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Development of Brownies Substituted with Modified Banana Flour towards Sensory Properties and Nutritional Content as Alternative Supplementary Food for Pregnant Women

Pengembangan Brownies Substitusi Tepung Pisang Modifikasi terhadap Sifat Sensori dan Kandungan Gizi sebagai Salah Satu Alternatif Makanan Tambahan bagi Ibu Hamil

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ABSTRACT

Background: Regardless of social background, brownies are popular snack among people of all ages, including adults and children. The goal of developing brownies with modified banana flour is to lessen reliance on wheat flour and provide a gluten-free, healthier substitute. More inventive product creation is required because of disparity in sensory qualities of brownie items that are currently on the market. Since starch makes up majority of banana flour, modifying the starch can help to improve the flour's quality. Physical modification is one technique that can be applied to enhance the quality and functionality of banana flour in brownie recipes.
Objectives: To determine the sensory properties and nutritional content of brownies with modified banana flour (*Musa paradisiaca*) substitution.
Methods: The research design used a Completely Randomized Design (CRD) with 5 treatments (K=5), 1 experimental unit and 3 repetitions. The treatment carried out was by substituting modified banana flour for wheat flour in brownies products with various different formulations. The resulting brownies products were then analyzed for sensory tests and nutritional content including water content, protein content, fat content, fiber content, ash content, carbohydrates and energy.
Results: The results showed that the addition of 80% modified banana flour provided the most preferred sensory properties by respondents in terms of color, aroma, texture, and taste. The nutritional content of 80% modified banana flour substitute brownies including water content, protein content, fat content, fiber content, ash content and carbohydrates were respectively 11.77%; 5.69%; 20.31%; 2.25%; 1.08% and 58.90%.
Conclusions: Brownies substituted with modified banana flour have high nutritional content, making it a good choice to meet daily nutritional needs.

INTRODUCTION

Vulnerable groups such as pregnant women require additional nutritional intake to overcome nutritional problems[1]. Based on Total Diet Survey (SDT) in 2014, it was found that more than half of toddlers (55.7%) had energy intake below the recommended Energy Adequacy Rate (EAR)[2]. One of the common nutritional challenges faced by pregnant women is chronic energy deficiency (SEZ), which can affect fetal growth and development[3,4]. Mothers with malnutrition during pregnancy are at risk of giving birth to babies with stunting potential[5,6,7].

Therefore, the fulfillment of macro and micro nutrients through supplementary food is very important for pregnant women to prevent the birth of low-weight babies and the risk of stunting in children[7,8,9]. According to the Minister of Health Regulation No. 51/2016 on Nutritional Supplementation Product Standards, the government recommends a Supplementary Feeding Program (PMT) in the form of vitamin and mineral fortified snacks specifically for pregnant women with SEZ. This PMT aims to increase energy and protein intake during pregnancy[2]. Research by Zulaidah et al. showed that PMT consumption can significantly increase the

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baby's weight at birth and effectively reduce the number of pregnant women with SEZ[8].

According to the 2023 Indonesian Health Survey (IHS), only 20.2% of pregnant women in Indonesia received PMT in the form of biscuits or other supplementary foods. According to data from the 2023 Indonesian Health Survey, the measurement of the Upper Arm Circumference indicates that 16.9% of pregnant women experience KEK, which is also a result of low absorption of PMT[10]. Furthermore, the 2014 Total Diet Survey (SDT) revealed that a lack of nutrient-dense food consumption during pregnancy was one of the reasons why over half of Indonesian toddlers (55.7%) had not reached the recommended Energy Adequacy Intake (AKE) based on Indonesian Energy Adequacy Rate (ERA)[11]. Therefore, ensuring pregnant women to receive nutritious supplementary foods is an important step to meet their nutritional needs.

One method of processing PMT is by using local foods, like bananas. One of the main horticultural products produced in Lampung Province is bananas. Its output has risen one spot since 2022[12], making it one of the provinces in Indonesia with the second-largest banana production[13]. One of the most valuable banana downstream products is banana flour. Banana is better than wheat because it could be planted in a local area[14]. The high starch content in banana flour provide a potential alternative to wheat flour in the food industry. In addition, banana flour contains high nutritional value and is easier to digest[15]. Banana flour offers several advantages over wheat flour in terms of its chemical and physical characteristics, making it a promising alternative ingredient for functional food products. One of its main benefits is the high content of resistant starch (RS), particularly when derived from unripe bananas. Resistant starch acts as a dietary fiber that bypasses digestion in the small intestine and is fermented in the large intestine, providing prebiotic effects and helping to regulate blood glucose levels due to its lower glycemic response compared to wheat flour[16]. Moreover, the combination of resistant starch and dietary fiber in banana flour enhances its water absorption capacity, contributing to improved moisture retention, softer texture, and extended shelf life in baked goods [17]. Additionally, banana flour is rich in phenolic compounds such as gallic acid, catechins, and epicatechins, which serve as natural antioxidants that neutralize free radicals[18] a benefit not commonly found in significant amounts in wheat flour. Furthermore, banana flour is naturally gluten-free, making it suitable for individuals with celiac disease or gluten intolerance[19]. It also contains higher levels of essential minerals like potassium, magnesium, and phosphorus compared to wheat flour, giving it a superior nutritional profile[19]. Given these benefits, banana flour represents a healthier and more functional alternative to wheat flour in various food applications.

Enzymatic modification can improve the functional properties of banana flour, such as strengthening the gel, increasing water absorption capacity, solubility and expandability. Physical, chemical, or enzymatic methods can all be used to modify starch. Since the physical method is the least expensive and most straightforward of these techniques, it is most frequently employed to alter starch. Precooking at a temperature higher than the starch gelatinization temperature and then drying to alter some or all of the starch granules is the basic idea behind the physical starch modification procedure. Kearsley and Dziedzic state that the gelatinization temperature range for banana starch is between 55 and 70 degrees Celsius[20]. This method also optimizes the paste characteristics and gelatinization process, thereby increasing the usefulness of banana flour in various food applications[15].

One of the banana varieties that has the potential to be processed into flour is janten banana. The variety selection affects the nutritional composition of the final product[21]. Janten banana contains energy, protein, and fiber which can be an additional nutrient for pregnant women[22]. Janten banana flour has several advantages compared to flour from other banana varieties. One of its main advantages is its high yield, around 35-36%, which indicates that this flour is more efficient in the processing process. In addition, its low fat content makes it more resistant to damage due to fat oxidation, making it suitable for use in products with a long shelf life. The fairly high resistant starch content, around 26.17%, also provides functional benefits as dietary fiber that supports digestive tract health. From a visual aspect, janten banana flour has a uniform and attractive yellowish-white color, which can improve the appearance of processed products. The fairly good vitamin C content also adds to the nutritional value of this flour. With these advantages, janten banana flour is very suitable for development in various innovative food products, such as brownies, baby food, or other functional foods[23,24,25]. Brownies is a one of banana downstream product which is high consumer savor. According to a number of earlier research, utilizing local food products instead of flour while preparing brownies improves their texture and scent appeal[26,27]. Initial in this research[28] showed that brownies with 50% natural banana flour were preferred by consumers in terms of color, aroma, and texture. Based on previous study, he use of banana flour as a substitute in brownies production is expected to support the government's food diversification program. Therefore, this study aims to examine the effect of modified banana flour addition on the sensory quality and nutritional content of brownies.

METHODS

Design, Place, and Time of Research

This research was conducted in the Laboratory at the Lampung State Polytechnic, specifically the Patisserie Laboratory and Agricultural Product Technology (THP) of *Politeknik Negeri Lampung*, from December 2024 to February 2025. The research has been approved by the Mitra Indonesia University Faculty of Health Research Ethics Committee No. S.25/155/FKES10/2024 on December 10th, 2024. Proximate analysis was conducted at Food Technology Laboratory *Politeknik Negeri Lampung*. Tests for sensory analysis were carried out in Sensory Laboratory for the Food Technology Study Program *Politeknik Negeri Lampung*.

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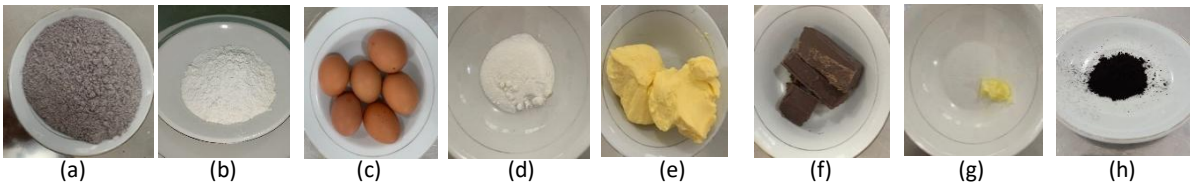
Material and Tools

The materials used in this study include medium protein wheat flour, modified banana flour, eggs, margarine, granulated sugar, chocolate compound, cocoa powder, and cake emulsifier (Figure 1). Modified banana flour is produced from janten bananas that have undergone a partial pragelatinization process for 30 minutes. The process of making modified banana flour begins with the selection of green janten bananas, which are obtained from traditional markets in Bandar Lampung City. The bananas were manually peeled, washed, and thinly sliced into chips with a thickness of 2 millimeters. The banana slices were then washed again under running water, drained, and dried using a rotary drum dryer at 70°C for 30 minutes. Drying continued in a cabinet dryer at 55°C until the moisture content reached 12%. Once drying was complete, the chips were ground using a flour mill to 80 mesh size to produce modified banana flour. One technique for heating-induced physical alteration is the partial gelatinization approach, which uses a spray dryer or drum dryer[29]. The starch to be dried is poured into a heating apparatus in the drum dryer method, and the resulting thin layer is subsequently ground into the appropriate size of powder. Regarding the spray dryer method, materials containing starch or starch slurry are dried in a spray dryer set to 285°C for approximately 4 seconds, resulting in a powdered product[30,31]. Figure 3 shows the flow of making banana brownies. Mix 300 g eggs, 200 g sugar, 6 g cake emulsifier until it develops a characteristic white hue, indicating proper aeration. Add 200 g banana flour with white flour, 5 g chocolate powder, 200 melted margarine, 250 g melted chocolate compound with spatula until homogen. Pour into baking pan and bake in 165°C for 30 minutes.



(a) Modified Banana Flour | (b) Medium Protein Wheat Flour | (c) Eggs | (d) Granulated Sugar | (e) Margarine | (f) Chocolate Block | (g) Cake Emulsifier | (h) Chocolate Powder

Figure 1. Banana Brownies main ingredients

(a) Mix Eggs, Sugar, and Emulsifier | (b) Mix until Pale White Coloration | (c) Mix with Banana Flour | (d) Bake in 165°C | (e) Brownies

Figure 2. Flow of making banana brownies

Formulas

The completely randomized design (CRD) was used as an experimental design. Experiments were conducted with various ratio of modified banana flour towards wheat flour, namely 20%:80%, 40%:60%, 60%:40%, 80%:20%, and 100%:0%, as listed in Table 1. Each treatment was conducted three times to ensure the accuracy of the results.

Table 1. Experimental Design of Modified Banana Flour Substitution

Trial Unit	Repetition		
B1	B11	B12	B13
B2	B21	B22	B23
B3	B31	B23	B33
B4	B41	B24	B43
B5	B51	B25	B53

B1=Treatment group of 20% modified banana flour substitution in brownies, B2=Treatment Group of 40% modified banana flour substitution in brownies, B3=Treatment group of 60% modified banana flour substitution in brownies, B4=Treatment group of 80% modified banana flour substitution in brownies, B5=Treatment group of 100% modified banana flour substitution in brownies, 1; 2; 3=Experimental replicates of brownies making

Table 2. Various of Modified Banana Flour and Wheat Flour Addition in Brownies Composition

Material	Composition				
	B1	B2	B3	B4	B5
Modified Banana Flour (g)	40	80	120	160	200
Medium Protein Wheat Flour (g)	160	120	80	40	0

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Material	Composition				
	B1	B2	B3	B4	B5
Egg (g)	300	300	300	300	300
Granulated Sugar (g)	200	200	200	200	200
Margarine (g)	200	200	200	200	200
Chocolate Block (g)	250	250	250	250	250
Cake Emulsifier (g)	6	6	6	6	6
Chocolate Powder (g)	5	5	5	5	5

The process of making brownies is done through several stages. First, 300 g chicken eggs, 6 g cake emulsifier, and 200 g granulated sugar were put into a basin, then beaten using a mixer for 15 minutes until the dough turned white and fluffy. Next, 200 g of a mixture of modified banana flour and wheat flour was added according to the treatment applied. Using a low mixer speed, 5 g of chocolate powder, 200 mL of melted margarine, and 250 g of chocolate block were added to the dough. After all the ingredients were evenly mixed, the batter was poured into a square pan measuring 20 cm × 20 cm × 4 cm that had been lined with baking paper. The next stage is the baking process at 165°C for 30 minutes. Once cooked, the brownies were removed from the pan and cooled at room temperature[32]. This method is a development of previous research. The flowchart of the brownies production can be seen in Figure 1.

The chemical composition analysis of the modified banana flour included measurements of moisture, ash, fat, protein and carbohydrate content. Water content was analyzed using the oven drying method referring to AOAC (2012), while ash content was measured by the direct method of AOAC (2012). Crude fiber content was analyzed using the gravimetric method AOAC (2012), protein content was determined using the Kjeldahl method AOAC (2012), and fat content was measured using the Soxhlet method AOAC (2012). Meanwhile, the total carbohydrate content was calculated using the difference method. Observations of the brownies included various parameters, such as cooking properties, water content, ash, crude fiber, fat, protein, carbohydrate, and sensory evaluation. Cooking properties were analyzed based on expandability using the AACC 66-50 method (AACC, 2010) with some adjustments. To test the energy content, the analysis was conducted using the 2017 Indonesian Food Composition Table (TKPI) with the following empirical method[33]:

$$\text{Energy} = \frac{\text{Ingredients (g)}}{100\ \text{g}} \text{ x Energi Value of Ingredients}$$

Description:
*) Energy Value (calories/100 g ingredients)

The brownie rise test[34] in this study is as follows: the dough before baking is placed in a paper container with a diameter of 6 cm with an initial uniform dough height of 3 cm (A), after baking then the height of the brownie is measured using a ruler (B), then calculated using the following equation:

$$\text{Dough Development Properties} = \frac{(\text{B} - \text{A})}{\text{A}} \text{ x } 100\%$$

Description:
A = Height of dough before baking (cm)
B = Height of dough after baking (cm)

Protein content was analyzed using the Kjeldahl method in accordance with AOAC (2012) standard No. 978.04. Sensory evaluation involved 25 semi-trained panelists, consisting of 9 men and 16 women with an age range of 19-26 years. Panelists rated the color, aroma, texture, and taste of the brownies on a hedonic scale. The assessment was carried out using a hedonic scale of 1-5, where a score of 5 indicates very like, score 4 like, score 3 neutral or somewhat like, score 2 dislike, and score 1 very dislike[35]. The evaluation results were then compiled in tabular form and analyzed descriptively.

To determine the sensory characteristics of brownies made with modified banana flour, data were analyzed using One Way ANOVA statistical test with 95% confidence level (α=0.05). Statistical analysis was performed using SPSS 16.0 software. If the results show p-value<0.05, there is a significant difference between treatments. If the result shows a p-value≥0.05, there is no significant difference. If a significant difference was found, a follow-up test was conducted using the LSD method to identify the treatment that caused the difference[36].

RESULTS AND DISCUSSIONS

The results of the chemical composition analysis of the modified banana flour conducted in the initial study are presented in Table 3. The modified banana flour used in this study has a relatively low moisture content, which is below 10%. This level of moisture content provides the advantage of a longer product shelf life[37]. Protein content is an important factor that influences the texture characteristics of a food product[38]. The protein level of the flour greatly influences the end product's texture and quality when creating brownies. The softness and structure of brownies may be impacted by the reduced protein level of banana flour compared to wheat flour. Brownies with a softer and moister texture can be made with low-protein banana flour. However, a mix with higher protein flour is needed to get a nice balance between softness and solidity[39,40]. In this study, the modified banana flour contained 10.96% protein, which is lower than the protein content of wheat flour, which ranges from 11.48% to 14.08% (by weight)[41].

Table 3. Chemical Composition of Modified Banana Flour

Chemical Composition	Value (%)
Water Content	9.86

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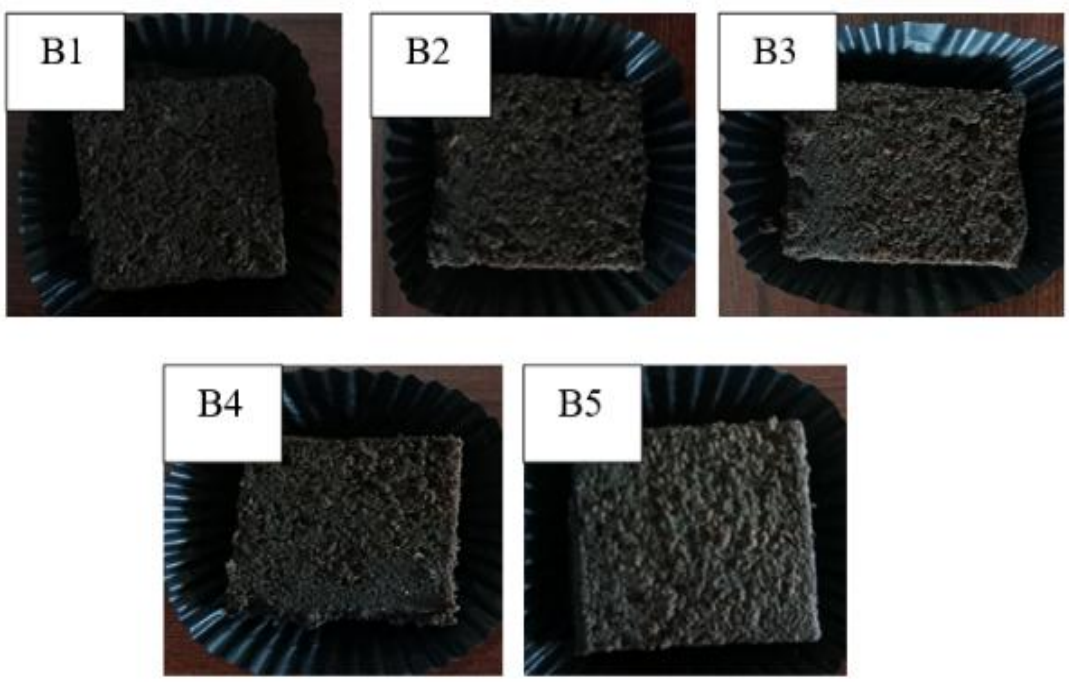
Chemical Composition	Value (%)
Ash Content	2.19
Crude Fiber Content	1.92
Fat Content	1.01
Protein Content	3.57
Carbohydrate Content	81.45

Ash content has an influence on the quality of the brownies produced. The modified banana flour has a fairly high ash level of 2.19%, although it is still lower than wheat flour which ranges from 3.18% to 3.69%[42]. In addition, the ash level also contributes to the discoloration of food products. To produce products with optimal quality, the ideal ash level is within the range of 0.5% to 0.6%[43]. Taste and texture may be impacted by a high ash concentration. A brownie with a high ash content has a darker color, a bitter taste, and a gritty texture.

Brownies Products

Figure 2 shows the appearance of brownies with various replacement compositions between modified banana flour and wheat flour. Visually, the more modified banana flour used, the darker the brownie color tends to be[44]. This is due to the compounds in banana flour that have an impact on the color and brightness of the final product. The decrease in brightness in brownies made with banana flour occurs because banana flour has a lower whiteness, 44.6, compared to wheat flour[27]. The color difference in the brownies was mainly influenced by the amount of modified banana flour used in the batter. Panelists generally prefer brownies with a brown color that is not too dark, so the level of acceptance is higher than brownies that are more intense in color. Chocolate blocks provide a more moist texture while chocolate powder provides a richer taste. The texture that pregnant women favored was produced in this study by adding more chocolate blocks than chocolate powder[45]. This color difference is related to the non-enzymatic browning reaction that occurs during the baking process. The sugar content in the banana flour used affects the non-enzymatic browning process. The sugar content in banana flour can react with amino acids to form brown compounds. So, more banana flour used, the sugar content in the product will increase so that it can affect the non-enzymatic reaction (Maillard reaction), which produces brown compounds. This reaction affects the color and taste of brownies.



B1: modified banana flour substitution treatment in brownies (20%); B2: modified banana flour substitution treatment 40% g in brownies; B3: modified banana flour substitution treatment 60% g in brownies; B4: modified banana flour substitution treatment 80% g in brownies; B5: modified banana flour substitution treatment 100% g in brownies.

Figure 3. The appearance of modified banana flour substitution brownies

Table 4. Duncan Test Results on Brownies Color

Treatment	Color	Aroma	Texture	Taste
B1 (20%)	1.92±0.22^{b}	2.80±0.76^{b}	3.28±0.55^{a}	2.92±0.79^{b}
B2 (40%)	2.04±0.21^{a}	3.04±0.19^{a}	3.36±0.94^{a}	3.16±0.14^{b}
B3 (60%)	2.16±0.16^{a}	3.32±0.22^{a}	3.40±0.78^{a}	3.28±0.38^{b}

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B4 (80%)	2.56±0.09[a]	3.44±0.89[a]	3.48±0.30[a]	3.88±0.99[a]
B5 (100%)	2.40±0.11[a]	3.16±0.47[a]	3.44±0.61[a]	3.52±0.51[a]

Mean values followed by the same letter are not significantly different according to LSD test at 5% level

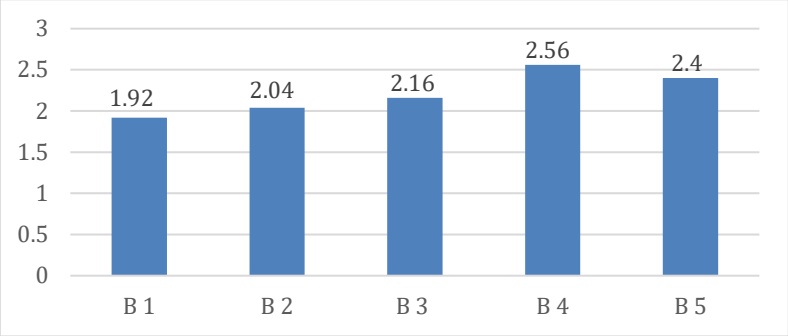

Figure 4. Brownies Color Analysis Results

Color Sensory Test

The results of sensory analysis of brownie color can be seen in Figure 4. The combination of modified banana flour, granulated sugar, and chocolate powder and bar affects the color variation of the brownies. The interaction of these ingredients produces a distinctive brown color in the brownies. Panelists generally preferred brownies with a darker color, which increased their acceptance level compared to brownies with a lighter color. This is related to the occurrence of non-enzymatic browning reactions during the baking process.

The results of variance analysis showed a significant difference in color between brownies with modified banana flour substitution and brownies made from wheat flour, especially at the 20% and 80% substitution levels. This difference is thought to be caused by an increase in the amount of modified banana flour in the formulation. Color is one of the main factors that influence consumer acceptance of a product. In food quality evaluation, aspects such as taste, color, texture, and nutritional content play an important role. However, color is often the first factor that attracts consumers attention. If a product has good nutritional value, delicious taste, and appropriate texture, but its appearance is unattractive, consumers tend to be reluctant to consume it.

This study found that brownies with 80% modified banana flour substitution were preferred by panelists compared to other substitution levels. This is due to the occurrence of non-enzymatic browning reactions, especially the Maillard reaction, during the heating process. Consumers like products with a golden brown color resulting from 80% banana flour substitution. Banana flour substitution up to 100% produces a dark brown color that is not attractive to pregnant women. According to Winarno[46], the Maillard reaction occurs due to the interaction between carbohydrates, especially reducing sugars, with primary amine groups. This reaction produces brown-colored compounds that are desirable in food products, although under some conditions it can cause a decrease in quality. Non-enzymatic browning occurs when reducing sugars react with compounds containing NH_2 groups, such as proteins, amino acids, peptides, and ammonium[47].

Flavor Sensory Test

The results of sensory analysis of brownies aroma can be seen in Figure 5. The results of the analysis of variance showed a significant difference in the aroma of brownies made with modified banana flour replacement compared to wheat flour-based brownies, especially at the 20% and 80% replacement levels. Based on the data in Table 4, the higher the proportion of modified banana flour added, the higher the level of panelist acceptance of the brownies aroma. The formulation with 20% replacement had the lowest mean acceptance value, which was 2.8. The addition of modified banana flour affects the aroma of the brownies, where an increase in concentration results in a more pronounced change in aroma. Brownies with modified banana flour have a distinctive banana aroma that can increase the attractiveness for consumers to taste it.

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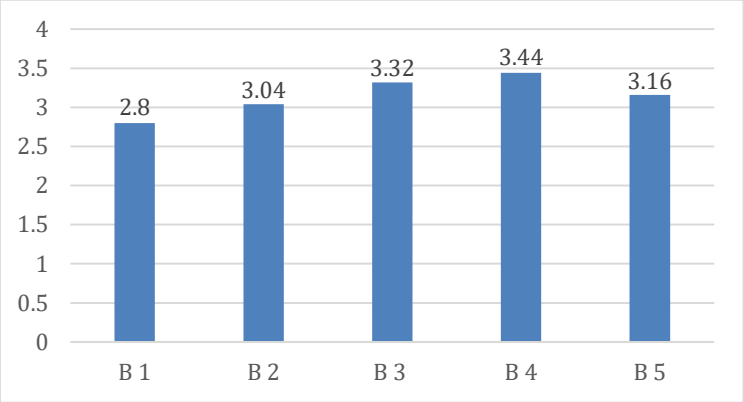

Figure 5. Brownies Aroma Analysis Results

Overall, the use of modified banana flour played a major role in determining the acceptability of the product. Taste, texture, scent, and color are some of the factors that affect how well-liked brownies made without banana flour are. The product's acceptance is impacted by its sweet banana flavor and powerful scent. Additionally, the smooth texture and golden brown hue of banana brownies influence the product's appeal. The higher the percentage of banana flour used, the stronger the banana aroma, so panelists are more likely to like the brownies. In addition, another research conducted also showed that variations in flour concentration affect the aroma produced in a food product[48].

Texture Sensory Test

The results of sensory analysis of brownies texture can be seen in Figure 6. Sensory evaluation of the texture of brownies with modified banana flour replacement showed that the average scores ranged from 3.28 to 3.52. Descriptively, this finding indicates that panelists liked the texture of the brownies containing modified banana flour.

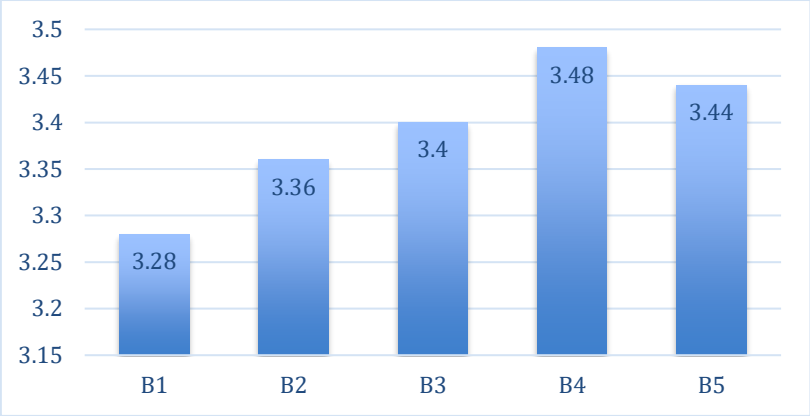

Figure 6. Brownies Texture Analysis Results

Overall, the graph showed a downward trend in the scores, indicating that the higher the level of modified banana flour replacement, the texture of the brownies tended to become softer. Research at 2024 found that when modified kepok banana starch was used in place of wheat flour when creating steamed brownies, the brownies' hardness value dramatically dropped with the proportion of substitution[49]. This demonstrates that when more banana flour is used, the brownies' texture gets softer. These results are further supported by a study which found that panelists prefer brownies made with banana flour because it has a softer texture. The softness of the brownies texture is a result of the starch granules expanding during baking due to the high starch content in banana flour[39]. Scientifically, more banana flour added to the brownie formulation, softer the brownies texture tends to be due to the resistant starch, amylopectin, and dietary fiber content in banana flour which interacts with water and fat during the baking process.

Based on Duncan's test analysis, no significant difference was found in the texture of the brownies among the various replacement levels, as all treatments were in the same group. Panelists considered the softness of the texture as one of the preferred characteristics. This is related to the protein content in wheat flour that plays a role in the formation of gluten, which gives the brownies an elastic and chewy structure[50].

Taste Sensory Test

The results of sensory analysis of the taste of brownies can be seen in Figure 7. Based on the sensory evaluation of taste conducted by panelists, the replacement of modified banana flour in brownies resulted in a significant difference in the taste of the final product. Duncan's test results showed that the

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replacement of modified banana flour at the 80% and 100% levels significantly affected the hedonic quality of brownies flavor compared to the 20%, 40%, and 60% levels, as the two treatments were in different groups.

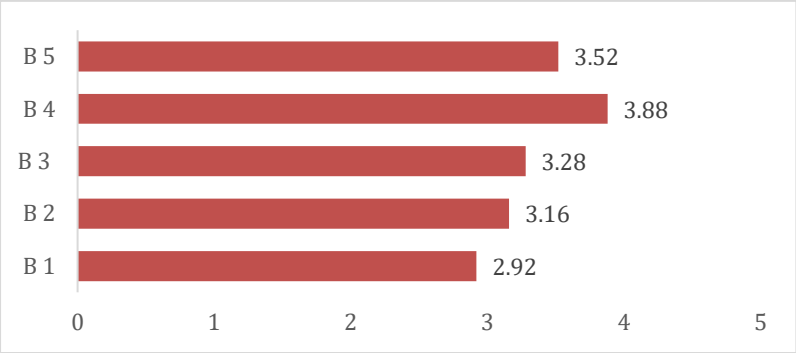

Figure 7. Brownies Flavor Analysis Results

On the other hand, although there was a difference in taste between the replacements at the 80% and 100% levels, the difference was not significant as they both belonged to the same group. Something similar happened at the 20%, 40%, and 60% levels, where although there was a variation in taste, the effect was not significant as these three treatments were also in the same group. Overall, the higher the proportion of modified banana flour in brownies, the more favorable the taste produced by panelists. This is because the taste of modified banana flour is more dominant than other ingredients, thus giving a more prominent distinctive taste on the tongue. The flavor of banana flour is typically neutral to slightly bitter. Banana flour can add a subtle banana flavor to brownies without overpowering the final product's flavor. The final taste and texture of brownies can be impacted by the usage of banana flour. A subtle banana scent can be produced by substituting banana flour for wheat flour in specific ratios without overpowering the product's flavor. On the other hand, adding too much banana flour can result in unfavorable texture and flavor alterations. In order to blend the unique flavor of banana flour with the intended brownies qualities, it is crucial to ascertain the proper ratio in the product formulation[27,51].

Dough Development Properties Power Analysis

The average specific expandability of brownies ranged from 0.16 cm^3 - 0.27 cm^3 (Table 8), where the highest average was 0.27 cm^3 in the treatment of 20% modified banana flour substitution and the lowest average was 0.16 cm^3 in 100% modified banana flour substitution. Brownies made with modified banana flour replacement in the range of 20% to 100% showed a decrease in the ability to expand. The greater the proportion of modified banana flour used, the lower the level of brownie rise. This decrease is due to the reduced gluten content in the batter, which is important in forming the structure of the brownies during the baking process.

Table 8. Riseability of Brownies

Repeat	Flour Substitution Treatment Modified Banana				
	20%	**40%**	**60%**	**80%**	**100%**
1	0.26	0.22	0.22	0.18	0.16
2	0.26	0.24	0.22	0.17	0.16
3	0.28	0.24	0.21	0.17	0.15
Average	0.27±0.01	0.23±0.01	0.22±0.01	0.17±0.01	0.16±0.01

The main factors that influence the ability of brownies to rise are the type of raw materials used and the baking process. The use of large amounts of modified banana flour causes the texture of the brownies to be less fluffy. One of the reasons for this is that wheat flour naturally contains two types of proteins, gliadin and glutenin. When these two proteins mix with water, they form gluten, a compound with cohesive and viscoelastic properties that allows the dough to stretch well[47]. The capacity of starch to expand after absorbing water is known as swelling power. Swelling power has no bearing on product development when it comes to brownies. Swelling power has little bearing on the development of brownies because they don't need to be developed like other bread or cake doughs. Swelling power has little effect on the texture of brownies since they are rich and moist rather than light and airy like bread[52].

Determination of the Best Formulation

The quality of a food product is assessed from both objective and subjective perspectives. Subjective quality is the quality determined from the assessment of human instruments or what is known as sensory properties. Determination of the best formulation is based on the observation of the sensory test properties of modified banana flour substitution brownie products. In addition to being evaluated objectively, food products are also evaluated subjectively for quality. Observations of brownies' nutritional content and the outcomes of sensory testing are used to identify the optimal formulation since subjective quality is assessed using human instruments, or more commonly, sensory qualities. The results of the sensory test data recapitulation are presented in Table 9.

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Table 9. Result of Brownies Sensory Test

Parameters	Flour Substitution Treatment Modified Banana				
	20%	40%	60%	80%	100%
Color	1.92	2.04	2.16	2.56	2.40
Aroma	2.80	3.04	3.32	3.44	3.16
Texture	2.92	3.16	3.28	3.88	3.52
Taste	3.28	3.36	3.40	3.48	3.44

Nutrition Content Analysis

Table 10 presents the nutritional composition analysis of the optimal modified banana flour-substituted brownies formulation, including key parameters such as moisture content, ash content, protein content, fat content, carbohydrate fiber content, and energy value. The data provides a comparative evaluation between three distinct variants: standard brownies formulated according to SNI (Indonesian National Standard) requirements, control brownies made with 100% wheat flour (untreated), and the selected best formulation containing 80% modified banana flour. This comparative nutritional profiling demonstrates the significant differences in macro- and micronutrient composition between conventional wheat-based brownies and the developed banana flour-enhanced product, particularly highlighting its potential as a nutritional alternative for pregnant women.

Table 10. Results of Brownies Nutritional Content Analysis

Component	Brownies Control	Best Brownies	Brownies Standard
Water (%)	12.35±0.08	11.77±0.22	Max. 16.78
Ash (%)	1.11±0.19	1.08±0.82	Max. 2.39
Fiber (%)	2.03±0.22	2.25±0.13	Max. 2.52
Fat (%)	20.66±0.09	20.31±0.03	Max. 26.93
Protein (%)	5.98±0.77	5.69±0.71	Min. 5.03
Carbohydrates	57.87±0.18	58.90±0.04	Min. 51.72
Energy (kcal)	442	475	450

The results of the analysis showed that the water content in brownies with modified banana flour replacement reached 11.77%. Although there is no Indonesian National Standard (SNI) that specifically regulates brownies with modified banana flour, the closest standard is wheat flour-based brownies. According to SNI, the maximum moisture content allowed in brownies is 16.78% (by weight). With a lower moisture content than wheat flour brownies, this product is still safe for consumption. The ash content in brownies using modified banana flour was recorded at 1.08%. Ash is the residue that remains after food is burned until the carbon is exhausted. Ash content reflects the amount of minerals in a material, where higher ash content indicates more mineral content. The amount of minerals, including calcium, phosphorus, magnesium, and potassium, in banana flour increases with its ash content. The reason for this is that ash, which is primarily composed of minerals, is an inorganic residue that is left over after burning organic molecules[53].

In addition, the protein content in brownies with modified banana flour reached 5.69%, higher than the SNI minimum standard[54], which is 5.03%. This indicates that the brownies meet the established protein content standards. Protein is important in providing amino acids that support the formation and maintenance of body tissues. However, compared to wheat flour-based brownies, the protein content is slightly lower. This is due to the low protein content of modified banana flour, which is only about 3.57%, so replacing wheat flour with modified banana flour can reduce the protein content in the final product. Wheat flour itself has the ability to form gluten which contributes to the elastic and chewy texture of brownies. Wheat flour granules are arranged in a gluten protein matrix, which allows interaction with other materials through ionic bonding, hydrogen, as well as hydrophobic reactions[55].

Protein is an essential nutrient that functions in the formation of enzymes, hormones, and body structures. In addition, proteins containing amino acids and insulin-like growth factor play a role in lipid production and bone growth. IGF also regulates protein consumption and controls growth. For pregnant women, adequate protein is necessary to support fetal development and embryogenesis. Protein deficiency during pregnancy can inhibit fetal growth and increase the risk of low birth weight[56].

In this product, the fat comes from margarine and chocolate blocks. The fat content in brownies with modified banana flour replacement reached 20.31%. Fat serves as a more efficient source of energy than carbohydrates or protein, with each g of fat producing 9 kcal, while carbohydrates and protein only contribute 4 kcal per g[57]. Fiber analysis results showed that brownies made from modified banana flour contained 2.25% fiber. Based on recommendations from the Nutrition Department of the Ministry of Health and the Institute of Health in 1999, a product can be categorized as a source of dietary fiber if it contains 3-6 g of fiber per 100 g[58]. Food fiber plays a role in determining the physical properties of food ingredients and is physiologically defined as plant components that cannot be digested by enzymes in the stomach or small intestine[46].

Based on the results of the analysis, the total energy in the brownie control sample was 442 kcal, still below the nutritional composition standard of additional food for pregnant women according to PERMENKES RI NUMBER 5 of 2016, which is set at 450 kcal[59]. Meanwhile, brownies with 80% modified banana flour replacement have a total energy of 475 kcal, so they have met the

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nutritional standards of additional food for pregnant women. Energy plays an important role in supporting various physiological processes in the body, such as metabolism, protein synthesis, and circulation. During pregnancy, adequate energy intake is essential to support the growth of the fetus, placenta and maternal body tissues. Energy deficiency, especially in the second and third trimesters, can increase the risk of low birth weight babies[60]. For pregnant women who experience Chronic Energy Deficiency (CHD), consumption of two pieces of brownies as snacks in the morning and evening can help meet nutritional needs during pregnancy.

The results of the analysis show that brownies with 80% replacement of modified banana flour contain 475 kcal, which is in accordance with the standards of SNI 2973: 2011 and PERMENKES RI NUMBER 5 of 2016 regarding the fulfillment of calories in additional food for pregnant women. According to the study's findings, brownies made without banana flour can be an additional healthy snack option for expectant mothers. This is evident from the nutritional content analysis, which is in line with pregnant women's requirements. The fiber and resistant starch found in banana flour work as prebiotics, promoting the development of beneficial bacteria in the intestines. Pregnant women frequently get constipation, which is avoided by doing this[61]. This proves that modified banana flour can be used in making brownies to increase nutritional value and meet energy needs for pregnant women.

CONCLUSIONS

The addition of modified banana flour in brownies production affects sensory characteristics, such as color, aroma, texture, and taste, with formula B4 (80% replacement of modified banana flour) producing the best results. The nutritional composition of the best brownies with 80% replacement of modified banana flour includes 11.77% moisture content, 5.69% protein, 20.31% fat, 2.25% fiber, 1.08% ash, and 58.90% carbohydrate. Brownies made with modified banana flour are a suitable option to satisfy daily nutritional needs because of their high nutritional content and panelists' favored sensory qualities. For further development, it is recommended to add tempeh flour or soy flour to increase the protein content in brownies. Thus, it is hoped that this brownies can play a role in overcoming nutritional problems, especially in infants and toddlers.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

There is no conflict of interest in writing this article. This research is a research conducted by a team of lecturers from *Politeknik Negeri Lampung* across study prog independently.

AUTHOR CONTRIBUTIONS

ZA: conceptualization, methodology, analysis, and writing original draft; AV: data curation; writing editing, review and editing; FW: format analysis, and visualization; AF: format analysis, writing review and editing.

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