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Penja Fish Flour Cookies: Nutritional Composition and Sensory Acceptability as a Local Food-Based Intervention for Child Undernutrition

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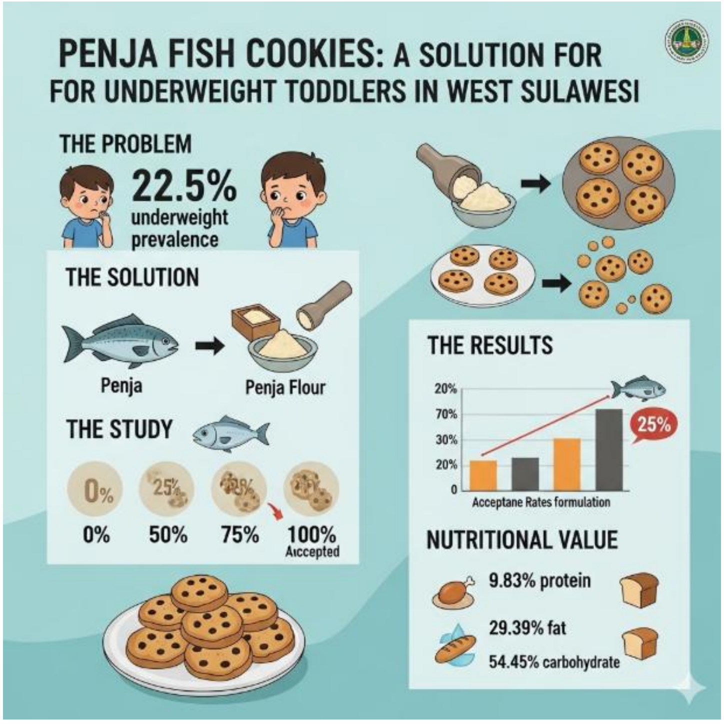
ABSTRACT

Penja fish, a local food with higher protein content than anchovies, offers potential as a supplementary food for addressing child undernutrition. However, its traditional use remains limited to salting and direct consumption. Processing *penja* fish into flour for cookies provides a sustainable, innovative strategy to diversify intake and mitigate seasonal supply challenges. This experimental study, employing a post-test only control group design, was conducted between September and November 2024 at Universitas Hasanuddin and Universitas Muslim Indonesia. Cookie formulations were developed with varying substitution levels of *penja* fish flour (0%, 25%, 50%, 75%, and 100%). Nutritional composition was assessed using proximate analysis, and acceptability was evaluated through hedonic testing with 25 semi-trained panelists and 5 expert panelists, who rated color, aroma, taste, and texture. Significant differences ($p < 0.05$) were found across formulations for color, aroma, taste, and texture, with the 25% substitution (Formula B) showing the highest preference (overall acceptance 62.5%). Overall acceptance declined with increasing levels of fish flour. Formula B was selected for proximate analysis, showing 9.83% protein, 29.39% fat, 54.45% carbohydrate, 2.04% ash, and 5.30% moisture. This composition contributes approximately 20% of the recommended protein and 12% of the energy requirements for toddlers aged 1–3 years, based on WHO/FAO (2007) recommendations, indicating its potential for supplementary feeding programs. These results demonstrate that fortifying cookies with *penja* fish flour enhances nutritional value while maintaining acceptable sensory qualities at moderate substitution levels. Formula B therefore represents an optimal balance between nutrition and acceptability and has practical application in addressing underweight among toddlers.

Key Messages:

- Cookies fortified with 25% *penja* fish flour offer a sustainable, acceptable, and nutritionally appropriate supplementary food to help address underweight among toddlers in West Sulawesi.

GRAPHICAL ABSTRACT



INTRODUCTION

Undernutrition and severe malnutrition continue to represent significant global health challenges, particularly in low- and middle-income countries. According to the World Health Organization (WHO), an estimated 45.4 million children under the age of five worldwide are undernourished, with 13.6 million classified as experiencing severe wasting. In Indonesia, findings from the 2024 Indonesian Nutrition Status Survey (in Indonesia: Survei Status Gizi Indonesia (SSGI)) indicated an underweight prevalence of 16.8% among children under five (1,2), reflecting an increase from 16.3% reported in 2019. Children with severe malnutrition are at a substantially higher risk of mortality, estimated at 5 to 20 times, compared to their well-nourished peers (3). Despite extensive efforts by the government and multiple stakeholders, addressing undernutrition remains complex, compounded by challenges such as limited food accessibility, high prevalence of infectious diseases, inadequate childcare practices, and insufficient healthcare services.

West Sulawesi Province continues to report an underweight prevalence among children that exceeds the national average. Data show a decline from 24.8% in 2017 to 22.5% in 2022, and 21.9% in 2024 (1,2), suggesting some progress attributable to nutrition-focused interventions, yet persistent intra-provincial disparities remain evident. West Sulawesi is endowed with rich marine biodiversity, including *penja* fish (family *Gobiidae*), a small, translucent fish traditionally consumed either fresh or salted. However, its broader nutritional utility remains underexploited (4). Prior analyses have demonstrated that *penja* fish provides high concentrations of protein, calcium, and iron (5), with its protein quality classified under Category II and its carbohydrate and fat contents classified under Category I according to the Indonesian National Standard (in Indonesia: Standar Nasional Indonesia (SNI)) (Jayadi & Rahman). Furthermore, *penja* fish flour contains 54.19–56.6% protein, 8.4–9.72% fat, and 19.13–20.89% carbohydrates per 100 grams, surpassing the protein content typically found in anchovies (5).

Protein is essential for tissue growth, maintenance, and immune system function (6). Animal-source foods, particularly fish, are recognized as excellent providers of high-quality protein (7). Addressing undernutrition among toddlers necessitates the provision of supplementary foods that are dense in energy and protein. The Indonesian government's Supplementary Feeding Program (In Indonesia: Program Makanan Tambahan (PMT)) aims to improve the nutritional status of underweight children through the distribution of specially formulated biscuits (PMT-P), which can be enhanced with locally available,

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nutrient-rich ingredients (8). Given its nutritional profile and availability, *penja* fish represents a sustainable and innovative option for the development of supplementary foods.

The abundant availability of *penja* fish in the waters of West Sulawesi positions it as a promising and sustainable raw material, particularly as it is a locally caught resource that has not yet been widely utilized in the form of nutrient-dense processed foods. While the nutritional potential of *penja* fish has been recognized, its incorporation into a sensorially acceptable and stable supplementary food for children has not been previously evaluated. Addressing this gap is critical to ensure both nutritional adequacy and acceptability for real-world feeding programs. Therefore, the objective of this study was to analyze the nutritional composition and sensory acceptability of cookies formulated with *penja* fish flour as a supplementary food for undernourished toddlers.

METHODS

This study used an experimental food product design (formulation and organoleptic testing), conducted between September and November 2024. The production of *penja* fish flour was carried out at the Product Development Laboratory, Faculty of Agriculture, Hasanuddin University, while the cookie formulation was developed at the Nutrition Laboratory, Faculty of Public Health, Muslim University of Indonesia. The proximate analysis of the cookie samples was conducted at the Food Technology Laboratory, Faculty of Agriculture, Hasanuddin University.

The main raw material utilized in this study was fresh *penja* fish, sourced from local fishermen groups in Polewali Mandar Regency, West Sulawesi. Additional ingredients included wheat flour, *penja* fish flour, cornstarch, powdered sugar, margarine, baking powder, cinnamon powder, vanilla, salt, chicken eggs, and full-cream milk. The equipment used for cookie production included a 60-mesh sieve, strainer, spatula, baking trays, cookie molds, measuring spoons, digital scales, pastry brushes, mixers, and ovens. For the proximate analyses, equipment used included tongs, distillation units, pipettes, burettes, desiccators, ovens, analytical balances (Sartorius), porcelain crucibles, muffle furnaces, petri dishes, filter papers, water baths, and standard glassware (fat flasks, volumetric flasks, measuring cylinders, beakers, Kjeldahl flasks, and Erlenmeyer flasks), as well as a Hach spectrophotometer.

The study consisted of three stages: formulation, sensory evaluation, and nutritional composition analysis of the *penja* fish-based cookies. The formulation stage involved five levels of *penja* fish flour substitution: 0%, 25%, 50%, 75%, and 100%. Following the formulation, the acceptance of the cookies was evaluated through sensory testing.

The sensory evaluation involved 25 semi-trained panelists and 5 expert panelists, who assessed four attributes: color, taste, texture, and aroma. Semi-trained panelists were undergraduate nutrition students who had received basic orientation on sensory evaluation, while expert panelists were lecturers with professional experience in food product development and sensory testing. Sensory evaluation was conducted using a scoring test method, applying a five-point hedonic scale where panelists rated each attribute based on their level of preference: 5 (like very much), 4 (like), 3 (slightly like), 2 (dislike), and 1 (dislike very much), with 1 representing the lowest and 5 representing the highest level of acceptance. Informed consent was obtained from all participants (both semi-trained and expert panelists) prior to their involvement in the sensory evaluation.

Proximate analyses were carried out to measure the moisture, ash, protein, fat, carbohydrate, and energy content of the chosen cookies (the most preferable). Moisture was determined by oven drying at 105 °C, ash by combustion in a muffle furnace at 550 °C, protein by the Kjeldahl method, and fat by Soxhlet extraction. Carbohydrate content was calculated by difference, and energy was estimated using Atwater factors. Data were analyzed using descriptive statistics for nutrient composition and sensory scores. Differences between cookie sensory acceptances were tested with the Kruskal–Wallis test followed by the Mann–Whitney test if significant ($p < 0.05$). All analyses were performed using SPSS software for Windows.

RESULTS

Sensory Evaluation

Organoleptic testing is one of the methods employed to evaluate consumer acceptance. The assessment

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was carried out using a hedonic quality test involving 25 semi-trained panelists and 5 trained or expert panelists. he evaluation focused on aroma, color, taste, and texture preferences, and the results are presented in Table 1.

Table 1. Distribution of Panelists' Preference Levels for Color, Aroma, Taste, and Texture of Cookies Fortified with *Penja* Fish Flour

Atribute/ Formula	*Penja* Fish Flour (%)	Strongly Dislike (n (%))	Dislike (n (%))	Neutral (n (%))	Like (n (%))	Strongly Like (n (%))	Total (n (%))	Mode
Color								
A	0	0 (0.0)	0 (0.0)	2 (6.7)	8 (33.3)	20 (66.7)	30 (100)	5ᵃ
B	25	1 (3.3)	1 (3.3)	5 (16.7)	13 (43.3)	10 (33.3)	30 (100)	4ᵃ
C	50	1 (3.3)	10 (33.3)	7 (23.3)	11 (36.7)	1 (3.3)	30 (100)	4ᵇ
D	75	1 (3.3)	15 (50.0)	8 (26.7)	6 (20.0)	0 (0.0)	30 (100)	2ᵇ
E	100	10 (33.3)	10 (33.3)	6 (20.0)	4 (13.3)	0 (0.0)	30 (100)	2ᶜ
Aroma								
A	0	0 (0.0)	0 (0.0)	3 (10.0)	13 (43.3)	14 (46.7)	30 (100)	5ᵃ
B	25	0 (0.0)	4 (13.3)	12 (40.0)	8 (26.7)	0 (0.0)	30 (100)	3ᵇ
C	50	3 (10.0)	9 (30.0)	12 (40.0)	6 (20.0)	0 (0.0)	30 (100)	3ᶜ
D	75	2 (6.7)	17 (56.7)	7 (23.3)	3 (10.0)	1 (3.3)	30 (100)	2ᶜ
E	100	11 (36.7)	9 (30.0)	5 (16.7)	5 (16.7)	0 (0.0)	30 (100)	1ᵈ
Taste								
A	0	0 (0.0)	0 (0.0)	3 (10.0)	8 (26.7)	19 (63.3)	30 (100)	5ᵃ
B	25	0 (0.0)	5 (16.7)	8 (26.7)	9 (30.0)	8 (26.7)	30 (100)	4ᵇ
C	50	8 (26.7)	12 (40.0)	7 (23.3)	2 (6.7)	1 (3.3)	30 (100)	2ᶜ
D	75	9 (30.0)	17 (56.7)	1 (3.3)	3 (10.0)	0 (0.0)	30 (100)	2ᶜ
E	100	20 (66.7)	7 (23.3)	2 (6.7)	1 (3.3)	0 (0.0)	30 (100)	1ᵈ
Texture								
A	0	0 (0.0)	0 (0.0)	3 (10.0)	8 (26.7)	19 (63.3)	30 (100)	5ᵃ
B	25	0 (0.0)	0 (0.0)	9 (30.0)	8 (26.7)	13 (43.3)	30 (100)	5ᵃ
C	50	3 (10.0)	3 (10.0)	13 (43.3)	6 (20.0)	5 (16.7)	30 (100)	3ᵇ
D	75	2 (6.7)	7 (23.3)	11 (36.7)	7 (23.3)	3 (10.0)	30 (100)	3ᵇ
E	100	8 (26.7)	8 (26.7)	6 (20.0)	6 (20.0)	2 (6.7)	30 (100)	1ᵇ

Note: A = 0% *penja* fish flour, B = 25% *penja* fish flour, C = 50% *penja* fish flour, D = 75% *penja* fish flour, and E = 100% *penja* fish flour; Different superscript letters (a, b, c, d) indicate significant differences within each sensory attribute group (α = 0.05).

Table 1 presents the distribution of panelists' preference scores for the color, aroma, taste, and texture of cookies fortified with varying levels of *penja* fish flour (0%–100%). The sensory evaluation revealed that fortification level had a significant impact on all assessed attributes ($p < 0.05$).

In terms of color, the control sample (Formula A, 0% *penja* fish flour) was the most favored, with 66.7% of panelists rating it as "strongly like" and a mode score of 5, reflecting high visual appeal. Formula B (25%) also maintained good acceptance (mode = 4; mean = 3.93), though the proportion of panelists indicating "like" or "strongly like" declined by approximately 17% compared to Formula A. However, further increases in fish flour concentration, particularly in Formulas D (75%) and E (100%), resulted in a marked decrease in color preference, with acceptance rates falling to 20.0% and 13.3%, respectively, compared to 93.3% in the control.

A similar trend was observed for aroma. The control sample achieved the highest scores, with 90% of panelists indicating "like" or "strongly like" and a mode of 5. The mean score (4.37) further emphasized its high acceptability. In contrast, the inclusion of 25% fish flour (Formula B) already reduced aroma preference (mode = 3; mean = 3.27**)** with positive ratings dropping by nearly half (46.7%) compared to the control. At 100% substitution (Formula E), aroma acceptability was particularly low, with 36.7% of panelists expressing "strongly dislike" and only 16.7% providing positive ratings, representing an 81% decline relative to the control sample.

Preference patterns for taste followed a similar progressive decline. The control cookies (Formula A) were the most preferred, with 63.3% of panelists selecting "strongly like" and an overall positive acceptance rate of 90.0% (mode = 5; mean = 4.53). A moderate reduction was observed at 25% substitution (Formula B), where positive responses declined to 56.7%, representing a 33% reduction compared to the control. At higher levels (Formulas C–E), acceptability dropped sharply, with only 3.3% of panelists positively rating the 100% substitution cookies (Formula E), indicating a 96% decrease in taste acceptance compared to the control.

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Regarding texture, fortification up to 25% (Formulas A and B) did not adversely affect preferences, both retaining a mode of 5 (means = 4.53 and 4.43), with 90.0% and 70.0% positive responses, respectively. However, increasing fish flour content to 50% or more reduced textural liking, with positive acceptance falling to 36.7% (Formula C) and as low as 26.7% at 100% substitution (Formula E). The reduction in texture acceptability may be attributed to increased protein and fat content, which altered mouthfeel and structural integrity.

Overall, the inclusion of both mode and mean values, along with quantified acceptance rates, provides a more precise interpretation of the sensory results. These findings indicate that while *penja* fish flour can be successfully incorporated into cookies up to 25% without significantly compromising sensory quality, higher substitution levels substantially reduce acceptability across all evaluated attributes.

Table 2. Overall Sensory Acceptance of Cookies Fortified with Various Levels of *Penja* Fish Flour

Attribute	Formula A (n (%))	Formula B (n (%))	Formula C (n (%))	Formula D (n (%))	Formula E (n (%))
Color	28 (93.3)	23 (76.7)	12 (40.0)	6 (20.0)	4 (13.3)
Aroma	27 (90.0)	14 (46.7)	6 (20.0)	4 (13.3)	5 (16.7)
Taste	27 (90.0)	17 (56.7)	3 (10.0)	3 (10.0)	1 (3.3)
Texture	27 (90.0)	21 (70)	11 (36.7)	10 (33.3)	8 (26.7)
Overall Acceptance	27 (90.83)	19 (62.5)	8 (26.7)	6 (19.17)	5 (15.0)

Note: A = 0% *penja* fish flour, B = 25% *penja* fish flour, C = 50% *penja* fish flour, D = 75% *penja* fish flour, and E = 100% *penja* fish flour

The overall sensory acceptance of cookies fortified with varying levels of *penja* fish flour is presented in Table 2. In general, panelists' acceptance decreased as the concentration of fish flour increased across all attributes, including color, aroma, taste, texture, and overall acceptance.

Formula A (0% *penja* fish flour) consistently achieved the highest acceptance scores, with 93.3% for color, 90.0% for aroma, 90.0% for taste, and 90.0% for texture, resulting in an overall acceptance rate of 90.83%. Formula B (25% substitution) still demonstrated relatively good acceptance, particularly for color (76.7%) and texture (70.0%), although a decline was observed compared to the control. Specifically, overall acceptance decreased from 90.83% (Formula A) to 62.5% (Formula B), representing a reduction of approximately 31%.

At higher substitution levels, acceptance rates declined markedly. For Formula C (50% substitution), overall acceptance fell to 26.7%, which is a 70% reduction compared to the control. A further decline was evident in Formula D (75%), with overall acceptance of 19.17%, and Formula E (100%) showed the lowest acceptance rate of only 15.0%, an 83% decrease relative to the control.

Attribute-specific declines were also notable. For example, color acceptance dropped from 93.3% in Formula A to 40.0% in Formula C and just 13.3% in Formula E. Similarly, taste acceptance decreased from 90.0% in the control to 10.0% in Formula C and only 3.3% in Formula E, indicating a 96% reduction in positive taste ratings. Aroma acceptance was even more sensitive to substitution, with positive ratings falling from 90.0% in the control to 46.7% in Formula B and just 16.7% in Formula E, representing an 81% decline compared to the control.

These results clearly demonstrate that while low-level substitution (up to 25%) of *penja* fish flour can maintain acceptable sensory qualities, higher levels substantially compromise consumer acceptance. The quantified declines across attributes highlight that fortification above 25% leads to significant reductions in preference, with the most pronounced decreases observed in aroma and taste.

Nutritional Composition

The proximate analysis of the most preferred cookie formulation (Formula B, 25% *penja* fish flour) is presented in Table 3, alongside the Indonesian National Standard (SNI 01-2973-1992) requirements for cookies.

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Table 3. Nutritional Composition of Cookies Fortified with *Penja* Fish Flour Compared to SNI 01-2973-1992 Standards

Nutrient	*Penja* Fish Flour Substituted Cookies (%)[a)]	SNI Standard for Cookies (%)[b)]
Protein	9.83	Min. 9
Fat	29.39	Min. 9.5
Carbohydrate	54.45	Min. 7
Ash	2.04	Maks. 1.5
Moisture	5.30	Maks. 5

Note: [a)] Primary data source, 2024; [b)] Indonesian National Standard (SNI) 01-2973-1992 for cookies (9).

The results indicate that the fortified cookies achieved a protein content of 9.83%, which exceeds the SNI minimum requirement of 9%, thereby demonstrating the protein-enriching effect of *penja* fish flour. The fat content was 29.39%, more than three times higher than the minimum SNI standard (9.5%), suggesting that the formulation resulted in a substantially higher fat concentration, which may contribute positively to energy density but could also raise concerns about excessive fat content relative to standards.

Carbohydrate content was 54.45%, well above the minimum requirement of 7%, indicating sufficient carbohydrate presence to provide energy. In contrast, the ash content (2.04%) exceeded the SNI maximum limit of 1.5% by approximately 36%, reflecting the elevated mineral contribution from *penja* fish flour. Similarly, the moisture content (5.30%) slightly surpassed the SNI limit of 5%, by about 6%, which could have implications for texture and shelf-life stability.

Overall, these findings confirm that the incorporation of *penja* fish flour at a 25% substitution level successfully enhances the protein and mineral profile of cookies, making them nutritionally superior to the standard. However, adjustments in fat and moisture levels may be required to better align with SNI thresholds and ensure compliance with quality standards.

DISCUSSION

Sensory Acceptability of Cookies Fortified with *Penja* Fish Flour

Sensory acceptance is a key indicator of consumer preference, representing an individual's like or dislike for a food product, evaluated through organoleptic testing using the five senses. The sensory attributes—such as color, aroma, taste, and texture—are critical in influencing consumer acceptance and are therefore central to the development of new food products (10). In the current study, the color of cookies was found to be least favored in Formula E (33.3%), whereas Formula B, which contained 25% *penja* fish flour, emerged as the most preferred formulation (33.3%). The Kruskal-Wallis test demonstrated a significant impact of *penja* fish flour substitution on the color of the cookies ($p=0.000$). A discernible trend emerged, where increasing the concentration of *penja* fish flour led to a shift in the cookie color from a golden yellow to a darker brown. This change is likely due to the natural brown hue of *penja* fish flour. Statistical analysis confirmed that the various formulations, with differing levels of fish flour incorporation, led to significant differences in cookie color.

Hedonic testing revealed a clear inverse relationship between the proportion of *penja* fish flour and panelists' preferences. As the amount of fish flour increased, the cookies exhibited a more pronounced fish aroma, which became increasingly less acceptable to the panelists. The Kruskal-Wallis test again highlighted the significant effect of fish flour substitution on the aroma of the cookies ($p=0.000$). This finding aligns with previous studies on anchovy- and catfish-fortified baked goods, which also reported decreased aroma acceptance as fish flour levels increased (11). Similarly, Tilapia flour fortification in bread was found to intensify fishy odors that reduced consumer liking (12). These comparisons suggest that the decline in aroma preference is not unique to *penja* fish flour but reflects a broader sensory challenge common to fish-based fortification.

Taste is another fundamental sensory attribute that significantly influences food choice and is often the primary determinant in consumer selection. Individual taste perceptions, however, can vary widely (13). In this study, the taste of the cookies was shaped by a combination of ingredients, including wheat flour, *penja* fish flour, cornstarch, butter, sugar, eggs, and milk. The results indicated that as the

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proportion of *penja* fish flour increased, panelists' preference for the taste of the cookies decreased. The cookies formulated with 25% *penja* fish flour (Formula B) were the most favored, with 30% of panelists expressing a liking and 26.7% rating them as "strongly liked." Panelists were not accustomed to cookies with a dominant fish flavor, which may explain the lower preference for the higher fish flour formulations. Similar outcomes have been documented in studies fortifying snacks and baked products with snakehead and anchovy flour, where high substitution levels led to bitter or fishy aftertastes that reduced consumer acceptability (14).

Taste is another fundamental sensory attribute that significantly influences food choice and is often the primary determinant in consumer selection. Individual taste perceptions, however, can vary widely (13). In this study, the taste of the cookies was shaped by a combination of ingredients, including wheat flour, *penja* fish flour, cornstarch, butter, sugar, eggs, and milk. The results indicated that as the proportion of *penja* fish flour increased, panelists' preference for the taste of the cookies decreased. The cookies formulated with 25% *penja* fish flour (Formula B) were the most favored, with 30% of panelists expressing a liking and 26.7% rating them as "strongly liked." Panelists were not accustomed to cookies with a dominant fish flavor, which may explain the lower preference for the higher fish flour formulations. Despite the nutritional benefits of fish, such as its high protein content, fish-flavored cookies are not widely available in the market, which could contribute to the unfamiliarity with this taste.

The perception of taste in food is influenced by several factors, including chemical compounds, temperature, and interactions with other flavor components (15). The addition of *penja* fish flour resulted in a pronounced salty and bitter flavor profile, with a distinct fishy aftertaste that contributed to the lower acceptability of Formula E. The bitterness is likely due to the hydrolysis of amino acids, particularly lysine, during the processing of the *penja* fish flour and cookie preparation. Lysine, known for its bitter taste, may have contributed to the undesirable aftertaste. The strong salty flavor observed in the cookies can be attributed to the drying process of the *penja* fish, which retains its inherent saltiness even after multiple washings. The Kruskal-Wallis test confirmed that the substitution of *penja* fish flour had a significant effect on the taste of the cookies (p=0.000).

Texture is another critical factor influencing sensory acceptance, as it encompasses mechanical properties (such as hardness and chewiness), geometric characteristics (such as grittiness), and mouthfeel (such as oiliness or moistness). In this study, the control cookies (Formula A), which did not contain any *penja* fish flour, had the most preferred texture. This preference is likely due to the gluten content in the wheat flour used in the control formulation, which imparts a chewy and elastic texture to the cookies. In contrast, *penja* fish flour lacks gluten, and increasing its proportion negatively impacted the texture of the cookies. The study revealed a significant effect of *penja* fish flour substitution on the texture of the cookies (p=0.000), aligning with previous research, which also showed that increasing the proportion of fish flour leads to a decrease in panelists' acceptance of the product's texture. Comparable findings have been observed in cookies fortified with anchovy and catfish flour, where higher substitution levels reduced crispness and overall textural appeal (16,17). Interestingly, no significant difference in texture preference was observed between Formula A and Formula B, suggesting that a 25% substitution of *penja* fish flour did not adversely affect the panelists' texture preferences. These results are consistent with earlier studies indicating that moderate concentrations of fish flour do not significantly impact the sensory texture of baked goods.

Taken together, these comparisons indicate that the sensory challenges encountered in *penja* fish flour fortification are consistent with those reported for other fish flours. The decline in color, aroma, taste, and texture acceptance at higher substitution levels reflects a common pattern across fish species, reinforcing the importance of identifying an optimal substitution level—in this case, 25%—to balance nutrition with consumer acceptability. These findings strongly support the potential of *penja* fish flour as a locally sourced ingredient for supplementary foods, provided optimal incorporation levels are maintained to ensure consumer acceptance. This strengthens its positioning as a viable local food-based intervention for addressing child undernutrition in West Sulawesi.

Nutritional Value of Cookies Fortified with *Penja* Fish Flour

The nutritional value of a food product is highly susceptible to changes during processing,

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including before, during, and after food preparation. Typically, nutrient degradation occurs gradually during processing, such as protein denaturation. However, the cooking process also enhances the aroma and taste of the food product. According to Winarno (1992), the loss of nutritional value during cooking depends on the temperature and duration of the heating process. Three main reactions contribute to nutrient loss during heating: (1) oxidation of fatty acids, (2) denaturation of proteins, leading to altered amino acid bonds and impaired absorption, and (3) the Maillard reaction, a chemical interaction between reducing sugars and amino groups.

The proximate analysis of the selected cookies in this study showed that the protein content met the SNI (Indonesian National Standard) for cookies. The protein content in the cookies is largely attributed to the use of eggs, though their relatively small amount in the dough had a minimal impact on the overall protein levels. Additionally, the baking process can lead to protein loss. Protein denaturation typically occurs at temperatures between 60°C and 80°C, which is consistent with the baking temperature of approximately 150°C for 20 minutes. The dry heat during baking accelerates moisture loss and may cause the breakdown of essential proteins. Specifically, protein loss is more significant in the outer layer of the cookies, especially in thicker layers. Additionally, the thinness of the cookies allows heat to penetrate quickly from the surface to the inside, exacerbating protein degradation (18).

Fat plays a critical role in providing flavor and giving cookies a soft texture. It also serves as a source of energy, offering more calories than carbohydrates or protein. The laboratory analysis revealed that the fat content of the selected cookies was 29.39%, which met the SNI standard for cookies, which requires a minimum fat content of 9.5%. The high fat content in these cookies is likely due to the margarine and butter used in the formulation, which act as shortenings to enhance flavor and texture (19). While this elevated fat content is beneficial for increasing caloric density in undernourished toddlers, it also underscores the importance of careful portion control to prevent excessive intake, or further research into formulations that optimize macronutrient ratios while retaining palatability.

Carbohydrates are a crucial source of energy and contribute to the taste, texture, and color of food. The chemical analysis of the cookies indicated that the carbohydrate content was 54.45%. This high carbohydrate level is primarily due to the wheat flour and sugar added to the dough, which are the main contributors of carbohydrates. While carbohydrates provide energy, they are not the only energy source, as fats can also serve as an alternative. It is important to note that the digestibility of starch and resistant starch affects the availability of glucose from carbohydrates in the body (20). Despite the presence of fats, carbohydrates are still essential for providing energy, particularly for brain and nerve function, which rely on glucose as their primary energy source (21).

The ash content of the cookies, which reflects the mineral content, was found to be 2.04%. This value exceeds the SNI standard, which limits ash content to a maximum of 1.5%. The elevated ash levels, while indicating a rich mineral profile, also raise practical concerns related to product quality. Excessive ash can affect sensory properties and suggest the need for refinement in formulation.

Moisture content is another critical characteristic of food, as it affects the appearance, texture, and flavor of the product. The moisture content in the selected cookies was found to be 5.30%, which exceeds the maximum allowable limit of 5% according to the SNI standard for cookies. It is suggested that an optimal moisture content range of 3-7% helps maintain product stability, reducing the risk of microbial growth and chemical reactions, such as browning, lipid oxidation, or hydrolysis. The high moisture content in these cookies may be linked to the protein content, as proteins have hydrophilic groups that absorb water, particularly those with carboxyl groups. The addition of *penja* fish flour, which increases the protein content in the cookies, likely contributes to the higher moisture retention (22). The elevated ash and moisture content, while suggesting improved mineral contributions and enhanced texture, may negatively impact shelf stability and increase susceptibility to microbial growth. Future research should therefore investigate controlled drying methods or the incorporation of humectants to align these parameters more closely with SNI standards and extend product shelf life.

From a nutritional standpoint, Formula B (25% substitution) provides a promising balance between acceptability and nutrient contribution. Based on proximate analysis, one 30 g serving of Formula B cookies could contribute approximately 3.5–4 g of protein, equivalent to about 20% of the Recommended

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Nutrient Intake (RNI) for toddlers aged 1–3 years (23). In addition, the fat content of a serving provides 8–9 g of fat, contributing around 15–18% of toddlers' daily fat needs. The elevated ash content also suggests a meaningful contribution to mineral intake, particularly calcium and phosphorus. These values highlight the potential of *penja* fish flour cookies to serve as a supplementary food that can help close nutrient gaps in young children.

This study underscores that incorporating *penja* fish flour in cookies enhances their nutritional value, particularly in terms of protein, fat, and mineral content, while maintaining acceptable sensory quality at moderate substitution levels. However, the baking process and the specific ingredients used in the formulation also influence texture, ash, and moisture levels, which may affect shelf stability and long-term consumer acceptance. Future product development should therefore focus on optimizing flavor masking strategies, improving moisture control, and quantifying micronutrient contributions, to better position *penja* fish flour cookies as a viable local food-based supplementary intervention for child undernutrition.

CONCLUSION

This study analyzed the nutritional composition and sensory acceptability of cookies fortified with *penja* fish flour for undernourished toddlers. Results showed that a 25% substitution level provided the best balance between enhanced nutritional value and acceptable sensory qualities (color, taste, aroma, and texture). The inclusion of *penja* fish flour significantly improved the nutritional profile, with Formula B containing 9.83% protein and 2.04% ash content, thereby contributing essential protein and minerals that are suitable for addressing nutritional deficiencies in toddlers. In contrast, higher substitution levels (≥50%) significantly reduced acceptability due to the dominant fish flavor. These findings highlight the potential of *penja* fish flour cookies as a locally based supplementary food to help combat undernutrition among children.

Future research priorities should be structured into immediate and longer-term steps. Immediate efforts should explore flavor-masking strategies, controlled drying techniques, and adjustments in formulation to improve sensory acceptance and align with SNI standards. Longer-term studies are needed to assess nutrient bioavailability, evaluate the impact on child growth outcomes, and investigate storage stability and scalability for community-level interventions.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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