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INNOVATIVE USE OF BANANA PEEL FLOUR IN BROWNIES PRODUCTION: NUTRITIONAL AND SENSORY IMPACTS

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Abstract

This study examines the innovative application of banana peel flour as a partial substitute for wheat flour in brownie production, with a focus on its nutritional benefits and sensory impact. As banana peels are a commonly discarded agricultural by-product despite their rich composition of dietary fiber, antioxidants, and minerals, their transformation into flour presents a valuable approach to waste reduction and functional food development. The research involved formulating brownies with varying concentrations of banana peel flour at 10%, 25%, and 50%. Each formulation was evaluated based on proximate composition and sensory attributes, including color, aroma, taste, and texture. Results indicated that substitution levels of up to 25 percent improved nutritional value, particularly in terms of fiber and mineral content, without significantly compromising consumer acceptability. The 10 percent formulation achieved the highest scores across all sensory parameters, while the 50 percent formulation exhibited reduced palatability due to increased bitterness and changes in texture. These findings highlight the potential of banana peel flour as a sustainable and nutritious ingredient in baked products when used in optimal proportions.

Keywords: ***brownies, banana peel flour, dietary fiber, sensory evaluation, wheat flour substitution***

INTRODUCTION

Banana is one of the most widely produced tropical fruit commodities in Indonesia, with cultivation spread across various regions of the archipelago. As one of the world's largest banana-producing countries, Indonesia generates millions of tons of bananas annually (FAO, 2021; Kompas, 2024). With rising population growth and increasing public awareness of the health benefits of banana consumption, the accumulation of banana peel waste has become a growing concern. Often discarded or used as animal feed, banana peels are generally overlooked despite their significant potential as a source of functional food ingredients with high economic value. Recent studies have revealed that banana peels contain bioactive compounds that can be utilized in food formulations (Senevirathna & Karim, 2024). Banana peels exhibit promising nutritional and functional properties, including antioxidant activity and dietary fiber content, which make them valuable for the development of health-oriented food products (Mohd Zaini et al., 2022a).

Nutritionally, banana peels are rich in carbohydrates, proteins, dietary fiber, vitamins, minerals, and antioxidants, all of which offer health benefits for consumers. Their utilization is aligned with the principles of the circular economy, which emphasizes waste reduction and value creation from underutilized resources. Transforming organic waste into economically valuable food products is considered a strategic approach in advancing sustainable development. One of the emerging innovations in this context is the production of banana peel flour, a form that is more stable, storable, and versatile for incorporation into various food applications. (Saleh et al., 2025) reported that banana peel flour could be used as a partial substitute for wheat flour in cake production, offering a more nutritious and cost-effective ingredient. Such substitution not only reduces dependence on imported wheat flour but also enhances the nutritional quality of the final product. The high dietary fiber content of banana peels is particularly advantageous, resonating with the growing consumer trend toward fiber-rich diets that support digestive health and help prevent chronic diseases (Mohd Zaini et al., 2022b).

Brownies, as a popular baked product, are known for their dense yet tender texture, rich chocolate flavor, and broad appeal across age groups. Commonly enjoyed as a snack or dessert, brownies possess strong market potential and are widely produced at both household and industrial levels. A study by (Arifah & Sofyan, 2024) evaluated the chemical and sensory characteristics of brownies made with kepok banana peel flour, showing promising results in terms of consumer acceptance and nutritional enhancement. Their findings suggest that partial substitution of wheat flour with banana peel flour can be implemented up to a certain level without significantly compromising sensory quality.

While previous studies have highlighted the nutritional potential of banana peel flour and its application in various baked products, there remains limited exploration of its use specifically in brownies, a product with distinct texture and sensory expectations. Most research has focused on cakes or cookies, which differ in formulation and consumer perception. Moreover, the optimal substitution level of banana peel flour that balances nutritional enhancement with sensory acceptance in brownies has not been clearly established. This study addresses that gap by evaluating the effects of different substitution levels on the physical, chemical, and sensory characteristics of brownies. In doing so, it contributes to the broader effort of valorizing agricultural waste into functional food ingredients, supporting both dietary health and sustainable food innovation.

LITERATURE REVIEW

The utilization of banana peel flour in food products exemplifies a notable advancement in food science and sustainability. As the food industry progressively adopts circular economy principles, research into repurposing food waste such as banana peels into valuable functional ingredients has significantly expanded. Banana peels are nutrient-dense, rich in dietary fiber, carbohydrates, potassium, polyphenols, flavonoids, and other bioactive compounds. (Kumari et al., 2023) conducted a comprehensive review highlighting the phytochemical richness of Musa species and reported high antioxidant and antimicrobial activity in banana peels, positioning them as suitable for nutraceutical and functional food applications. Moreover, (Mahomud et al., 2024) formulated probiotic yogurt using banana peel extract demonstrates significant enhancement in nutritional value and antioxidant properties without compromising sensory acceptability.

Functional food

The conversion of banana peels into flour allows better stability and integration into bakery items. (Teshome et al., 2023*)* emphasized the water-holding and oil-binding capacities of banana peel flour, which are essential for maintaining texture in baked goods. Studies such as (Mabogo et al., 2021) these support the idea that partial substitution of wheat flour with banana peel flour in brownies can yield acceptable taste and texture profiles. (Zaky et al., 2024)In their review of dietary fiber integration in bakery products, they reported that such substitutions have a positive impact on glycemic control and overall fiber intake, a desirable attribute in modern diets.

Sensory Evaluation and Consumer Acceptance

Despite its nutritional merits, the sensory impact of BPF needs careful evaluation. (Alam et al., 2023) observed that BPF's slightly bitter taste and darker color can affect its appearance and flavor, limiting its inclusion to less than 10–20% in baked goods. However, (Kamil et al., 2023) the study showed that adjustments in sweeteners and fat content can balance flavor and texture, thereby improving acceptability. (de Medeiros et al., 2024) studied composite flours and found that fiber-rich flours, such as BPF, increased browning and moistness, which are favorable for a brownie texture. The utilization of banana peels is strongly aligned with sustainable food innovation. (Hashim et al., 2024) demonstrated the potential of banana peels in developing nutraceuticals, reducing organic waste, and lowering dependency on imported ingredients like wheat flour. This supports Indonesia’s food sovereignty and waste reduction goals. (Schappo et al., 2025) It was also highlighted that banana peel valorization is part of a broader trend toward the full utilization of fruit by-products in the food industry, consistent with global zero-waste ambitions.

METHOD

Material and ingredients

The ingredients used in the formulation of banana peel brownies included wheat flour, cocoa powder, baking powder, baking soda, banana peel flour, salt, eggs, granulated sugar, vanilla powder, and dark chocolate. These components were selected to replicate the standard characteristics of brownies while incorporating banana peel flour as a partial substitute for wheat flour, consistent with previous applications in functional bakery products (Mabogo

et al., 2021). The tools used in this study included a blender, oven, digital scale, electric mixer, baking pan, spatula, mixing bowls, and an 80-mesh sieve. These instruments were essential for ingredient preparation, mixing, baking, and evaluating product consistency, in accordance with general laboratory-scale food product development protocols (Gisslen, 2018). The research began with the preparation of banana peel flour. Fresh banana peels were first separated from the fruit, washed thoroughly, sliced into small pieces, and then dried at a low temperature to preserve their nutritional integrity. Once dried, the peels were finely ground using a blender and sieved through an 80-mesh screen to obtain a uniform flour texture suitable for baking applications. This method follows standard pre-processing techniques used in fruit by-product flour development, ensuring consistency in particle size and minimizing moisture content (Alam et al., 2023).

Brownies were prepared in four different formulations based on the proportion of banana peel flour used as a substitute for wheat flour: control (0%), 10% substitution, 25% substitution, and 50% substitution. All formulations followed a standardized mixing method. Eggs and granulated sugar were first whisked until light and foamy. Separately, margarine and dark chocolate were melted together. The dry ingredients, comprising wheat flour, banana peel flour (according to each formulation: 0%, 10%, 25%, and 50%), cocoa powder, baking powder, baking soda, and salt, were combined and mixed thoroughly. The wet and dry mixtures were then folded together to form a uniform batter. The batter was poured into a baking pan and baked at 180°C for 30 minutes.

Sensory Evaluation

A hedonic sensory test was conducted involving 20 untrained panelists to assess consumer preference for each formulation. Evaluation was performed using a five-point hedonic scale, where scores ranged from 1 (“strongly dislike”) to 5 (“strongly like”). Panelists were instructed to evaluate the brownies based on four sensory attributes: color, taste, aroma, and texture. The scoring scale is presented in Table 1.

Table 1. Hedonic test measurement

Numeric scale	Color	Taste	Aroma	Texture
5	Strongly like	Strongly like	Strongly like	Strongly like
4	Like	Like	Like	Like
3	Moderately like	Moderately like	Moderately like	Moderately like
2	Dislike	Dislike	Dislike	Dislike
1	Strongly dislike	Strongly dislike	Strongly dislike	Strongly dislike

Proximate and statistical analysis

A proximate analysis was conducted to determine the moisture content, crude protein, crude fat, crude fiber, nitrogen-free extract (NFE), and ash content of the brownies. All chemical analyses were carried out at the Feed Chemistry Laboratory, Faculty of Animal Science, Hasanuddin University, using standard AOAC methods. All quantitative data were analyzed using one-way analysis of variance (ANOVA) at a 5% significance level ($\alpha = 0.05$). Data processing was conducted using SPSS software version 22.0 to identify statistically significant differences among treatment group

RESULTS AND DISCUSSION

Table 2. Proximate Test Results

Measurement	Method	Unit	Result		
			10%	25%	50%
Moisture (water)	5.4/IK/2/2.19.1 (analyzed using thermogravimetric method)	%	21.97	24.15	22.49
Crude protein	SNI 01-2891-1992 point 7.1 5.4/IK/	%	8,29	6,49	7,65
Crude fat	Analyzed using Soxhlet extraction method	%	19,43	17,65	19,18
Crude fiber	2/2.44 (Enzymatic Gravimetry)	%	0,24	0,61	0,81
BETN	Calculated as the difference from 100% minus water, ash, protein, fat, and fiber	%	48,14	48,95	47,25
Total ash	01-2891-1992 point 6.1 SNI	%	1,92	2,15	2,62

Moisture Content

Moisture content is a critical indicator for determining both the shelf life and quality of food products. Elevated moisture levels increase water activity (Aw), which can promote microbial spoilage, thereby reducing product safety and quality (Patarata et al., 2022). In this study, the highest moisture content was observed in the 25% substitution formulation (24.15%), while the lowest was in the 10% formulation (21.97%). Despite the fluctuations, all formulations remained within the safe moisture range for baked goods, generally defined as below 30%. These variations may be attributed to the hygroscopic nature and differences in fiber content of the substituted ingredients (Winarno, 2004). A lower moisture level is beneficial as it prolongs shelf life and reduces the risk of microbial contamination (Wahyuni et al., 2023). This aligns with findings by (Lestari & Saputri, 2023), who reported that incorporating fibrous ingredients such as banana peel can reduce the moisture content in brownies.

Crude Protein

Crude protein content refers to the total nitrogen in the product, typically converted to protein using a standard factor (usually 6.25). Protein plays a vital role as a structural nutrient and is essential for maintaining texture and body in food products. Analysis results indicate that the highest protein content occurred in the 10% substitution sample (8.29%), followed by a decline at 25% (6.49%), and a subsequent increase at 50% (7.65%). These fluctuations suggest that the presence of banana peel as a plant-based protein source does not have a linear correlation with protein content. Other factors, such as interaction with wheat flour or changes in protein structure during baking, may also be involved. These findings are consistent with (Rahayu et al., 2023) who found that substituting banana stem flour significantly enhanced the protein content in brownies.

Crude Fat

Crude fat reflects the total lipid content extracted via organic solvents. Besides being a primary energy source, fats contribute to the sensory attributes of food, including flavor, texture, and softness. The fat content in this study remained relatively stable, with values of 19.43% (10%), 17.65% (25%), and 19.18% (50%). The decreasing trend with higher banana peel substitution is likely due to the naturally low lipid content in banana peel flour (Mohd Zaini et al., 2022b). This finding is consistent with observations by (Ahsan et al., 2025; Petka & Topolska, 2025), who noted that increasing substitution with low-fat materials results in a reduction in total fat content. Nutritionally, the fat levels observed remain within acceptable ranges, contributing to the development of healthier brownie formulations.

Crude Fiber

Dietary fiber plays a crucial role in maintaining digestive health and is associated with a reduced risk of chronic diseases, including diabetes and cardiovascular disorders. In this study, fiber content increased proportionally with the level of banana peel substitution: 0.24% (10%), 0.60% (25%), and 0.81% (50%). This trend confirms that banana peel contributes positively to the fiber profile of the final product. Although the fiber levels do not yet meet the criteria for high-fiber claims (≥6 g/100 g), the upward trend suggests the potential of this approach in developing functional foods. Similar results were reported by (Fu et al., 2022; Kumari et al., 2023)[author], who

demonstrated that banana peel flour enhances the fiber content in processed products. Increased fiber intake supports gut microbiota balance and better blood glucose regulation.

Ash Content

Ash content represents the total mineral concentration in food samples. The ash content increased with greater levels of banana peel flour: 1.92% (10%), 2.15% (25%), and 2.26% (50%). This indicates that banana peel contains considerable mineral quantities, particularly potassium and magnesium, both of which are essential for metabolic functions (Alshehri et al., 2024). These findings reinforce the potential of brownies made with banana peel flour as a supplementary source of dietary minerals. Similarly, reported higher ash content in brownies substituted with banana stem flour suggests an enhanced functional value.

Nitrogen-Free Extract (NFE or BETN)

Nitrogen-Free Extract (NFE) refers to digestible carbohydrates, such as starches and sugars, and is calculated by subtracting moisture, ash, protein, fat, and fiber from 100%. These carbohydrates are the primary sources of energy in food. The BETN values observed were highest in the 25% substitution group (48.95%), followed by the 10% group (48.14%), with a notable drop in the 50% group (47.25%). This significant reduction is likely due to the accumulation of fiber, ash, and moisture in the 50% formulation, which mathematically lowers the available carbohydrate portion. This trend aligns with findings by (Nafees et al., 2023), who noted that increased substitution with non-carbohydrate ingredients typically reduces BETN values due to a relative rise in protein, fiber, and mineral content.

Table 3. Hedonic test result

Formulation	Color	Taste	Aroma	Texture
Brownies (10% banana peel flour)	4,60	4,30	4,30	4,05
Brownies (25% banana peel flour)	4,55	4,10	3,95	4,05
Brownies (50% banana peel flour)	4,40	3,10	3,80	3,85

Color

The sensory evaluation results revealed that the highest color score was recorded in the formulation containing 10% banana peel flour (4.60), followed by 25% (4.55), with the lowest observed at 50% (4.40). The decreasing trend corresponds with the inherently darker color of banana peel flour, which intensifies as its concentration increases, resulting in a darker final product. This darkening effect is attributed to the presence of phenolic compounds and the Maillard reaction during baking. These findings are in agreement with the study by (Mildner-Szkudlarz et al., 2023), which noted that incorporating banana peel flour into bakery products altered the color and influenced consumer acceptance.

Taste

Taste evaluation demonstrated a significant decline in scores at higher substitution levels, particularly at 50%, which received the lowest rating (3.10). This drop is likely due to the elevated presence of tannins and phenolic compounds in banana peels, which are known to impart bitterness or astringency. In contrast, the 10% formulation received the highest taste score (4.30), remaining within the "liked" category. These results align with (Bakke & Vickers, 2011),who observed that substituting more than 25% banana peel flour tends to reduce taste acceptability due to the increased bioactive compound content. The decline in palatability at higher concentrations may also be caused by a disruption in dough balance, masking the characteristic sweetness of traditional brownies (Sayas-Barberá et al., 2023). Likewise, it is cautioned that although antioxidant compounds in banana peel offer health benefits, excessive use can detract from the overall flavor profile (Mohd Zaini et al., 2022b).

Aroma

Aroma scores declined gradually with increased banana peel flour concentration, from 4.30 at 10% to 3.80 at 50%. Despite this decline, the aroma was still deemed acceptable by panelists across all formulations. The change in aroma is likely attributed to the intensification of the natural scent of banana peel, which may be unfamiliar to some consumers. Incorporating high-fiber fruit waste materials altered the aroma characteristics of bakery products (Ahmad et al., 2022). Notably, at the 25% level, although a slight drop in aroma score was observed, the formulation remained within the "liked" category. While color (4.55) and texture (4.05) remained relatively stable at this level, slight declines in aroma (3.95) and taste (4.10) were observed, potentially due to the influence of bioactive compounds, such as tannins and phenolics, which begin to manifest at medium concentrations.

Texture

Texture evaluation remained consistent for the 10% and 25% formulations (both 4.05) but showed a modest decline at 50% (3.85). The reduction is attributed to the higher fiber content at elevated substitution levels, which results in a denser, coarser texture. The additional fiber from banana peel flour likely absorbs more moisture, affecting the softness and mouthfeel of the product. (Aydogdu et al., 2018) highlighted that the inclusion of high-fiber ingredients in baked goods influences crumb structure and elasticity. (Zaini et al., 2023) also noted that the lignocellulosic structure of banana peel is not readily degradable during baking, which may contribute to rougher textures and unfamiliar aroma profiles in products with high substitution levels. Based on the sensory evaluation of brownies formulated with varying concentrations of banana peel flour (10%, 25%, and 50%), it can be concluded that banana peel flour significantly influences the sensory quality of the product, particularly in taste, aroma, and texture. The 10% substitution yielded the highest scores across nearly all attributes: color (4.60), taste (4.30), aroma (4.30), and texture (4.05). This suggests that at low concentrations, banana peel flour can be effectively integrated as a functional food ingredient without negatively affecting the sensory characteristics of brownies. Furthermore, this formulation retained the visual appeal and familiar flavor that consumers expect.

At 25% substitution, a slight decline in sensory scores was observed across all parameters; however, the values remained within an acceptable range (color: 4.55, taste: 4.10, aroma: 3.95, texture: 4.05), indicating that the product is still well-received. This concentration may offer a viable compromise between enhanced nutritional properties, such as increased fiber and antioxidants, and sensory quality. Conversely, at 50% substitution, significant declines were recorded, especially in taste (3.10), along with reductions in aroma (3.80) and texture (3.85). These findings suggest that higher concentrations of banana peel flour negatively impact the sensory appeal of brownies, likely due to the bitterness caused by phenolic and tannin compounds, as well as the denser texture resulting from increased fiber content. Although the darker color was less of a concern, it may still influence initial consumer perception. The optimal concentration of banana peel flour for brownie production ranges from 10% to 25%. Within this range, nutritional value particularly dietary fiber content can be improved without compromising consumer acceptance. A 50% substitution is not recommended due to its adverse effects on key sensory attributes such as taste and texture. These findings are consistent with prior studies (Dana & Sonia, 2024; Mendis et al., 2025; Mohd Zaini et al., 2022b), which emphasize that while banana peel flour contributes to food sustainability and nutritional enhancement, its use in bakery formulations should be carefully moderated to preserve overall product quality.

CONCLUSION

Based on the findings presented in the introduction, literature review, methodology, and discussion, it can be concluded that incorporating banana peel flour into brownie formulations offers a promising strategy to enhance the nutritional quality of baked products while supporting sustainable food innovation. The study demonstrated that banana peel flour contributes beneficial dietary components, such as fiber, minerals, and antioxidants, without substantially compromising sensory attributes when used in moderate concentrations. Specifically, substitution levels of 10% to 25% were found to maintain acceptable levels of moisture, protein, and fat content, while improving dietary fiber and mineral content. Sensory evaluation further confirmed that brownies containing up to 25% BPF were still well-received by panelists in terms of color, taste, aroma, and texture. However, a 50% substitution level resulted in noticeable declines in taste and texture acceptability, likely due to the increased presence of bitter phenolic compounds and the higher fiber content, which altered the product's structural and sensory profile. These findings imply that banana peel flour has significant potential as a functional food ingredient in bakery products, especially in regions with high banana production and abundant agricultural waste. Its application not only supports the valorization of organic by-products but also aligns with the principles of circular economy and food system sustainability. The use of BPF can reduce reliance on refined wheat flour, enhance the nutritional composition of

popular snack items, and promote consumer awareness regarding waste-based food innovations. For small- to medium-scale food producers, this represents a cost-effective and eco-conscious alternative that can help differentiate products in a competitive market. Future studies should investigate additional processing methods, such as fermentation, enzymatic treatment, or micronization, to mitigate the bitterness associated with higher concentrations of banana peel flour, thereby enhancing palatability. Moreover, investigating the effects of BPF on shelf life, glycemic response, and consumer preference across broader demographic groups would provide a more comprehensive understanding of its market potential. Scaling up the formulation for industrial applications, coupled with life cycle assessments and economic feasibility studies, is also recommended to evaluate the commercial viability of banana peel flour-based products in diverse food sectors.

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