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Substitution of Mangrove Flour as a Food Functional Ingredient in Cookies

Tinda Yuvita[1], Oktaf Rina[1*], Nurbani Kalsum[1]
[1]Politeknik Negeri Lampung
Jl. Soekarno Hatta No.10, Rajabasa, Bandar Lampung 35144, Lampung, Indonesia
*Corresponding Email: oktafrina@polinela.ac.id

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ABSTRACT

Functional foods are increasingly becoming a focus in the development of food products that meet basic nutritional needs and provide additional health benefits. One food ingredient with the potential to become a source of functional food is mangrove flour, produced from the fruit of mangrove trees in coastal areas. Mangroves contain fiber, antioxidants, and bioactive compounds that can improve the nutritional quality of food products. Mangrove flour possesses significant potential to enhance the nutritional value of cookies, a popular bakery product, without compromising their sensory quality. This study aimed to evaluate the effect of mangrove flour substitution in cookie formulations. Variations in mangrove flour substitution were carried out at levels of 10%, 20%, 30%, 40%, and 50% and were tested based on color, taste, aroma, texture, and overall acceptability. The results showed that mangrove flour substitution had a significant impact on consumer preference, with the average score at 20% substitution for color, taste, and aroma. However, at higher substitutions, a decrease in preference was observed, especially for aroma and texture. Overall acceptability also decreased at substitutions exceeding 30%. These findings demonstrate the importance of balancing mangrove flour formulation in cookies to maintain optimal sensory quality

Keywords: Mangrove Flour Substitution; Cookies; Sensory; Preference; Functional Food

INTRODUCTION

Functional foods are food commodities that not only provide essential macro- and micronutrients but also contain bioactive components with physiological health benefits, such as dietary fiber, antioxidants, vitamins, and certain minerals that can help prevent the risk of degenerative diseases and support the body's metabolic function (Dixit et al., 2023). The global trend towards functional foods is increasing in line with changing consumption patterns, with people becoming more health-conscious and seeking food products that not only satisfy their appetite but also improve their quality of life (Zarzycki et al., 2024). In the context of bakery products, pastries such as cookies are an ideal medium for functional nutrient enrichment due to their high popularity and processing that allows the addition of alternative ingredients rich in bioactives without compromising the product's basic sensory properties. Indonesia has significant potential for local food diversification based on superior local resources rich in bioactive compounds, including mangrove fruit, which is processed into mangrove fruit flour. Several studies have shown that mangrove fruit contains carbohydrates, fiber, minerals, and bioactive compounds that have the potential to be used as functional food ingredients if processed using appropriate methods to reduce anti-nutrient components such as tannin and HCN (Titisari et al., 2023). The use of mangrove flour in processed food formulations is seen as a strategy to enrich the nutritional profile of local products while increasing the added value of coastal natural resources that have been underutilized as a basis for functional foods.

Research on the use of mangrove flour specifically in bakery products has shown promising results in increasing the nutritional content and functional value of products. For example, a cookie formulation based on mangrove flour showed changes in sensory and chemical characteristics, where the substitution of mangrove flour impacted the fiber content, texture, and color of the final product (Simamora et al., 2024). Furthermore, another study utilizing a combination of mangrove flour and other local ingredients, such as soy flour, also successfully produced an improved nutritional profile, including increased energy, protein, and essential minerals compared to a control product based on pure wheat flour (Afifah et al., 2021). This suggests that substitution of mangrove flour can increase the content of functional compounds and support the diversification of bakery products that do not rely solely on wheat flour. Considering consumer demand for food products that not only meet basic nutritional needs but also offer additional health benefits, substituting mangrove flour as a functional ingredient in cookies has the potential to provide added economic and health value while minimizing dependence on imported raw materials such as wheat flour. The integration of mangrove flour in cookie formulation is expected to address local food security issues, provide locally based functional food alternatives, and support healthy food product innovation efforts that suit today's consumer preferences (Basyuni et al., 2025). This study aims to evaluate the impact of mangrove flour substitution on cookie formulation, manufacturing process, and sensory characteristics as a basis for recommendations for effective and safe functional food formulations.

LITERATURE REVIEW

Mangroves

Mangroves, plants found in tropical coastal areas, have great potential as a food source rich in nutrients and bioactive compounds. Mangroves, particularly the *Bruguiera gymnorrhiza* species, have long been known for their ability to survive in environments with high salinity levels. In addition to their ecological benefits, mangroves also have potential as a functional food ingredient. Mangrove fruit contains bioactive compounds, such as flavonoids, tannins, and phenolics,

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which have antioxidant activity and may play a role in preventing degenerative diseases. Their high fiber content also makes them an ideal ingredient for enriching food products to support a healthy diet (Botosoa & Shahidi, 2026). However, despite their rich benefits, the use of mangrove fruit as a food ingredient remains limited. Most research focuses on the extraction of bioactive compounds, while their application in food products remains to be developed. Therefore, utilizing mangroves in the form of flour is a strategic step to overcome the limitations of mangrove utilization in the food industry while providing an alternative, environmentally friendly local raw material (Rudianto et al., 2022).

Mangrove Flour

Mangrove flour, produced by processing mangrove fruit into flour, has various potential applications in the food industry. One of the advantages of mangrove flour is its high fiber content, which can help meet dietary fiber needs in the daily diet. Research by Afifah et al. (2021) shows that mangrove flour can be used as a partial substitute for wheat flour in bakery products, providing additional nutritional benefits without compromising the product's sensory quality. Furthermore, proper processing of mangrove flour, such as proper drying and milling, is crucial for maintaining nutritional stability and reducing anti-nutritional components such as tannins and HCN. Several studies have also shown that mangrove flour has potential for use in various other processed food products. In a study conducted by Simamora et al. (2024), substituting mangrove flour in cookies increased fiber and antioxidant content, making it a healthier functional food ingredient. Therefore, mangrove flour can be an attractive alternative raw material for functional food products.

Cookies

Cookies are a popular food product due to their ease of consumption and the variety of flavors they offer. Cookies can be categorized as a processed food product made from a mixture of flour, fat, sugar, and other additives, baked to a crispy or soft texture, depending on the dough formulation used. The diversity of raw materials used in cookie production offers the potential to create healthier products by enhancing nutritional content, for example through the use of high-fiber flour or other functional ingredients (Papagianni et al., 2021). Cookie development aims not only to create delicious flavors but also to improve nutritional value and enhance product functionality. In recent years, cookie products have begun to be developed by adding ingredients that can increase nutritional value, such as flour rich in fiber, protein, and bioactive compounds that can provide health benefits. The cookie manufacturing process focuses on a balance between texture and flavor, which requires precise adjustment of ingredient proportions to ensure the final product remains acceptable to consumers.

Functional Foods

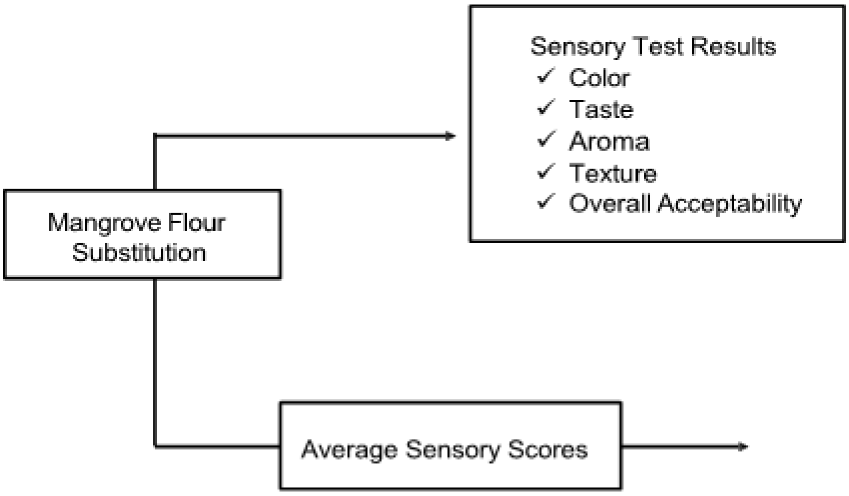
Functional foods are foods that, in addition to meeting basic nutritional needs, also provide specific health benefits that can prevent or reduce the risk of disease. Functional foods can contain a variety of components, such as fiber, vitamins, minerals, antioxidants, or other bioactive compounds that have positive effects on health (Vlaicu et al., 2023). The application of the functional food concept to processed products, including cookies, aims to transform everyday consumption products into resources that can help improve consumers' quality of life (Lainawa et al., 2025). For example, numerous studies have shown that bakery products like cookies can be enriched with various functional food ingredients, such as fiber-rich flour or ingredients containing antioxidants, which can help prevent cardiovascular disease, diabetes, and digestive disorders. According to research by Fu et al. (2022), adding functional ingredients to cookies can contribute to increasing daily fiber intake and improving gut microbiota balance, which is associated with digestion and longterm health. Cookies enriched with dietary fiber, for example, can help improve digestive function and reduce the risk of chronic digestive diseases. In addition to fiber, bioactive components such as flavonoids, polyphenols, and omega-3 fatty acids are also widely used in the development of functional food products. These ingredients can help reduce oxidative stress in the body and support the immune system (Mondal et al., 2021). Therefore, cookies as a popular product among consumers have great potential to be developed as functional foods that not only provide delicious taste but also sustainable health benefits (Tunde et al., 2026).

Research Hypothesis

Mangrove flour substitution in cookie formulation can affect consumer acceptance of the final product.

Conceptual Framework

The conceptual framework can be seen in Figure 1**.**



RESEARCH METHOD

The research was conducted at the THP Laboratory and the Pastry Laboratory of the Politeknik Negeri Lampung from November 2025 to April 2026. The equipment used in this study were an analytical balance, a mixer, bowl, spoon, baking pan, and an oven. The main ingredient used is mangrove flour, tapioca flour, coconut milk, eggs, granulated sugar, palm sugar, margarine, baking soda, and salt. This study was a single factor study arranged using a Completely Randomized Block Design with 3 replications. The factor studied was the level substitution of mangrove flour which consisted of 5 evels, namely 10% (P1), 20% (P2), 30% (P3), 40% (P4), and 50% (P5). The data obtained was then analyzed to obtain an average. The resulting cookies were then subjected to sensory testing including color, aroma, taste, texture, and overall acceptance. The sensory test in the form of a hedonic test or preference test is one type of acceptance test, in this test, 25 panelists were asked to express responses regarding likes or dislikes. In addition, the panelists also stated scores by conducting a scoring test. These levels of liking are referred to as a hedonic scale of 1-5, namely very dislike (1), dislike (2), somewhat like (3), like (4), and very like (5). The Hedonic Scale can be stretched according to the desired scale. The hedonic scale is transformed into a numeric scale with ascending numbers according to the level of liking. With this hedonic scale, the test can indirectly be used to determine differences (Rahayu et al., 2019)

RESULTS

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The research results of mangrove flour cookies that have been made in 5 treatments were tested for acceptance through hedonic sensory analysis on 25 panelists regarding color, aroma, taste, texture and overall acceptability. The average data of the sensory test results can be seen in Table 1 and the tabulation of the sensory test results is presented in Table 2.

Table 1. Average Data of Sensory Test Results

Parameters	**Repetition**	**our Substitution (%)**				
		10	**20**	**30**	**40**	**50**
Color	1	3.64	3.92	3.40	3.24	3.16
	2	4.12	4.32	3.88	3.48	3.12
	3	3.84	4.00	3.52	3.56	3.12
	Average	3.87	4.08	3.60	3.43	3.13
Taste						
	1	3.64	3.92	3.28	3.00	3.16
	2	4.12	4.32	3.68	3.28	3.08
	3	3.68	3.80	3.28	3.12	2.92
	Average	3.81	4.01	3.41	3.13	3.05
Aroma						
	1	3.84	3.92	3.00	2.84	3.04
	2	4.20	4.16	3.84	3.32	3.04
	3	3.96	4.12	3.64	3.16	2.96
	Average	4.00	4.07	3.49	3.11	3.01
Texture						
	1	3.76	3.80	3.52	3.40	3.36
	2	4.16	4.20	3.88	3.64	3.56
	3	3.84	3.88	3.48	3.48	3.12
	Average	3.92	3.96	3.63	3.51	3.35
Overall acceptance						
	1	4.08	4.24	3.60	3.20	3.08
	2	4.04	4.16	3.92	3.72	3.36
	3	4.00	4.12	3.92	3.80	3.40
	Average	4.04	4.17	3.81	3.57	3.28

Source: Primary data processed, Researcher (2026)

Table 2. Tabulation of Sensory Test Results Data

Mangrove Flour Substitution (%)	**Color**	**Taste**	**Aroma**	**Texture**	**Overall acceptance**
10	3.87	3.81	4.00	3.92	4.04
20	4.08	4.01	4.07	3.96	4.17
30	3.60	3.41	3.49	3.63	3.81
40	3.43	3.13	3.11	3.51	3.57
50	3.13	3.05	3.01	3.35	3.28

Source: Primary data processed, Researcher (2026)

DISCUSSION

Color

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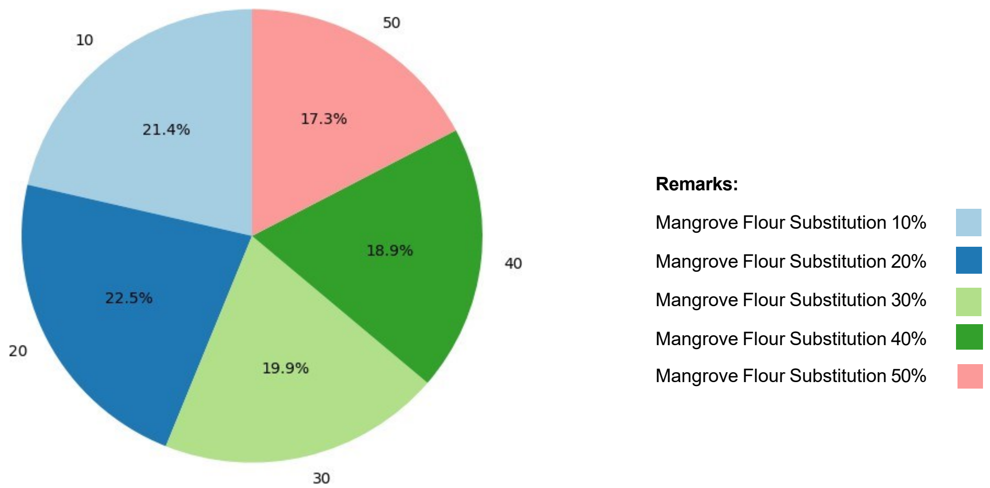
Color is a crucial factor in consumer acceptance of food products, especially processed products like cookies. In this study, substitution of mangrove flour in cookies showed clear variations in color preference. Based on the data obtained, a 10% mangrove flour substitution resulted in the highest average color preference score, at 3.87, which was still considered acceptable by panelists. However, as the mangrove flour substitution increased (20%, 30%, 40%, and 50%), color preference scores tended to decrease, with the average color score at 50% substitution recorded at only 3.13. This indicates that although mangrove flour substitution provides color variation in cookies, higher proportions lead to decreased color preference (Anggraeni et al., 2025; Maesaroh et al., 2026). Sensory test data showed that 10% and 20% mangrove flour substitutions still produced cookies with colors more acceptable to consumers, with average scores of 3.87 and 4.08, respectively. However, when the mangrove flour substitution increased above 30% (Figure 2), consumers began to assign lower values, suggesting that consumers may prefer cookies with a lighter, more uniform color.

Figure 2. Comparison of Color Preferences in Mangrove Flour-Substituted Cookies



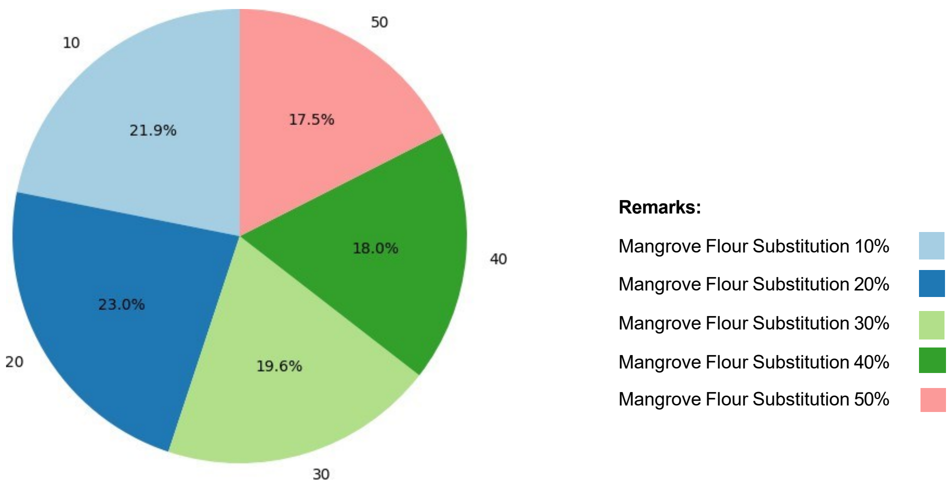
Source: Data Processed by Researcher (2026)

The decrease in color scores in cookies with higher mangrove flour substitution is likely due to the darker natural color characteristics of mangrove flour. When mangrove flour is used in higher quantities, the natural pigments in the flour interact with other ingredients during baking, causing the cookies to darken. This aligns with previous research showing that wheat flour substitutes often alter product color, and higher flour substitutions lead to increased darkness (Wang & Jian, 2022). Furthermore, the baking process also plays a role in changing cookie color, with Maillard reactions and caramelization occurring at high temperatures. The decrease in color preference scores with higher substitutions may be an important consideration in the development of mangrove flour-based cookie products. As a functional food ingredient, it is important to find a balance between health benefits and consumer preferences.

Taste

Taste is one of the key attributes influencing consumer acceptance of food products, including cookies. Based on the data obtained, mangrove flour substitution significantly varied cookie taste preferences. At 10% substitution, cookies received the highest average taste score of 3.81, indicating that panelists preferred the taste of cookies at this low substitution level. However, as mangrove flour substitution increased, taste scores began to decline, with 50% substitution producing the lowest average taste score of 3.05. This suggests that although mangrove flour substitution provides functional benefits, consumers tend to prefer more familiar flavors and are less influenced by the stronger or more distinctive flavors of substitutes (Afifah et al., 2021). Overall, 10% and 20% mangrove flour substitutions produced acceptable cookie flavors, with average scores of 3.81 and 4.01, respectively, indicating that consumers are still accepting the taste of cookies with low substitution levels. However, at higher substitution levels (30%, 40%, and 50%), consumers began to give lower scores, indicating that the taste of cookies with higher mangrove flour content was less preferred (Figure 3). This highlights the importance of making formulation adjustments to enhance the taste of cookies with mangrove flour without sacrificing the desired functional benefits.

Figure 3. Comparison of Taste Preferences in Mangrove Flour-Substituted Cookies



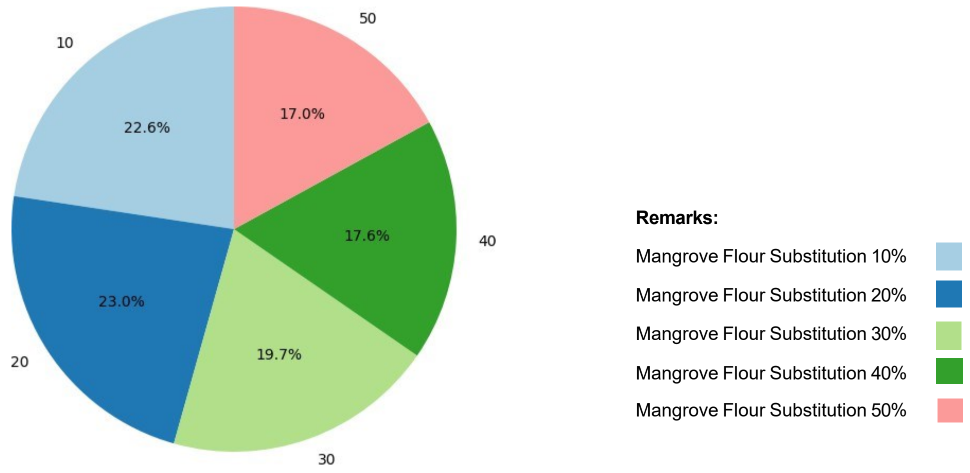
Source: Data Processed by Researcher (2026)

The decrease in taste preference for cookies with higher mangrove flour substitution may be due to the natural taste of mangrove flour, which tends to be more bitter or has a flavor profile that does not align with the expectations of consumers accustomed to wheat flour-based cookies. Previous research has shown that substituting flour with local or alternative ingredients often results in acceptable taste differences for consumers if the proportion of the substitute ingredient is not too dominant (Muhammad et al., 2022). Therefore, it is important to find a balance in dough formulation to minimize flavor changes that could reduce consumer preference.

Aroma

Aroma is one of the main sensory factors that significantly influences consumer decisions when assessing the quality of food products such as cookies, as aroma is directly linked to taste perception and comfort when consuming food. Research on food aroma chemistry indicates that aroma is formed from various volatile compounds produced during processing, including baking, which influence the sensory image of the final product and are closely correlated with consumer acceptance. Aroma compounds such as aldehydes, esters, and ketones are dominant components in cookie aroma and can vary depending on the raw materials and processing methods used (Hasanah et al., 2025). Based on aroma sensory test data for cookies with mangrove flour substitution, it can be seen that the highest average aroma scores occurred at 10% and 20% substitution, namely 4.00 and 4.07, respectively. This indicates that the addition of mangrove flour at low levels still produces an aroma that is acceptable and even preferred by panelists. However, at higher substitutions (30%, 40%, and 50%), the aroma score continued to decrease to 3.01 at 50% substitution (Figure 4). This decrease can be explained by the increasing contribution of the stronger or less familiar aroma of mangrove flour to the panelists' sense of smell, thus decreasing their aroma preference a common phenomenon when alternative raw materials affect the release of volatile compounds in cookies (Mardiyanto et al., 2024).

Figure 4. Comparison of Aroma Preferences in Mangrove Flour-Substituted Cookies



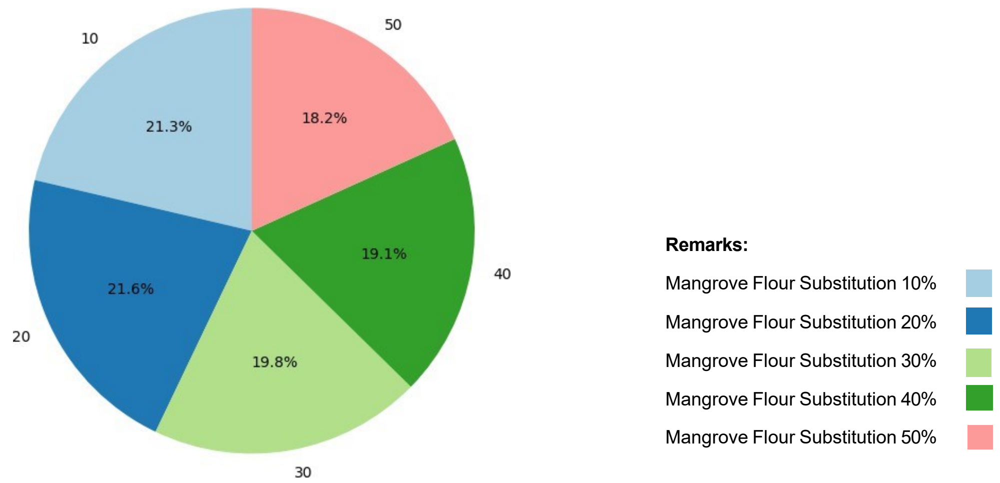
Source: Data Processed by Researcher (2026)

Research on various ingredient-substituted cookie studies shows a similar pattern: alternative flour substitution often affects the aroma profile of the final product, where the initial aroma remains acceptable at low concentrations but can become stronger and less desirable at higher concentrations. In the study of okara flour-substituted cookies, for example, the distinctive aroma of the substituted ingredient significantly impacted panelists' aroma ratings, demonstrating the importance of the aroma content of the raw material in determining the final sensory quality.

Texture

Texture is an important sensory attribute in evaluating bakery products such as cookies because it affects the sensations experienced when chewing, such as crunchiness or softness. Based on the data obtained, texture preference for cookies with mangrove flour substitution also showed a decreasing trend as the proportion of substitution increased. The highest average texture scores were achieved at 10% substitution (3.92) and 20% (3.96), while at 30%, 40%, and 50% substitutions, the scores decreased to 3.63. 3.51; and 3.35, respectively (Figure 5). This indicates that the greater the amount of mangrove flour in the dough, the texture sensation perceived by the panelists tends to be less preferred or does not match the expectations of the ideal cookie texture (crispy or crunchy). This decreasing pattern aligns with the findings of studies examining the effect of alternative flour substitutions on cookie texture. For example, substitution of high-tannin peanut flour increased hardness and altered the texture structure of cookies, thus affecting panelists' sensory perception of texture, even though the formulation improved the product's nutritional value. These studies indicate that substitution of ingredients with different characteristics than wheat flour (such as higher protein or fiber content) can alter dough structure and the final texture of cookies. Research on local flour substitutions, such as modified purple sweet potato flour, also demonstrates a relationship between substitution levels and cookie texture preferences: the higher the substitution, the more the texture structure changes (e.g., becoming crispier or softer) compared to control cookies, and this affects panelists' assessment of overall texture sensation (Khamassi et al., 2025). Based on these results, the data indicate that substitution of mangrove flour at low levels can still produce a texture relatively close to the desired cookie characteristics, but at higher levels the texture structure begins to change, making it less sensorially acceptable.

Figure 5. Comparison of Texture Preferences in Mangrove Flour-Substituted Cookies

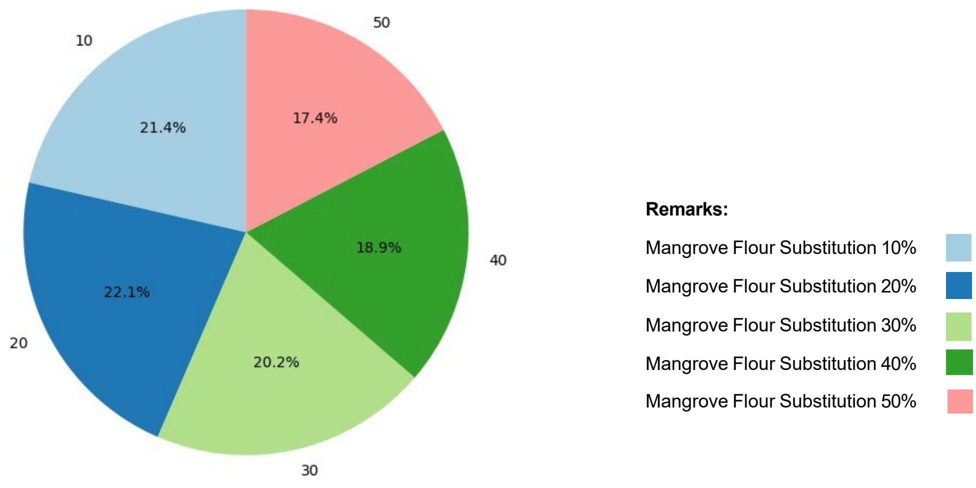


Source: Data Processed by Researcher (2026)

Overall Acceptance

Overall acceptance in sensory testing is an important indicator that reflects how panelists evaluate a product as a whole based on a combination of attributes such as color, taste, aroma, and texture. Based on the data obtained, cookies with low levels of mangrove flour substitution (10% and 20%) had the highest average overall acceptance scores, at 4.04 and 4.17. This indicates that panelists tended to prefer cookies with a balanced combination of sensory attributes at these substitution proportions. However, when the substitution increased to 30%, 40%, and 50%, the overall acceptance scores decreased to 3.81; 3.57; and 3.28, respectively (Figure 6).

Figure 6. Comparison of Overall Acceptance Preferences in Mangrove Flour Substituted Cookies



Source: Data Processed by Researcher (2026)

This decrease reflects that cumulative changes in sensory attributes, particularly aroma, taste, and texture, began to influence panelists' overall preference. This aligns with other research findings showing that alternative flour substitutions in cookies can affect panelists' overall acceptance when sensory attributes change significantly due to differences in ingredient composition (Kumalasari, 2024). Previous research on the overall acceptability of cookies based on almond flour and sweet corn flour showed a similar pattern, where panelists' overall preference fluctuated with variations in the substitute flour formulation. In that study, hedonic testing of cookies made with various flour blends demonstrated that ingredient variations can significantly impact consumers' overall assessments, particularly when sensory attributes such as taste, aroma, and texture did not align with consumer expectations for conventional cookies. The results showed that overall acceptability scores ranged from dislike to like, depending on the composition of the alternative flour used (Purnamasari et al., 2022), supporting the findings of this study that a decrease in overall panelist acceptance occurred at higher levels of mangrove flour substitution.

Findings from other studies have also shown similar dynamics in organoleptic testing of cookies using local alternative flours such as pumpkin flour, where increasing the proportion of substitute ingredients gradually decreased sensory scores, including for overall parameters. In that study, panelists gave higher scores to moderate wheat flour substitute formulations than to higher ones, demonstrating the importance of formulation balance to maintain the sensory quality expected by consumers. The data from this study reflect the same result: mangrove flour substitution at 10% and 20% still resulted in higher overall scores, while substitution above 30% tended to decrease panelists' overall preference for the cookies. Overall, the results of this study indicate that mangrove flour substitution can affect the overall acceptability of cookie products, especially when accumulative sensory changes are perceived by panelists. Significant changes in dough composition at high substitution levels have the potential to produce cookies that differ sensorially from the control cookies, thus affecting the overall assessment. The optimal formulation for functional cookies made from mangrove flour is likely at substitution levels below 30%, where panelists still provide an overall positive response.

CONCLUSION

Based on the average value of sensory tests covering color, taste, aroma, texture, and overall acceptance, it can be concluded that mangrove flour substitution has a significant impact on the characteristics of cookies. Mangrove flour substitution at 10% and 20% levels resulted in cookie colors that were still acceptable to consumers, with the highest average score at 20% substitution. However, at substitutions exceeding 30%, color preference scores began to decline, indicating that increasing the proportion of mangrove flour resulted in darker cookies, which impacted the visual assessment of the product. For the taste attribute, mangrove flour substitution scored the highest at 20%, indicating that the taste of cookies with low substitutions was still well-received by panelists. However, at higher substitutions (30%, 40%, and 50%), a decrease in taste scores was evident, indicating that the more dominant mangrove flour flavor may be less in line with consumer preferences for cookies. The average aroma score went down by 50% when more than 30% of the flour was replaced with mangrove flour. The same was true for cookie texture, which tended to become harder and less crispy with higher mangrove flour substitution, with the lowest average texture score at 50%. This decrease implies that higher levels of mangrove flour substitution can influence sensory characteristics like aroma and texture. Overall cookie acceptability showed the highest score at 20% substitution, indicating that panelists preferred cookies with moderate levels of mangrove flour substitution. Overall acceptability decreased with

substitutions exceeding 30%, reflecting a decrease in consumer preference for cookies with higher mangrove flour content, which may impact the overall sensory quality of the product. Overall, mangrove flour substitution can improve the functional content of cookies. However, consumers may not accept the product's color, taste, aroma, and texture if substitution levels are excessively high. Therefore, the optimal formulation for mangrove flour-based cookies is likely at a substitution level below 30%, which allows for functional benefits without sacrificing the sensory qualities desired by consumers.

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DECLARATION OF CONFLICTING INTERESTS
The authors hereby declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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ABOUT THE AUTHOR(S)

1st Author
Tinda Yuvita is a student in the Applied Master's Program in Food Security, Politeknik Negeri Lampung, Bandar Lampung, INDONESIA.

2nd Author
Oktaf Rina is a lecturer of the Applied Master's Program in Food Security, Politeknik Negeri Lampung, Bandar Lampung, INDONESIA. ORCID ID is https://orcid.org/0000-0001-7479-4198.
Email: oktafrina@polinela.ac.id.

3rd Author
Nurbani Kalsum is a lecturer of the Applied Master's Program in Food Security, Politeknik Negeri Lampung, Bandar Lampung, INDONESIA.