedada and lindur fruit were obtained from Sidoarjo Mangrove farmers in East Java, Indonesia. The equipment and chemical reagents for analysis were obtained from the Food Technology Department at Universitas Pembangunan Nasional "Veteran" in East Java. The chemicals and reagents used were of analytical grade. The pedada and lindur flour were processed according to the procedure by [14]. The tubers flour was processed through washing, cutting, and drying at 50 - 600°C for 15 h, milling, and 80 mesh sifting.

2.2. Proportion of Flour

Table 1. Proportion of Flour for Biscuit-Making

Composition	GL (%)	P (%)	L (%)
GL	100	0	0
PGL-1	90	10	0
PGL-2	80	20	0
LGL-1	90	0	10
LGL-2	80	0	20
GD	0	0	0
PGD-1	0	10	0
PGD-2	0	20	0
LGD-1	0	0	10
LGD-2	0	0	20

Note: GL: Gembili Flour; P: Pedada Fruit Flour; L: Buah Lindur Ftuir Flour; GD: Gadung flour

2.3. Preparation of Biscuits

Biscuits were produced from the ten formulations using the method described by [14]. The sugar, salt, glucose syrup, sodium stearoyl lactylate, skimmed milk powder, and baking powder were mixed thoroughly. Then, the margarine and egg were added and mixed correctly to make the dough, then rolled to a uniform thickness sheet. The sheet was cut according to the shape and size of the biscuits, baked in the oven at 160°C for 20 min, cooled for 30 minutes, and stored in a plastic container before analysis.

2.4. Proximate Analysis

The proximate analysis of the biscuit samples was determined using the method described by [15].

2.5. Organoleptic Evaluation

Organoleptic evaluation of the biscuits used twenty (20) panelists from the students in Dept. of Food Technology, with four attributes including taste, color, aroma, and texture

2.6. Glycemic Index (GI) and Glycemic Load (GL)

Determination of the glycemic index and glycemic load of biscuit products used pure glucose as standard food. Determination of the glycemic index used 22 respondents. Respondents had nutritional status characteristics (BMI 17.19-28.53 kg/m2), a fasting blood glucose range of 79-100 mg/dl, and were 20-23 years old. Blood glucose levels were measured after the respondents fasted from 22:00 to 08:00 in the morning. Then, respondents were asked to consume test food (pure glucose and biscuit samples) containing 50 grams of available carbohydrates. Blood samples were taken every 30 minutes within 2 hours. Respondents' blood glucose data were then spread on the X axis as time (minutes) and the Y axis as blood glucose levels (mg/dL), then the food's glycemic index was calculated with these two values. The Glycemic Index was calculated using Incremental area under the blood glucose response curve (IAUC) method.

2.7. Statistical Analysis

The data obtained were analyzed using Minitab V.17 with $\alpha = 0.05$.

3. Results and Discussion

The results of the analysis of raw materials for making biscuits are presented in Table 2, which shows that lindur fruit flour has the highest moisture, fat, and protein than pedada fruit flour and gembili flour. In contrast, the moisture of pedada fruit flour is higher than other flours (66.56%).

Table 2. Raw Material Analysis

Composition	Pedada fruit flour	Lindur Fruit flour	Gembili flour	Gadung flour
		(%)		
Yield	7,00	31,34	9,67	10,28
Moisture	9,39	11,41	7,44	10,05
Ash	4,05	2,44	2,23	1,02
Protein	4,19	5,29	3,79	5,77
Fat	0,28	2,38	0,48	0,97
Charbohyidrate	82,09	78,48	86,06	82,19
Stacrh	-	23,02	75,02	81,54
Amylose	-	16,16	16,05	18,32
Dietary fiber	66,56	55,20	6,12	8,14

3.1. Proximate Analysis of Biscuit Products

Based on the results of the variance analysis, it is known that there is a significant effect ($p<0.05$) between the proportions of mangrove fruit flour (pedada and lindur flour) and tuber flour (gembili and gadung flour) on the moisture, ash, protein, fat, and carbohydrate content (Table 3).

Moisture shows that the humidity of biscuits declines by decreasing the proportion of tuber flour (gembili and gadung) and increasing the proportion of pedada fruit flour. It is due to the increase in pedada fruit flour, the lower starch content of the product, causing the moisture to decrease. The difference in starch between treatments is due to the different starch of each treatment. High starch causes an increase in moisture because, in the heating process, starch will be gelatinized so that water will enter the starch granules, which can form hydrogen bonds [16]. In addition to the starch, another factor that affects the moisture is the dietary fiber. Gadung flour is 8.14% higher than gembili flour at 6.12%. This component has a high water absorption capacity because of its large polymer size and complex structure, and it also contains many hydroxyl groups so that it can bind large amounts of water [17].

Table 3. Proximate Analysis of Biscuit Products

Proportion	Moisture	Ash	Protein	Fat	Carbohydrate
	(%)				
GL	3,42±0,08^{bc}	2,22±0,01^{d}	5,16±0,52^{a}	7,19±0,04^{a}	82,02±0,57^{g}
PGL-1	3,32±0,08^{b}	2,64±0,04^{f}	5,22±0,52^{b}	7,39±0,10^{b}	81,43±0,57^{fg}
PGL-2	3,19±0,09^{a}	2,82±0,11^{g}	5,43±0,69^{b}	7,48±0,11^{b}	81,07±0,60^{f}
LGL-1	3,50±0,11^{bcd}	2,37±0,09^{e}	5,62±0,08^{bc}	7,50±0,07^{b}	81,01±0,20^{ef}
LGL-2	3,62±0,04^{cde}	2,61±0,07^{f}	5,74±0,19^{bc}	7,71±0,05^{c}	80,32±0,14^{de}
GD	3,80±0,14^{ef}	1,85±0,04^{a}	6,25±0,07^{cd}	8,17±0,05^{d}	79,94±0,12^{cd}
PGD-1	3,73±0,07^{ef}	2,24±0,01^{d}	6,48±0,08^{d}	8,22±0,04^{d}	79,33±0,02^{bc}
PGD-2	3,69±0,02^{de}	2,25±0,01^{d}	6,56±0,08^{d}	8,45±0,11^{e}	79,04±0,03^{b}
LGD-1	3,93±0,06^{fg}	1,85±0,02^{b}	6,60±0,02^{d}	8,61±0,11^{ef}	78,99±0,18^{b}
LGD-2	4,16±0,07^{g}	2,02±0,02^{c}	6,81±0,05^{d}	8,72±0,04^{f}	78,29±0,04^{a}

Biscuits for the proportion of pedada and lindur fruit flour substituted with gembili flour (PGL-1; PGL-2; LGL-1; LGL-2) has higher ash than those substituted with gadung flour (PGD-1; PGD-2; LGD-1; LGD-2). It is because the ash of gembili flour (2.22%) is higher than that of gadung flour (1.01%). In addition, the minerals and the chemical composition in the ingredients that are not evaporated during the soaking process can also cause an increase in ash content, as well as the presence of salt and baking powder [18]. The ash in all biscuit formulas was higher than the ash content according to SNI, which is a maximum of 1.6%.

Biscuits with the proportion of pedada and lindur fruit flour substituted for gadung flour (PGD-1; PGD-2; LGD-1; PGD-2) have higher protein than those substituted for gembili flour (PGL-1; PGL-2; LGL-1; LGL-2), this is because the protein of gadung flour (5.77%) is higher than gembili flour (3.79%). During the heating process, proteins also undergo denaturation. It means proteins undergo changes or destruction of their secondary, tertiary, and quaternary structures [19].

The fat of the biscuits with the proportion of pedada and lindur fruit flour substituted with gembili flour (PGL-1; PGL-2; LGL-1; LGL-2) showed lower fat than those substituted with gadung flour (PGD-1; PGD-2; LGD-1; LGD-2), due to the lower fat of gembili flour (0.48%) than gadung flour (0.97%). The fat content of biscuits in all formulations has not met the SNI requirements (minimum 9.5%). Although adding margarine does not impact increasing fat content, this margarine only functions to tenderize biscuits and can improve the texture of biscuits [20].

Biscuits with the proportion of pedada and lindur fruit flour substituted for gembili flour (PGL-1; PGL-2; LGL-1; LGL-2) have higher carbohydrates than those substituted for gadung flour (PGD-1; PGD-2; LGD-1; LGD-2) because the carbohydrate of gembili flour raw materials (86.06%) is higher than gadung flour (82.18%). Other nutritional components influence the carbohydrate calculation differently; if these components are low, the carbohydrate content in the product will be high, and vice versa [21].

3.2. Starch, Total Sugar, and Available Carbohydrate

Table 4 provides that the biscuits with the proportion of pedada/lindur fruit flour substituted with gembili flour (PGL-1; PGL-2; LGL-1; LGL-2) showed lower starch compared to those substituted with gadung flour (PGD-1; PGD-2; LGD-1; LGD-2).

This difference is attributed to the starch of gembili flour (75.02%), which is lower than gadung flour (85.54%) (Table 2).

Table 4. Starch, Total Sugar, Available Carbohydrate

Composition	Starch	Total sugar	*Available Carbohydrate*
	(%)		
GL	68,39±0,03[bc]	29.90 ±0.14[bc]	105.23±0.46[bc]
PGL-1	67,81±0,90[b]	28.37 ±0.28[fg]	102.97±0.24[ab]
PGL-2	67,21±0,07[a]	28.25 ±0,42[def]	102.18±0.77[a]
LGL-1	68,65±0,08[c]	29.09 ±0,26[hi]	104.61±0.23[cd]
LGL-2	68,84±0,06[c]	29.04 ±0,17[gh]	104.76±0.05[ef]
GD	71,05±0,23[de]	26.95 ±0,49[j]	105.11±0.19[g]
PGD-1	70,60±0,05[d]	26.02 ±0,06[a]	103.69±0.11[cd]
PGD-2	70,44±0,32[d]	25.94 ±0,09[ab]	103.42±0.27[bc]
LGD-1	71,39±0,08[e]	26.61 ±0,09[cd]	105.14±0.06[h]

3.3. Glycemic Index and Glycemic Load

Based on the analysis, it is known that there is a significant effect ($p \leq 0.05$) between the proportions of mangrove fruit flour (pedada and lindur flour) and tuber flour (gembili and gadung flour) on the glycemic index value and glycemic load of biscuit products (Table 5). The glycemic index values ranged from 54.33-66.93 and were classified as medium GI. This IG value is lower than the research results reported by [4], with IG value of boiled gembili tubers 85.56, steamed gembili 87.56, and fried gembili 83.61. The GI value of the results of this study is higher than the boiled gadung 51, which also has hypoglycemic properties [22]. The difference in glycemic index values is evidence that the GI value is influenced by one factor, namely the processing method, either heating, steaming, boiling or frying, causing different glycemic index values, as reported by [23].

Table 5. Glycemic Index and Glycemic Load of Biscuits

Composition	Glycemic index	Glycemic load
GL	66,93±2,41[f]	17,59±0,63[f]
PGL-1	60,89±1,76[cd]	15,67±0,30[c]
PGL-2	58,52±0,92[bc]	14,95±0,22[b]
LGL-1	63,27±0,47[de]	16,55±0,14[de]
LGL-2	62,28±0,22[de]	16,31±0,07[de]
GD	64,35±0,20[ef]	16,91±0,09[e]
PGD-1	57,25±0,20[b]	14,84±0,04[b]
PGD-2	54,33±0,69[a]	14,05±0,23[a]
LGD-1	62,79±1,58[de]	16,50±0,43[de]
LGD-2	61,33±0,13[d]	16,12±0,02[cd]

Foods of the same type can have different glycemic index values when processed and cooked differently. Processing can change the structure and composition of food nutrients. According to [3], cooking or processing makes carbohydrates easier to digest so that it can increase the glycemic index value. Other factors affecting the Gl value are food fiber content and the ratio of amylose and amylopectin [23]. [24] reported, in general, high food fiber content contributes to low GI values. Fiber can slow down the rate of food in the digestive tract and inhibit enzyme activity so that the digestive process, especially starch, becomes slow and the blood glucose response will be lower.

Another factor that affects the glycemic index is amylose content. The results showed that the amylose content of flour was 18.32%, and gembili flour was 16.05%. According to [4], there is a significant relationship between the ratio of amylose and amylopectin, where an increase in amylose levels will reduce the value of the glycemic index. Amylopectin is more easily gelatinized and consequently easier to digest, so the blood glucose response is higher if a food has higher amylopectin levels than amylose levels [23]. Foods with high fat content tend to slow down the rate of gastric emptying, so the rate of food digestion in the small intestine is also slow. Meanwhile, high protein levels are thought to stimulate insulin secretion [3] so that glucose in the blood is not excessive and under control.

Table 5 shows that the glycemic load value of the biscuits is 14.05 - 17.59 and is classified as moderate. PGD-2 biscuits had the lowest glycemic load value compared to the other treatments. glycemic load (GL) is used to measure the potential impact of food on blood sugar. Calculating the glycemic load value assesses the effects of carbohydrate consumption by considering the food's glycemic index value. Foods with a high glycemic index but not many carbohydrates per serving on average will not have much impact on blood sugar. A food's glycemic load is calculated by multiplying the glycemic index by the carbohydrate amount in a serving and then dividing by 100. A glycemic load of 20 and above is categorized as high, 10-19 as moderate, and less than 10 indicates a low GL value [3].

3.4. Organoleptic Analysis of Biscuits

Based on Freidmen's test on biscuit color, it had no significant effect ($p > 0.05$), while taste, texture, and aroma had a considerable impact ($p < 0.05$). The organoleptic test score of biscuits is presented in Table 6. Overall, GL biscuits were preferred over GD, except for texture. It can be seen in Table 6 that panelists liked the color of biscuits in the GL composition with a score of 3.60, and GD-2 composition biscuits with a score of 3.55, the lowest score on PGL-2 biscuits score of 2.75. The biscuit colors of PGL and LGL have a lower color score than PGD and LGD because the biscuit color is brighter and less preferred by panelists.

Table 6. Organoleptic Test of Biscuits

Composition	Colour	Taste	Texture	Aroma
GL	3.60	3.85	3.05	3.40
PGL-1	2.85	3.25	3.10	3.10
PGL-2	2.75	2.60	3.30	2.70
LGL-1	2.90	2.85	3.15	2.80
LGL-2	2.90	2.60	2.65	2.70
GD	2.95	1.55	3.20	2.90
PGD-1	3.40	3.40	3.45	3.00
PGD-2	3.55	3.70	3.65	3.20
LGD-1	3.05	2.20	3.05	2.90
LGD-2	3.35	2.15	2.85	3.00

The texture of biscuits with the increase of lindur fruit flour with the addition of gembili flour showed that it was increasingly disliked by panelists (LGL-2; LGD-2), while in biscuits, LGL-1 and LGD-1 panellists liked it. This is thought to be the influence of amylose from gembili and gadung flour, resulting in a rather hard biscuit texture, as [25] reported that amylose and amylopectin affect the texture of cookies.

The score for biscuit aroma ranged from 2.70 to 3.40. Biscuits from pedada and lindur fruit flour with gadung flour were preferred by panelists in the pedada formula and gadung in the proportion of 20:80 (PGD-2). Meanwhile, the biscuit product that the panelists did not like was the formula of lindur flour and gembili flour in the proportion of 20:80 (PGL-2). The biscuit formula of pedada flour and gadung flour were preferred by panelists because pedada flour and gadung flour had a distinctive aroma that made them attractive to panelists.

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