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The effect of *gembili* flour (*Dioscorea esculenta* L.) substitution on dietary fiber contents, sensory, and chemical characteristics of cookies

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Abstract
Cookies are preferred by many people of all ages but are poor in dietary fiber. Gembili (*Dioscorea esculenta* L.) is a high-fiber local food ingredient, which is quite abundant in Indonesia but has not been utilized optimally. The purpose of this study was to determine the effect of gembili flour substitution on dietary fiber contents and chemical and sensory characteristics of cookies. This study used a one factor completely randomized design with three treatment levels of gembili flour substitution (0%, 50%, and 100%), which were repeated three times. Gembili flour substitution significantly increased the ash content and dietary fiber but significantly decreased the sensory quality and protein content of cookies. Based on the sensory evaluation, cookies with 50% substitution of gembili flour were the selected product because these did not differ significantly from the control cookies (0% gembili flour) for all sensory attributes tested, except for aroma. Although the hedonic ratings of gembili flour cookies were still lower than those of the control cookies, they contained a higher content of dietary fiber. Therefore, gembili flour, which is high in dietary fiber content, can be used as a functional ingredient in cookies and in other bakery products. These findings are expected to provide new insights for research and bakery industries in developing high fiber cookies from local food sources.

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1. Introduction

The prevalence of degenerative diseases, also known as noncommunicable chronic diseases, has significantly increased since the industrial revolution (1). Currently, these diseases have become the leading cause of death globally, where 41 million people die annually, accounting for 74% of all deaths (2,3). Obesity issues are associated with an elevated risk of degenerative diseases such as diabetes and cardiovascular disease (4). Food consumption patterns, which have changed to a preference for fast foods that are generally rich in sugar and low in dietary fiber, are the main factors causing obesity or overweight (5–7). Dietary fiber is not fully digested or absorbed in the small intestine but can be fermented prebiotically by probiotics (8). Dietary fiber can play an important role in human health when

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regularly consumed (9,10). Currently, the correlation of dietary fiber with health has increased the public awareness of healthy food consumption. The interest in healthy foods that are rich in dietary fiber and antioxidants has provided advantages in food development (11). Researchers and industries are responding to this trend by developing healthier products by substituting with functional food ingredients, which are rich in nutrients and high in dietary fiber content (12).

Gembili (*Dioscorea esculenta* L.), a local tuber from Papua (13), can be used as a food ingredient and is rich in nutrients with a high dietary fiber content (14). The chemical composition of *D. esculenta* L comprises 12.08% moisture, 0.00% lipid, 3.00% protein, 1.27% ash, 86.69% carbohydrate, and 9.04% fiber (15). According to Soetoko et al. (16), gembili tuber contains high levels of inulin as a dietary fiber, which can ameliorate insulin resistance and lipid profile in metabolic syndrome (MetS) model rats by reducing cholesterol, triglyceride (TG), and low-density lipoprotein (LDL). Gembili tubers contain glucomannan, which can slow stomach emptying and is therefore a good diet component for people with diabetes (17,18). Gembili tubers have also been shown to have anticolon cancer activity (19) and can reduce menstrual pain and improve symptoms of premenstrual syndrome (20); furthermore, they contain phenolic components, alkaloids, succinic acid, saponins, and cardiac glycosides and have antioxidant and antidiabetic capacities (21,22). Unfortunately, the high potential of gembili tubers has not been widely utilized in processed food products. The use of gembili tubers is still not optimal and is limited to simple processing of foods such as boiling (23). Currently, with simple processing technology, gembili tubers can be processed into flour, which has a longer shelf life and is easier to apply to processed food products (24).

Cookie snacks are popular with people in Indonesia because of their delicious taste and unique shape (25). The basic formula for cookies includes butter, powdered sugar, eggs, powdered milk, salt, baking powder, powdered vanilla, and wheat flour (26). Wheat flour, which is generally used in cookie products is an imported commodity, so efforts are needed to find alternative raw materials sourced from local commodities. Wheat flour can be replaced with other flour that does not contain gluten. This is because soft wheat with a low gluten content is used in making cookies so that the cookie dough does not need expand excessively (27,28). Furthermore, cookies that generally use wheat flour are poor in dietary fiber. According to Ervietasari (29), cookies with wheat flour as a raw material contain 0.52% dietary fiber. Therefore, as gembili flour has a high content of dietary fiber, it has the potential to be used as a functional ingredient in cookies to increase its dietary fiber content.

The use of local commodities in cookies can increase the dietary fiber content and reduce wheat flour imports (25). Currently, several studies have used gembili flour in several processed food products, including noodle products (30), ice cream (31), yogurt (32), and bread (33). The use of gembili flour in cookies has been studied by Luglio et al. (34) and Ervietasari (29). Cookies with the addition of gembili showed improved lipid profiles in adults with obesity by reducing low-density lipoprotein and total cholesterol levels (34). Substitution with gembili flour can increase the dietary fiber and inulin content but does reduce the sensory acceptance of cookies (29). However, previous studies have not examined the effect of gembili flour on chemical characteristics such as nutritional content and dietary fiber, especially in cookies without sugar added. Thus, this study aimed to examine the effect of gembili flour substitution on the dietary fiber content and sensory and nutritional characteristics of cookies.

2. Materials and Methods

2.1. *Ingredients of Gembili Cookies*

The main ingredients of the cookies used were *Hasil Bumiku* gembili flour, *Kunci Biru* wheat flour, margarine, and white-sweetened condensed milk. Materials were purchased from a supermarket in the Pamulang, South Tangerang, Indonesia. Gembili flour was obtained from Small and Medium Industries (UMKM) Kusuka Ubiku, Kepuh Kulon, Wirokerten, Banguntapan, Bantul Yogyakarta.

2.2. *Processing of Gembili Cookies*

The process of making cookies includes weighing the ingredients and making, molding, and baking the dough. The control cookie formula and gembili flour substitution are shown in Table 1. The margarine and sweetened condensed milk were placed into a mixer bowl and stirred for 3 min at medium speed. Sifted and weighed flour ingredients were gradually added to the mixer bowl and stirred until evenly mixed. The dough was then molded with a thickness of ±5 mm. The molded cookie dough was baked in an oven at 140 ^{o}C for 40 min.

Table 1. Formulation for making cookies control and formulated by gembili flour.

Materials (g)	The amount of ingredients in each formula		
	F1	F2	F3
Gembili flour	0	30	60
Wheat flour	60	30	0
Margarine	200	200	200
Sweetened condensed milk	180	180	180

Note: g: gram, F1: cookies prepared with no gembili flour as a control, F2: cookies with addition of 50% gembili flour, F3: cookies with addition of 100% gembili flour

2.3. *Response Analysis*

2.3.1. Sensory Analysis

Cookie samples made to the same size were used for sensory evaluation color, aroma, taste, and texture by 12 trained panelists who had experience in performing evaluation tests for product sensory attributes (35–37). The sensory characteristics of the cookie samples were evaluated after 1 day of baking. Before testing the product, the test sample was given a random three-digit code, and then the panelists were given verbal instructions regarding the test conditions not to compare between test samples. This sensory evaluation uses a hedonic rating test with a seven-point scale as follows: 1: dislike very much, 2: dislike moderately, 3: dislike slightly, 4: neither like nor dislike, 5: like slightly, 6: like moderately, and 7: like very much.

2.3.2. Nutritional and Dietary Fiber Content Analysis

The proximate analysis included moisture, ash, fat, protein, and carbohydrate contents (by difference methods) referring to the Association of Official Analytical Chemists (AOAC) method (AOAC 2006) and analysis of dietary fiber referring to the enzymatic-gravimetric method (AOAC 991.43).

2.3.3. Calory Calculation

Calories were calculated based on the results of the proximate test, namely protein, fat, and carbohydrates in 100 g of sample cookies. The caloric value per g of protein, fat, and carbohydrates was 4, 9, and 4 kcal respectively, as per Janowicz et al. (38) using Equation (1), where E = energy value (Kcal/100 g product), f = fat content (g/100 g product), p = protein content (g/100g product), and c = carbohydrate content (g/100 g product).

$$E = (f\ x\ 9\ kcal) + (p\ x\ 4\ kcal) + (c\ x\ 4\ kcal) \quad (1)$$

2.4. Data Analysis

This study used a one-factor completely randomized design with three concentrations of gembili flour substitution (0%, 50%, and 100%). This research was repeated three times. All data were subjected to one-way analysis of variance (ANOVA) at the level of $p < 0.05$ using SPSS (IBM SPSS version 21.0 for Windows, SPPS Inc, Chicago, IL). If the ANOVA results were significant, then Duncan's multiple range comparison test was performed to differentiate the average between treatments.

3. Results and Discussion

3.1. Sensory Characteristics of Gembili Cookies

Gembili flour substitution significantly reduced the cookie sensory assessment score on all test attributes (color, aroma, texture, and taste) ($p < 0.05$). A decreasing trend in the average cookie sensory assessment score was present as the level of gembili flour substitution increased (Figure 1). The cookie formula with 50% gembili flour substitution was identified as the best formula because this had an average sensory score that was not significantly different ($p > 0.05$) from that of control cookies on all sensory attributes tested, except aroma.

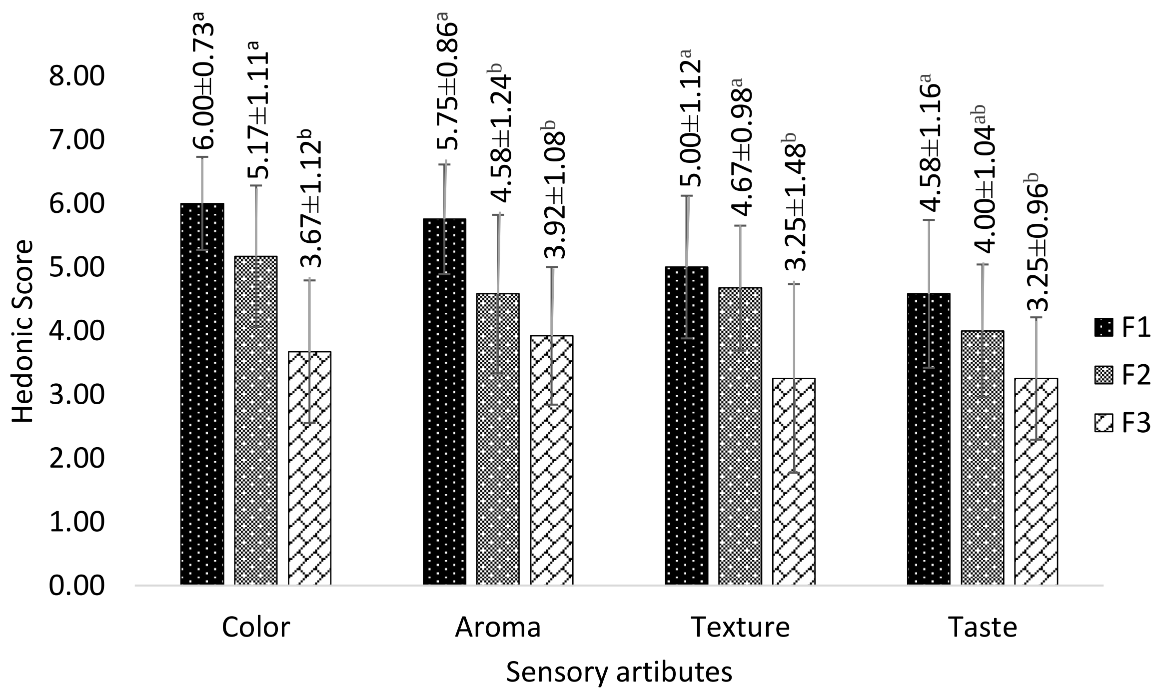

Figure 1. Hedonic score of cookies (F1): Cookies prepared with no gembili flour as a control, (F2): cookies with the addition of 50% gembili flour, (F3): cookies with the addition of 100% gembili flour

A substitution rate of >50% resulted in a significantly lower sensory quality than that of the control. The average sensory score of cookies with 100% gembili flour substitution was significantly lower ($p < 0.05$) than that of the control on all sensory attributes tested (color, aroma, texture, and taste). The decrease in the preference score for cookies substituted for gembili flour was influenced by the darker color, off-flavor, harder texture, and slightly bitter taste.

The results of the sensory analysis showed that the addition of gembili flour significantly affected the light color of the cookies. The higher the concentration of gembili flour added, the lower the color-acceptance score. Wheat flour cookies had the highest lightness value, whereas 100% gembili cookies had the lowest lightness value. The colors of the control and gembili flour cookies are shown in Figure 2. Based on sensory evaluation, gembili cookies had a darker color than wheat flour cookies, so the panelists tended not to like them (29). These results agreed with those in previous studies, which stated that a higher level of gembili flour substitution generally lowered the lightness of *bagiak* (17) or a traditional Banyuwangi cake, which is made from arrowroot starch and sugar (39). Substitution of gembili flour in the product significantly reduced the color sensory assessment of gembili flour cookies as they became darker (17). The darker color changes in gembili flour cookies are considered to be due to differences in the color of wheat and gembili flour. The lightness value (L*) of wheat flour is higher (94.99) than gembili flour (84.09) (40).

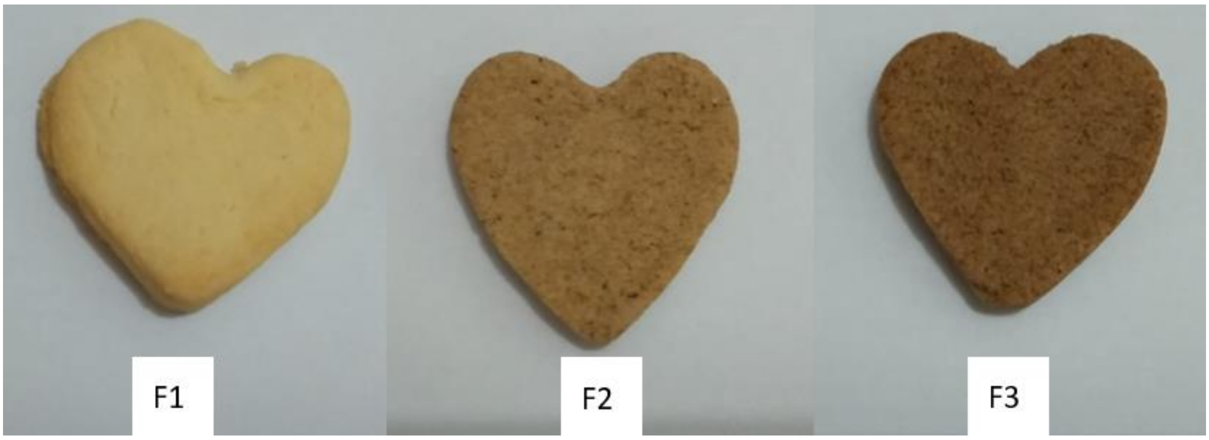

Figure 2. Visual appearance of control cookies prepared with no gembili flour (F1), cookies with the addition of 50% gembili flour (F2), cookies with the addition of 100% gembili flour (F3)

Sensory analysis showed that the addition of gembili flour significantly affected the sensory acceptance of the aroma attributes of cookies. The higher the concentration of gembili flour added, the lower the aroma acceptance score. These results are consistent with those of Sari et al. (30), who stated that the addition of >15% gembili flour in noodle production can reduce sensory aroma acceptance. According to Umbara et al. (41), the addition of flour as a raw material can affect the aroma of *bagelan* bread. The distinctive aroma of *begelan* will be reduced by the addition of gembili flour because this reduces the sensory assessment of the aroma.

ANOVA analysis showed that the addition of gembili flour significantly affected the sensory acceptance of the taste attributes of the cookies. The higher the concentration of gembili flour added, the lower the taste acceptance score. The decrease in the sensory assessment scores on taste attributes is considered to be due to the bitter taste of gembili flour cookies, which may be because of the presence of saponin compounds in gembili flour that have bitter properties (29). The use of gembili flour in cake products has been evaluated by Masrikhiyah (42), who stated that the addition of gembili flour gave a bitter taste to cakes. This is because gembili flour has phenolic and alkaloid compounds, which endow a bitter taste Another study stated that flakes with added gembili flour exhibited a bitter taste resulting from the phenolic and alkaloid components in gembili (43).

The addition of gembili flour also significantly affected the sensory acceptance of the texture attributes of cookies. The decrease in sensory scores of the textural attributes is influenced by the ability of the dough to expand during baking. Gembili flour has a lower swelling ability (3.90 g/g) than wheat flour (7.33 g/g) (40). The presence of dietary fiber and inulin, which have a high ability to bind water, causes the dough to be less hydrated so that during processing, the starch gelatinization and formation of gluten necessary for dough expansion during baking are disrupted (44). This condition causes the crispiness of the cookies substituted for gembili flour to decrease and the texture of the cookies to become harder.

3.2. Chemical Characteristics and Dietary Fiber Content of Gembili Cookies

A chemical analysis on cookies was performed to determine the nutritional and dietary fiber contents and included moisture content, ash, fat, protein and carbohydrates, calories, and dietary fiber. The chemical characteristics of control cookies, formulated by 50% and 100% gembili flour are presented in Table 2. Gembili flour substitution had a significant effect on the values of ash, protein, and fiber content of cookies ($p < 0.05$) but did not affect the water, fat, or carbohydrate content or caloric value ($p > 0.05$). Gembili flour substitution significantly increased the ash and dietary fiber content but decreased the protein content of cookies ($p < 0.05$). The two flours differ in chemical composition. Gembili flour contains 9.04% fiber and 3.00% protein, whereas wheat flour contains 2.20% fiber and 9.90% protein (15).

Table 2. Chemical characteristics of cookies control and formulated cookies with the addition of gembili flour.

Parameter (%)	Mean and standard deviation		
	F1	F2	F3
Moisture content	4.43 ± 0.92^a	4.81 ± 0.63^a	4.36 ± 0.24^a
Calory	527.42 ± 7.54^a	528.50 ± 2.98^a	527.32 ± 0.33^a
Ash content	1.17 ± 0.01^a	1.35 ± 0.01^b	1.49 ± 0.00^c
Fat content	30.19 ± 0.67^a	30.11 ± 0.29^a	30.13 ± 0.20^a
Protein content	1.83 ± 0.00^a	1.59 ± 0.12^b	1.46 ± 0.06^b
Carbohydrate content	62.42 ± 0.42^a	62.14 ± 0.31^a	62.56 ± 0,47^a
Total dietary fiber	0.84 ± 0.16^a	1.30 ± 0.12^b	1.77 ± 0.36^b

F1: cookies prepared with no gembili flour as a control, F2: cookies with the addition of 50% gembili flour, F3: cookies with the addition of 100% gembili flour.

These results agree with those from previous studies that stated that the substitution of gembili flour significantly increased the ash content in fish nuggets (45), snack bars (46), and ice cream (47). According to Dewi et al. (2021), the high ash content in snack bars containing gembili flour was due to the high content of minerals such as calcium and phosphorus from the gembili flour. In addition, the difference in the ash content of gembili flour cookies, which was higher than that of the control, was affected by the difference in the ash content of wheat flour and gembili flour as raw materials. According to Bekti, (2009), gembili flour has a higher ash content (2.28%) than wheat flour (1.9%). The results of the high ash content in gembili cookies are probably due to the high mineral content of gembili flour. According to Keene et al. (49), a high ash content indicates a high mineral content. The calcium content contributes 37% of the ash content while the phosphorus content contributes 18.5% of the ash content (49). The mineral content in yam flour (*Dioscorea esculenta*) contains 5.16–5.23 mg/g potassium, 0.04–0.05 mg/g calcium, and 0.11 mg/g magnesium, 0.35–0.38 mg /g (50).

Table 2 shows that the protein content of cookies with gembili flour was significantly lower than that of the control. These results are consistent with research by Masrikhiyah, (2020), who stated that the higher the proportion of gembili flour, the lower the protein content of the cake. Dewi et al. (51) also found that substitution with gembili flour significantly reduced the protein content of snack bars. The average protein content of dry noodles decreased significantly as the concentration of gembili flour increased (52). In addition, the difference in the value of the protein content of the cookies is considered to be caused by differences in the protein content of the flour used as raw material. According to Bekti (48), the protein content of wheat flour is higher (8.90%) than that of gembili flour (4.25%).

The highest dietary fiber content was found in cookies with the addition of 100% gembili flour (1.17%), followed by cookies with the addition of 50% gembili flour (1.30%), and then cookies without gembili flour (0.84%). Similar research has stated that cookies made from gembili flour have fiber levels ranging from 1.83%–2.42% (29). The increase in dietary fiber content occurred in cookies with substituted gembili flour. The results of this study agree with those of Pratiwi et al. (45), who found that the substitution of gembili flour increased the dietary fiber content of fish nuggets. The increase in the dietary fiber content in gembili flour cookies is because of the rich fiber content of gembili flour. The content of dietary fiber in gembili flour comprises water-soluble polysaccharides and inulin (29,53). Inulin is categorized as soluble dietary fiber (54). The content of inulin in gembili is quite high at 10.53%–10.84% (55). The difference in dietary fiber content is influenced by the dietary fiber content of the flour raw material used in making cookies. According to Bekti (48), gembili flour has a higher dietary fiber content (6.39%) than wheat flour (2.84%).

4. Conclusion

The results indicated that the addition of gembili flour in cookie processing can significantly increase the ash and dietary fiber content but reduce the protein content and sensory quality of cookies. However, the substitution of gembili flour did not significantly affect the moisture, fat, or carbohydrate content or the caloric value of cookies. Cookies with the addition of 50% gembili flour were the selected product as this had average sensory ratings for color, texture, and taste that were not significantly different from those of control cookies. Although the panelists' sensory preferences for cookies made with gembili flour were lower than those for the control cookies, the gembili flour cookies had the advantage of a higher dietary fiber content. Therefore, the results of this study are expected to be used as a consideration in the formulation of healthy cookies from local food sources.

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Conflict of Interest

The authors of this manuscript declare that they have no conflict of interest.

Author Contributions

E.Y.E.S conceptualized design research, conducted research, formal analysis, data validation, review, and editing. R.R analyzed data, interpreted data, wrote the manuscripts. D.N.H reviewed and edited the manuscript. A.S managed project administration had primary responsibility for final content. A.L translated and proofread the manuscript.

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Data Availability Statement

Available data are presented in the manuscript.

Conflicts of Interest

Authors may declare no conflict of interest.

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