

Physical and Chemical Characteristics of Cookies Based on Modified Janten Banana Flour with Cassava Starch Substitution

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ABSTRACT

Cookies are one of the most popular food products, widely favored for their crunchy texture and distinctive taste. However, their formulation generally relies on wheat flour, which limits the diversification of local food resources. This study was conducted to evaluate the effect of substituting modified janten banana flour with cassava starch on the physicochemical characteristics of cookies. Treatments consisted of various proportions of banana flour and cassava starch. Analyses included moisture, ash, protein, fat, carbohydrate, and dietary fiber contents, while the physical properties examined were texture (hardness) and color (L, a, b, and whiteness index). The results showed that increasing the proportion of banana flour significantly affected the quality of cookies. Physically, higher banana flour substitution resulted in darker cookie color, lower whiteness index values, and increased hardness. Chemically, the use of banana flour increased ash, dietary fiber, and carbohydrate contents but reduced fat content, while protein content remained relatively stable. Formulations with 40% cassava starch + 60% banana flour and 20% cassava starch + 80% banana flour provided the best balance of quality and thus have potential for consumer acceptance. These findings emphasize the attractiveness of modified banana flour as an alternative raw feed-stock for healthy and functional cookies, while contributing to local food diversification too.*

1. INTRODUCTION

Banana (*Musa paradisiaca* Linn.) is one of the major tropical fruit commodities with high economic value and an important role in global food security (Jupri *et al.*, 2024; Sulistyowarni *et al.*, 2020). Originally from Southeast Asia, bananas are now cultivated in more than 130 tropical and subtropical countries, with consumption levels continuing to rise in line with increasing public awareness of healthy food (Evans *et al.*, 2020). Bananas are known as an easily digestible carbohydrate source, and are also rich in vitamins (A, B6, C) (Arinta *et al.*, 2021), minerals (potassium, magnesium) (Ishak *et al.*, 2025), and bioactive compounds such as phenolics, flavonoids, and tannins, which have potential as natural antioxidants (Nuur *et al.*, 2021). This potential makes bananas not only a fresh fruit but also a highly prospective raw material for processed food products. According to Statistics Indonesia (BPS), in 2024 Indonesia produced approximately 9.34 million tons of bananas, making it the highest-producing fruit compared to other horticultural commodities such as mango, citrus, and pineapple. This figure confirms bananas as one of the backbones of the horticulture sector in Indonesia.

Regionally, Lampung Province is one of the main banana production centers in the country. Based on regional statistics, Lampung's banana production in 2023 reached 1.322.030 tons, an increase of 8.1% compared to 2023 (BPS, 2024). This increase reflects the strong adaptability of banana plants to Lampung's agroclimatic conditions and reinforces the province's position as the second-largest banana producer in Indonesia after East Java. The abundant

banana production in Lampung opens up wide opportunities for the development of banana-based processed products such as banana flour. Such products have the potential to support local food diversification programs while also providing added value for farmers and small-medium enterprises (Ginting *et al.*, 2024; Septanta *et al.*, 2025). The plentiful supply of bananas represents a major opportunity for developing banana-based processed products as a strategy for local food diversification (Mairawita *et al.*, 2025). One promising local variety is *janten banana*. This variety, belonging to the *Musa paradisiaca* group, has dense flesh texture, neutral taste, and nutrient composition suitable for flour production. Modified janten banana flour is rich in carbohydrates, dietary fiber, and essential minerals such as potassium and magnesium, which play important roles in maintaining physiological functions. It also contains bioactive compounds with antioxidant activity that benefit health. However, banana flour often faces limitations in food formulation, such as low solubility, limited functional stability, and reduced dough expansion compared to other flours. To overcome these constraints, modification is required—one approach being physical modification through partial pregelatinization. This treatment involves heating starch granules to induce partial structural changes without completely destroying the matrix. Such modification can improve hydration capacity, water absorption, and viscosity, making banana flour more applicable in processed food products. One of the promising applications of modified starch is in cookies.

Cookies are popular snacks widely consumed across all age groups. The novelty of this study lies in the strategic utilization of partially pregelatinized janten banana flour as a functional partial substitute for cassava starch in cookie production, integrating starch modification technology with local commodity valorization. Unlike previous research that predominantly employed native banana flour or single-starch formulations, this study applies controlled partial pregelatinization to enhance the functional properties of banana flour prior to its incorporation into a composite flour system. This approach enables the simultaneous improvement of dietary fiber content, water-binding capacity, and structural stability of cookies while maintaining acceptable sensory attributes. Furthermore, this research provides a systematic assessment of the physicochemical–sensory balance at various substitution levels, offering practical formulation insights for the development of fiber-enriched cookies based on non-wheat, locally sourced ingredients. By combining physical starch modification with product-level optimization, this study contributes novel empirical evidence to the advancement of functional bakery products and supports sustainable food diversification strategies. Therefore, substituting part of the cassava starch with partially pregelatinized modified janten banana (*Musa paradisiaca* group) is a locally cultivated plantain-type variety characterized by high starch content in the unripe stage, along with appreciable dietary fiber, resistant starch, and essential minerals, improve nutritional profile, and provide additional functional characteristics without reducing consumer sensory acceptance. Previous studies have shown that modifying banana flour using partial pregelatinization enhances water-binding capacity, gelling ability, and the stability of baked products. Substitution of banana flour in cookies, up to certain levels, can increase dietary fiber content without significantly reducing physical or sensory quality. This reinforces the potential of utilizing modified janten banana flour to produce cookies with improved physicochemical properties, while also supporting food diversification based on local commodities (Nirmagustina *et al.*, 2024). Based on this background, the present study was conducted to investigate the physicochemical characteristics of cookies formulated with cassava starch partially substituted by pregelatinized modified janten banana flour. The findings are expected to provide scientific insights into the potential of janten banana as an alternative raw material for cookie production and to increase the added value of banana commodities in Lampung Province.

2. MATERIALS AND METHODS

2.1. Materials and Tools

The main ingredients used were modified janten banana flour (partially pregelatinized) and cassava starch (Gunung Agung brand). Additional ingredients included powdered sugar (Ratu brand), margarine (Blueband brand), chicken eggs, instant coconut milk (Kara brand), palm sugar, baking powder (Koepoe-Koepoe brand), and vanilla powder (Koepoe-Koepoe brand). Chemicals used for analysis consisted of distilled water, Sulfuric acid (H₂SO₄), Sodium hydroxide (NaOH), Hydrochloric acid (HCl), n-hexane, phenolphthalein indicator, and other reagents according to the analytical methods. The equipment employed in this study included an oven, mixer, baking tray, digital balance, texture analyzer, colorimeter, drying oven, disc mill, desiccator, and standard laboratory glassware.

2.2. Research Location

The location of the research was carried out Politeknik Negeri Lampung, Bandar Lampung. Analytical test was carried out at the Agricultural Product Laboratory of the Department of Food Technology, Faculty of Agriculture, Politeknik Negeri Lampung.

2.3. Procedure for Making Modified Janten Banana Flour

The preparation of modified janten banana flour was carried out using a partial pregelatinization method aimed at improving the functional properties of starch, such as rehydration capacity, solubility, and water absorption, making it more suitable for application in processed food products. The process began with peeling fresh janten bananas, which were then thinly sliced to a thickness of approximately ± 2 mm. Uniform slicing was intended to accelerate the drying process and produce flour with more homogeneous characteristics. The banana slices were subsequently dried in a drying oven at 60 °C until the moisture content dropped below 10%. This drying step was essential to inhibit microbial growth and extend the shelf life of the raw material (Fadhilla *et al.*, 2024; Nafilawati *et al.*, 2025).

The dried bananas were then milled using a disc mill to obtain flour with a particle size of 80 mesh. Modification was performed by mixing the banana flour with water at a ratio of 1:2, followed by heating at approximately 70–75 °C for 10 minutes. This heating process partially disrupted starch granules, breaking intergranular bonds and producing modified starch with improved rehydration ability without completely destroying the granule structure. The heated flour was then redried in an oven at 50 °C until a stable moisture content was achieved. The dried flour was subsequently remilled and sieved to 80 mesh to obtain uniform particles. The modified janten banana flour was stored in airtight containers to prevent moisture absorption and microbial contamination. Airtight storage helps maintain the functional quality and physical stability of the flour during storage. Overall, the partial pregelatinization process produced modified janten banana flour with enhanced functional properties compared to native flour. The modified flour exhibited higher solubility and water absorption capacity, which are highly important in cookies production and other bakery applications.

2.4. Procedure for Making Cookies

Cookies were prepared by substituting modified janten banana flour (JF) for cassava starch (CS) with the following formulations: F1 (80% CS + 20% JF); F2 (60% CS + 40% JF); F3 (40% CS + 60% JF); F4 (20% CS + 80% JF); F5 (0% CS + 100% JF). The cookies-making process began with weighing the ingredients, namely flour mixture (according to treatment) 200 g, margarine 200 g, powdered sugar 50 g, egg yolk 50 g, baking powder 0.2 g, and vanilla powder 0.1 g. Margarine and powdered sugar were whipped using a mixer until the dough expanded and became lighter in color. Egg yolk, baking powder, and vanilla powder were then added and mixed until homogeneous. Banana flour was subsequently incorporated gradually into the wet mixture until a smooth, moldable dough was formed. The dough was portioned at 8 g each, rounded according to the mold, and flattened on a baking tray lined with parchment paper. The dough was baked at 170 °C for 20 minutes until golden brown. After baking, the banana cookies were cooled at room temperature before packaging.

2.5. Experimental Design

This study used a Completely Randomized Design (CRD) with five banana flour substitution treatments (namely F1 to F5 as previously described) and three replications. Observational data were analyzed using Analysis of Variance (ANOVA), and if significant differences were found, Duncan's Multiple Range Test (DMRT) was used at a 5% significance level.

2.6. Test Parameters

2.6.1. Texture Analysis

Texture Analysis was conducted using a texture analyzer (TA.XTplusC). A 3 g sample was placed on the HDP/PFS probe, which was set at an initial position of 2.5 mm and operated at a speed of 0.10 mm/s.

2.6.2. Color

Color measurement was carried out using a Chroma Meter (Konica Minolta CR-400) in the Hunter L^* , a^* , b^* system. In this approach, L^* represents lightness (0 = black, 100 = white), a^* indicates chromaticity from green (-) to red (+), while b^* indicates chromaticity from blue (-) to yellow (+). These values provide an objective representation of sample color and facilitate comparison among treatments. To comprehensively describe “whiteness,” the whiteness index can be calculated in the CIELAB color space based on the distance from the nominal white point ($L^* = 100$, $a^* = 0$, $b^* = 0$) using the following equation:

$$WI = 100 - \sqrt{(100 - L^*)^2 + (a^*)^2 + (b^*)^2} \quad (1)$$

This index is widely used in food and material sciences because it combines the three color coordinates into a single metric sensitive to decreases in brightness and shifts toward yellowish or reddish hues. The CR-400 device supports both Hunter and CIELAB color space measurements for color quality control across various food matrices.

2.6.3. Moisture Contents

Moisture content was determined using the oven-drying method (AOAC 925.10). Approximately 5 g of cookie sample was weighed into a porcelain dish that had been pre-dried and weighed. The sample was dried in an oven at 105 ± 2 °C for 16 h or until a constant weight. The dish was then cooled in a desiccator for 30 minutes before reweighing.

2.6.4. Ash Contents

Ash content was analyzed using the dry ashing method in a muffle furnace (AOAC 923.03). About 3 g of cookie sample was placed in a pre-weighed crucible. The sample was first charred on a hotplate until no smoke remained, then ashed in a muffle furnace at 550 ± 25 °C for 6 hours until white to grayish ash was obtained. The crucible was cooled in a desiccator for 30 minutes prior to weighing.

2.6.5. Protein Contents

Protein content was determined using the Kjeldahl method (AOAC 979.09). Approximately 1 g of cookie sample was digested in a Kjeldahl tube with 10 mL concentrated H_2SO_4 and one catalyst tablet (K_2SO_4 - $CuSO_4$ mixture). Digestion was carried out at 420°C for 2 hours until the solution became clear greenish. The digest was cooled, diluted with 50 mL distilled water, and distilled in a Kjeldahl apparatus with the addition of 10 mL 40% NaOH. The released ammonia was collected in 25 mL of 4% boric acid solution containing a mixed indicator (methyl red–bromocresol green), then titrated with 0.1 N HCl until the solution turned pink. Protein content was calculated using a nitrogen-to-protein conversion factor of $N \times 6.25$.

2.6.6. Fat Contents

Fat content was determined using the Soxhlet extraction method (AOAC 920.39). About 2 g of cookie sample was wrapped in fat-free filter paper and placed in a Soxhlet extractor with 150 mL petroleum ether (bp. 40–60 °C) as solvent. Extraction was conducted for 6 hours until all fat was extracted. The solvent was evaporated using a rotary evaporator, and the fat residue was dried in an oven at 105 °C for 30 minutes before weighing.

2.6.7. Dietary Fiber Contents

Dietary fiber was analyzed using the enzymatic–gravimetric method (AOAC 991.43). Approximately 1 g of cookie sample was digested sequentially with α -amylase (100 °C, 30 min), protease (60 °C, 30 min), and amyloglucosidase (60 °C, 30 min). The residue was filtered, washed with 78% ethanol and acetone, and then dried at 105 °C to constant weight. Dietary fiber content was calculated from the residue weight after correcting for ash and protein.

2.6.8. Carbohydrate Contents

Carbohydrate content is calculated differentially (by difference), namely by subtracting the total of 100% from the total water, ash, protein, fat and dietary fiber content.

3. RESULTS AND DISCUSSION

3.1. Index and Status of Sustainable Environmentally Friendly Agriculture in Ngawi Regency

The preparation of cookies using modified janten banana flour substituted with cassava starch resulted in five formulations (F1–F5), each exhibiting distinct physical and chemical characteristics. Figure 1 shows the visual appearance of cookies with increasing levels of modified janten banana flour substitution (F1–F5). A clear color change is observed, where cookies become progressively darker as the proportion of banana flour increases. F1 appears lighter due to the dominance of cassava starch, while F3–F5 exhibit a more intense brown color. This visual trend is associated with the natural pigments in banana flour and enhanced browning reactions during baking. Despite the color differences, all treatments maintained a similar shape and surface pattern, indicating that banana flour substitution did not adversely affect the structural integrity of the cookies.

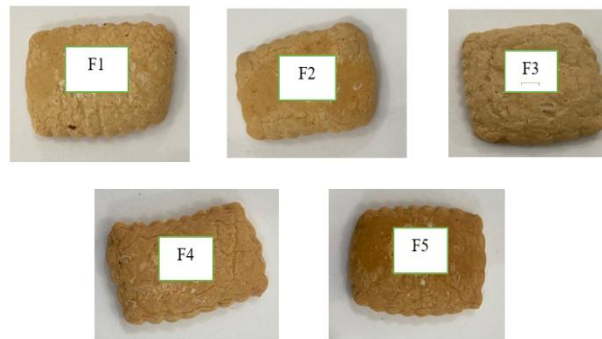


Figure 1. Cookies produced in this study: F1 (80% CS + 20% JF); F2 (60% CS + 40% JF); F3 (40% CS + 60% JF); F4 (20% CS + 80% JF); F5 (0% CS + 100% JF)

3.2. Texture Analysis

Physical properties are essential parameters in evaluating the quality of cookies because they are directly related to consumer perception, particularly in terms of texture and color. Texture, commonly assessed using the Texture Analysis method, reflects the crispiness and hardness characteristics of the product. In this study, substitution of modified janten banana flour with cassava starch had a significant effect on the hardness of the cookies. A higher proportion of banana flour tended to increase hardness. Resistant starch contributes to cookies texture through its structural stability and water-binding behavior. Unlike readily digestible starch, resistant starch maintains partial granular integrity during heating and tends to retrograde upon cooling, forming a tighter starch network. In addition, its high water-binding capacity limits excessive starch swelling and dough spread during baking. As a result, higher resistant starch levels promote a denser, more compact structure and increased firmness in the final cookies. According to [Apriyani *et al.* \(2025\)](#), increasing fiber content in cookies formulations reduces porosity and strengthens starch–protein molecular interactions, thereby increasing product hardness. Moreover, cassava starch, which is rich in readily gelatinized starch, contributes to a lighter and crispier texture, whereas banana flour tends to produce a denser structure ([Sylvia *et al.*, 2025](#)). The texture measurement results of the cookies are presented in Table 1.

The texture measurements of cookies in Table 1 revealed variations in hardness values resulting from different substitution ratios of modified janten banana flour and cassava starch. The average hardness of the cookies ranged from 4635.60 to 4835.77 gF, showing an increasing trend with higher proportions of banana flour. Cookies in formulation F1 (80% cassava starch + 20% banana flour) exhibited the lowest average hardness (4635.60 gF), while F5 (100% banana flour) showed the highest hardness (4835.77 gF). This indicates that substituting cassava starch with modified banana flour had a significant effect on product texture. The increase in hardness with higher levels of banana flour is associated with its higher resistant starch and dietary fiber content compared to cassava starch. Resistant starch contributes to the formation of a denser and more rigid matrix after baking, thereby enhancing resistance to deformation ([Yulianto, 2024](#)). In addition, dietary fiber reduces cookie porosity, leading to a firmer texture ([Kamal-Eldin *et al.*, 2020](#)). Conversely, cookies with higher cassava starch content (F1 and F2) demonstrated a lighter and crispier texture. This corresponds with the properties of cassava starch, which is rich in starch dominated

by amylopectin, producing a more fragile structure upon baking (Puspita *et al.*, 2025). The combination of cassava starch and modified janten banana flour at intermediate substitution levels produced a balanced texture characterized by moderate crispiness and acceptable hardness, which corresponded with the sensory evaluation results. Based on the hedonic test data, treatments with moderate substitution levels showed higher overall acceptance scores compared to formulations with the highest banana flour content. This indicates that excessive hardness at higher substitution levels may reduce consumer preference, while formulations that are too fragile may negatively affect perceived product quality. Therefore, the sensory data confirm that texture plays a critical role in determining consumer acceptance, and an optimal flour ratio is necessary to achieve a desirable balance between crispiness and hardness. Therefore, intermediate formulations (F3 and F4), with hardness values ranging between 4804.04–4820.88 gF, seem to provide a moderate texture balance and may be more favorable organoleptically. These findings align with recent reports highlighting that the use of composite local flours yields texture attributes more acceptable to consumers than single-flour formulations (Anunggiling Tyas *et al.*, 2022). Table 1 shows a numerical increase in cookie hardness with higher levels of modified janten banana flour; however, the differences among treatments were not statistically significant ($p>0.05$). This indicates that although a trend toward increased hardness was observed, cassava starch substitution did not significantly affect cookie texture under the conditions studied.

Table 1. Effect of treatment on the texture of cookies based on janten banana modified flour

| Section | Treatments* | | | | |
|--------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | F1 | F2 | F3 | F4 | F5 |
| Top (gF) | 4608.78±0.03 | 4776.97±0.02 | 4796.30±0.26 | 4825.10±0.14 | 4834.12±0.22 |
| Middle (gF) | 4619.23±0.04 | 4696.67±0.46 | 4809.71±0.06 | 4838.34±0.82 | 4844.83±0.42 |
| Bottom (gF) | 4678.78±0.24 | 4656.00±0.10 | 4806.11±0.08 | 4799.21±0.42 | 4828.35±0.43 |
| Average (gF) | 4635.60 ^a | 4709.88 ^a | 4804.04 ^b | 4820.88 ^b | 4835.77 ^b |

*) F1 (80% CS + 20% JF); F2 (60% CS + 40% JF); F3 (40% CS + 60% JF); F4 (20% CS + 80% JF); F5 (0% CS + 100% JF). Data with different superscripts are significantly different ($p<0.05$).

Table 2. Effect of treatment on the color attributes of cookies based on janten banana modified flour

| Color Attribute | Treatments† | | | | |
|-----------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | F1 | F2 | F3 | F4 | F5 |
| L^* | 80.09±0.03 | 78.22±0.04 | 77.54±0.12 | 76.29±0.03 | 75.27±0.04 |
| a^* | 0.05±0.02 | 0.22±0.01 | 0.52±0.22 | 0.51±0.02 | 0.44±0.02 |
| b^* | 7.34±0.04 | 7.45±0.05 | 7.56±0.04 | 7.58±0.02 | 7.65±0.02 |
| Whiteness Index | 78.78 ^a | 76.97 ^b | 76.30 ^b | 75.10 ^b | 74.12 ^b |

†) F1 (80% CS + 20% JF); F2 (60% CS + 40% JF); F3 (40% CS + 60% JF); F4 (20% CS + 80% JF); F5 (0% CS + 100% JF). Data with different superscripts are significantly different ($p<0.05$).

3.3. Color

In addition to texture, color is an important physical parameter that influences the visual appeal of cookies. The results of color analysis using the Hunter Lab system showed that the L^* value (lightness) tended to decrease with increasing proportions of banana flour, while the a^* value (toward red) and b^* value (toward yellow) showed a slight increase, as presented in Table 2. Increasing the proportion of banana flour in cassava starch-based cookie formulations significantly affected the L^* , a^* , b^* parameters, as well as the whiteness index (WI). The decrease in lightness (L^*) from 80.09±0.03 in F1 to 75.27±0.04 in F5 was statistically significant ($p<0.05$), indicating that increasing banana flour substitution resulted in darker cookies. The a^* value showed an increasing trend from F1 to F3, reflecting a shift toward a more reddish hue due to browning reactions, and then slightly stabilized at higher substitution levels. Meanwhile, the b^* value gradually increased with higher banana flour proportions, indicating enhanced yellow–brown coloration associated with natural banana pigments and Maillard reaction products. This decrease indicates that the cookies became darker as the proportion of banana flour increased. A similar trend was observed in the whiteness index (WI), which decreased from 78.78±0.01 (F1) to 74.12±0.12 (F5). Statistical analysis in Table 2 showed that F1

differed significantly from the other treatments ($p < 0.05$). These changes are closely related to the inherent color of banana flour, which tends to be yellowish-brown compared to the white color of cassava starch. The presence of natural pigments (such as carotenoids), phenolic compounds, and enzymatic oxidation products in banana contributes to the darker hue of the product (Amarasinghe *et al.*, 2021; Kunyane *et al.*, 2024). In this cookies formulation, the Maillard reaction was mainly driven by the interaction between reducing sugars and amino groups from protein-containing ingredients. The primary contributors of reducing sugars were banana flour (which contains natural sugars and may release simple sugars during heating) and added sugar in the formulation. Meanwhile, amino acids and proteins were mainly supplied by eggs and, to a lesser extent, banana flour.

During baking at high temperatures, these reducing sugars reacted with free amino groups from proteins, leading to the formation of brown melanoidin pigments that contributed to the darker color of the cookies, as well as sugar caramelization, produces brown-colored melanoidin pigments, further reducing the L^* and WI values (Ridhani & Aini, 2021). The a^* value, which represents the red–green hue, tended to increase from 0.05 ± 0.02 in F1 to 0.52 ± 0.22 in F3, then slightly decreased in F4 and F5. The increase in a^* indicates a shift toward a reddish color due to phenolic degradation and the formation of brown pigments. Meanwhile, the b^* value (yellow–blue) increased from 7.34 ± 0.04 in F1 to 7.65 ± 0.02 in F5. The rise in b^* reflects the contribution of natural carotenoid pigments in banana as well as Maillard reaction products, which impart a yellowish-brown hue (Bashmil *et al.*, 2025; Mashau *et al.*, 2022). These findings are consistent with previous studies reporting that the addition of banana flour in bakery formulations reduces lightness (L^*) and whiteness index while increasing a^* and b^* values (Amarasinghe *et al.*, 2021; Mashau *et al.*, 2022). From a sensory perspective, the decrease in lightness may influence consumer perception of the visual quality of cookies. Substitution of banana flour at low to moderate levels (20–40%) is still acceptable sensorially, whereas higher levels (>60%) may lead to excessive browning, reducing consumer acceptability (Kunyane *et al.*, 2024). Therefore, although the substitution of modified janten banana flour enhances the functional value of the product (dietary fiber, resistant starch, and bioactive compounds), formulation optimization is required to maintain a balance between nutritional quality and sensory attributes.

3.4. Proximate Analysis

This study produced banana flour–based cookies as a form of local food diversification. The formula utilized banana flour combined with other ingredients such as cassava starch, powdered sugar, eggs, margarine, and vanilla powder, then packaged in laminated plastic packaging with a net weight of 50 g per pack. The results of the chemical properties analysis of banana cookies are presented in Table 3.

Based on Table 3, the proximate analysis results of banana flour–based cookies across different treatments (F1–F5) showed notable variations. Moisture content tended to decrease with increasing proportions of banana flour, from 9.02% in F1 to 8.52% in F5. Ash content increased from 1.24% (F1) to 1.59% (F5). Protein content remained relatively stable among treatments, ranging between 8.29% and 8.88%. Meanwhile, fat content decreased from 25.96% in F1 to 22.07% in F5. In contrast, dietary fiber and carbohydrate content tended to increase, reaching the highest values of 4.90% and 54.04%, respectively, in F5. The variation in ingredient composition among treatments resulted in differences in the proximate composition of banana cookies.

Table 3. Effect of treatment on the proximate characteristic

| Parameter | Treatments* | | | | |
|---------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | F1 | F2 | F3 | F4 | F5 |
| Moisture content (%) | 9.02±0.43 ^a | 9.00±0.20 ^a | 8.68±0.15 ^b | 8.71±0.02 ^b | 8.52±0.86 ^b |
| Ash content (%) | 1.24±0.28 ^a | 1.33±0.35 ^a | 1.48±0.12 ^b | 1.55±0.14 ^b | 1.59±0.71 ^b |
| Protein content (%) | 8.33±0.54 ¹ | 8.46±0.86 ^a | 8.29±0.16 ^a | 8.75±0.28 ^a | 8.88±0.55 ^a |
| Fat content (%) | 25.96±0.06 ^a | 24.11±0.10 ^a | 23.79±0.08 ^a | 23.94±0.66 ^a | 22.07±0.42 ^b |
| Dietary fiber content (%) | 4.32±0.12 ^a | 4.51±0.64 ^a | 4.80±0.18 ^b | 4.76±0.86 ^b | 4.90±0.68 ^b |
| Carbohydrate content (%) | 51.13±0.24 ^b | 52.59±0.08 ^b | 52.96±0.04 ^b | 52.29±0.46 ^b | 54.04±0.80 ^b |

* F1 (80% CS + 20% JF); F2 (60% CS + 40% JF); F3 (40% CS + 60% JF); F4 (20% CS + 80% JF); F5 (0% CS + 100% JF). Data with different superscripts are significantly different ($p < 0.05$). Data with different superscripts are significantly different ($p < 0.05$).

3.4.1. Moisture Content

The moisture content of the cookies across all treatments ranged from 8.52–9.02%, still meeting the quality standard for cookies according to SNI 2973:2011 (BSN, 2011), which requires a maximum moisture content of 10%. It was observed that the higher the proportion of banana flour, the lower the moisture content tended to be. This may be due to cassava starch having a higher water-binding capacity compared to banana flour. When the proportion of cassava starch decreased, water retention in the dough also declined. This finding is in line with da Costa *et al.* (2021), who reported that formulations based on non-gluten starches such as cassava starch exhibit different water-binding capacities compared to banana flour, thereby affecting the final product's moisture content. Lower moisture content is associated with improved shelf life, as microbial activity and enzymatic reactions can be suppressed (Ali *et al.*, 2020).

3.4.2. Ash Content

The ash content of the cookies showed an increasing trend with higher levels of banana flour substitution, rising from 1.24% in F1 to 1.59% in F5. However, statistical analysis revealed that F1 was similar to F2 ($p>0.05$), while F3, F4, and F5 were also similar to each other ($p>0.05$). This indicates that at low substitution levels (20–40%), the mineral contribution from banana flour was still limited and diluted by the dominance of cassava starch, resulting in similar ash contents. In contrast, once the substitution level reached 60% or higher, the mineral-rich banana flour became the dominant component, leading to a higher but statistically stable ash content across F3–F5. This pattern suggests a threshold effect, where significant increases in ash content occur only after banana flour exceeds a certain proportion in the formulation. This is because bananas contain higher mineral content compared to cassava starch, which has relatively few minerals. Ranjha *et al.* (2022) stated that bananas are a source of potassium, magnesium, and phosphorus, which can enhance the nutritional value of the product. These results are also consistent with Rahman *et al.* (2021) who found that the use of banana flour in bakery products increased ash content as an indicator of minerals. Therefore, substituting banana flour for cassava starch can improve the mineral profile of cookies while enhancing their functional potential.

3.4.3. Protein Content

The absence of significant differences in protein content among treatments can be attributed to the inherently low and relatively comparable protein levels of both cassava starch and janten banana flour. Cassava starch contains minimal protein (<1%), while banana flour, including the janten variety, typically contains only modest protein levels (approximately 3–4% on a dry basis). This difference is insufficient to cause a statistically significant change in total protein when substitution is applied. Moreover, eggs, which were used at a constant level in all formulations, represent the primary source of protein in the cookie system. Their dominant contribution likely masked the minor variations arising from flour substitution, resulting in statistically similar protein contents across treatments. This indicates that the ratio of cassava starch to banana flour did not significantly affect total protein content. Although cassava starch contains only a small amount of protein, the contribution from banana flour, eggs, and margarine in the formulation helped maintain stable protein levels. Aworh (2023) also reported that the substitution of local flours in cookies generally does not reduce total protein content. Protein plays an important role in nutritional contribution and in forming cookie texture through interactions with starch and fat.

3.4.4. Dietary Fiber

Although the dietary fiber content increased from 4.32% in F1 to 4.90% in F5, the increase was not gradual across all treatments. Statistical analysis showed that F1 and F2 were not significantly different, but both differed significantly from F3, F4, and F5, indicating a threshold effect in fiber contribution. At substitution levels up to 40%, the amount of banana flour was insufficient to produce a statistically detectable increase in dietary fiber, whereas higher substitution levels ($\geq 60\%$) resulted in a significant rise due to the substantially higher fiber content of banana flour compared to cassava starch, which is predominantly starch. According to Kamil *et al.* (2023), increasing dietary fiber from local flours can provide functional benefits, including lowering the glycemic index of bakery products. Mengstu *et al.* (2021), also reported that banana-based cookies contain significant levels of fiber, which are beneficial for digestive health. This increase in dietary fiber adds value to these cookies as a functional food.

3.4.5. Fat Content

The fat content of cookies showed a decreasing trend from 25.96% in F1 to 22.07% in F5. This reduction is attributed to the higher proportion of banana flour, which has a lower oil absorption capacity compared to cassava starch. [Waziroh *et al.* \(2023\)](#) reported that non-gluten materials with denser fiber structures tend to reduce fat retention in bakery products. This phenomenon is also supported by [Wibowo *et al.* \(2024\)](#) who emphasized that products with lower fat content are increasingly preferred as they are considered healthier. Thus, substituting banana flour can be a strategy to produce low-fat cookies without compromising quality.

3.4.6. Carbohydrates

The carbohydrate content of cookies ranged from 51.13–54.04%, with the highest value found in treatment F5 (100% banana flour). The carbohydrate content was not significantly different among treatments because both cassava starch and banana flour are predominantly composed of carbohydrates. Replacing cassava starch with banana flour therefore did not substantially change the total carbohydrate proportion in the formulation. In addition, carbohydrate content was determined by difference (100% minus moisture, ash, protein, and fat), and since these components showed only minor variations across treatments, the calculated carbohydrate values also remained statistically similar. Although the substitution increased the proportion of resistant starch, it altered carbohydrate quality rather than total carbohydrate quantity, resulting in no significant difference among treatments. This is attributed to the higher resistant starch content in banana flour compared to cassava starch, as unripe banana flour typically contains substantial amounts of resistant starch, whereas cassava starch is predominantly composed of digestible starch. Resistant starch is a fraction of complex carbohydrates that is not easily digested and therefore functions as soluble fiber with prebiotic effects ([Solihah & Wijaya, 2020](#)). [Moko *et al.* \(2024\)](#) further noted that complex carbohydrates from resistant starch can help regulate blood glucose, improve gut health, and enhance lipid metabolism. Thus, the increase in carbohydrate content, particularly from resistant starch, strengthens the functional value of these cookies as a healthy food product.

4. CONCLUSION

Research on the physical and chemical characteristics of cookies based on modified janten banana flour (*Musa paradisiaca* Linn.) with cassava starch substitution showed that the proportion of the two flours had a significant effect on product quality. In terms of physical properties, higher substitution of banana flour resulted in increased cookie hardness and a decrease in lightness (L^*) and whiteness index, while a^* and b^* values tended to increase, indicating a color shift toward brownish-yellow. Regarding chemical properties, banana flour substitution increased ash, dietary fiber, and carbohydrate contents (particularly resistant starch), but reduced fat levels, while protein content remained relatively stable across treatments. Overall, formulations with intermediate compositions (F3 and F4) provided a balance between texture, color, and nutritional profile, making them more acceptable to consumers. The substitution of modified janten banana flour not only enriched the nutritional value of cookies by increasing dietary fiber and mineral content, but also supported the diversification of local food based on Lampung's superior commodities. These findings demonstrate that modified janten banana flour can be utilized as an alternative raw material with added value for the development of healthy and functional cookies.

AUTHOR CONTRIBUTION STATEMENT

| Author | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
|--------|---|---|----|----|----|---|---|---|---|---|----|----|---|----|
| Zuk | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| WRH | | | ✓ | | | ✓ | ✓ | | ✓ | | | | | |
| Mar | ✓ | ✓ | ✓ | | | | | ✓ | | | | | | |
| FD | ✓ | | | | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |

| | | | |
|----------------------|---------------------|-------------------------------|---------------------------|
| C: Conceptualization | Fo: Formal Analysis | O: Writing - Original Draft | Fu: Funding Acquisition |
| M: Methodology | I: Investigation | E: Writing - Review & Editing | P: Project Administration |
| So: Software | D: Data Curation | Vi: Visualization | |
| Va: Validation | R: Resources | Su: Supervision | |

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