JPPIPA 12(2) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Enhancing Nutritional Education Through the Development of Toddler Biscuits: A Focus on Mung Bean Flour and Patin Fish Paste as Effective Nutritional Interventions Against Malnutrition

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Received: November 26, 2025
Revised: January 23, 2026
Accepted: February 25, 2026
Published: February 28, 2026

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DOI: 10.29303/jppipa.v12i2.13381

Abstract: This study aims to formulate toddler biscuits from mung bean flour and patin fish paste and to analyze their sensory quality, proximate content, amino acid profile, and fatty acid profile. Biscuits were prepared with varying ratios of mung bean flour and patin fish paste (10:90 to 90:10). Sensory quality tests were conducted using a hedonic scale scoring method with 30 trained panelists. The best formulation was selected using the De-Garmo test. Proximate analysis, amino acid profile, and fatty acid profile were performed on the best formulation and compared with standard toddler PMT biscuits. The KHIP5050 formulation (50% mung bean flour: 50% patin fish paste) was determined to be the best treatment based on the highest total De-Garmo score (3.33). Nutritionally, KHIP5050 biscuits had higher energy (479.45 kcal), protein (16.81%), and fat (27.77%) compared to standard PMT biscuits. The fatty acid profile was superior, with higher levels of MUFA and PUFA, and the presence of EPA, DHA, and AA, which were not detected in the standard biscuits. Toddler biscuits based on mung bean flour and patin fish paste, especially the KHIP5050 formulation, have significant potential as a nutrient-dense food product to address malnutrition in toddlers.

Keywords: Biscuit; Mung Bean Flour; Patin Fish Paste; Stunting; Wasting

Introduction

Wasting and stunting are interconnected nutritional issues that worsen one another. Children who suffer from wasting and do not receive appropriate care have a threefold higher risk of developing stunting. The likelihood of mortality rises when a child faces both nutritional challenges (wasting and stunting) at the same time (Thurstans et al., 2022; UNICEF, 2023). Providing proper nutrition in the form of nutrient-dense, tasty foods is one strategy to combat wastage. A ready-to-eat dish that can be created with regional ingredients to solve nutritional issues is toddler biscuits (UNICEF Indonesia, 2022), and several studies have been conducted, namely research on toddler biscuit products made from green beans, cereals and vegetable oil. The results obtained show that they have the potential to be used as toddler biscuit products, seen from the ash content, protein, fat, carbohydrates, energy, dietary fiber, iron, calcium, protein digestibility and water activity (Novia et al., 2022). Research on other toddler biscuits using corn flour, whole soybeans and milk protein concentrate has shown potential effectiveness in treating malnutrition (Saeid Hadi, Reza Amani, Mostafa Mazaheri Tehrani, Vahid Hadi, Sudiyeh Hejri, 2022). The use of local toddler biscuits in the community has the same specifications as standard toddler biscuits (UNICEF, 2021).

The catfish (Pangasius hypopthalmus) is one of the fish widely cultivated in South Kalimantan. It is a freshwater fish species of the Pangasidae family and has a high protein content (16.01%)(Ayu et al., 2020), Apart from that, catfish fat also contains unsaturated fatty acids, namely Mono Unsaturated Fatty Acid (MUFA)

How to Cite:
Sajiman, S., & Dewi, Z. (2026). Enhancing Nutritional Education Through the Development of Toddler Biscuits: A Focus on Mung Bean Flour and Patin Fish Paste as Effective Nutritional Interventions Against Malnutrition. *Jurnal Penelitian Pendidikan IPA*, *12*(2), 777–791. https://doi.org/10.29303/jppipa.v12i2.13381

and Poly Unsaturated Fatty Acid (PUFA) (Pandiangan, 2021). Mung beans (Vigna radiata) are very rich in protein, containing around 20.97–31.32% protein content (Yi-Shen et al., 2018). Mung beans also contain fatty acids, namely palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid (F. Wang et al., 2021). Mung beans also contain minerals, namely phosphorus, calcium, zinc, iron and copper (Zafar et al., 2023).

The urgency of this research is based on the potential of combining mung bean flour and patin fish paste to create a processed product to prevent wasting, one of which is in toddlers. To measure the benefits of this product, research is needed to examine the effect of consuming processed mung bean flour and patin fish paste products on sensory and chemical parameters related to wasting in toddlers.

Method

The study used a post-test-only control group design to examine the efficacy of altering toddler cookies prepared with catfish paste and mung bean flour in avoiding childhood wasting. The making of mung bean flour refers to the research procedure carried out by Isyanti (Isyanti, 2021) as follows: first, the mung beans are washed with clean water, drained, and dried using an oven for 3 hours at a temperature of 50-65 0C, then floured and sieved.

The procedure for making patin fish paste is based on research by Suparmi, *et al* (Suparmi et al., 2020). First, prepare fresh patin fish meat that has been cleaned and filleted. Then, grind the meat using a blender or meat grinder until it achieves a smooth, homogeneous texture. The biscuit-making procedure refers to Khafsah's research (Khafsah et al., 2024). In a bowl, mix together the dry ingredients, including wheat flour, mung bean flour, baking powder, and salt. Mix thoroughly by stirring. In a different bowl, combine the wet ingredients. Using a mixer, thoroughly blend the egg yolks, margarine, powdered sugar, and catfish paste. Add the dry ingredients to the wet mixture gradually. Stir until a uniform dough is formed. Roll out the dough to the desired thickness, then shape it using a mold of your choice. Place the molded dough on a baking sheet greased with margarine or lined with parchment paper. Bake in a preheated oven at 170°C for 15 minutes or until the biscuits are golden brown. Once cooked, remove the biscuits from the oven and let them cool. Store the biscuits in an airtight container to maintain their crispness. The subjective quality test examined aroma, color, taste, and physical appearance. The method used in this test was a hedonic scale scoring method using a questionnaire. The test was conducted by 30 moderately trained panelists.

Composite flour was subjected to laboratory analysis in a recognized laboratory. 18-8-5/MU (gravimetry) is the proximate analysis used in fat content assessment. SNI 01-2891-1992 point 6.1 is used for ash content testing, while 18-8-31/MU (titrimetry) is used for protein testing. Testing for moisture content adheres to SNI 01-2891-1992 point 5. 1. A distinct approach is used for carbohydrate testing. The 18-13-1/MU (ICP-OES) method is used for zinc analysis. The 18-13-1/MU (ICP-OES) method is used for Fe analysis. Procedures referring to the internal technique 18-5-17/MU/SMM-SIG (UPLC-PDA) were used to analyze amino acids. 18-6-1/MU/SMM-SIG (GC-FID) is referred to as fatty acids.

Result and Discussion

Sensory Quality of Toddler Biscuits

Biscuit formulation trials using a combination of mung bean flour and patin fish paste were conducted in the food technology laboratory to determine the optimal composition for producing a biscuit product with both physical and sensory qualities. Several ratios of mung bean flour and patin fish paste were tested: 10:90; 20:80; 30:70; 40:60; 50:50; 60:40; 70:30; 80:20; and 90:10.

The test results showed that only combinations of 50:50 to 90:10 produced biscuit formulations, with a higher proportion of mung bean flour than patin fish paste. The dough in these combinations had a sufficiently dense and elastic consistency for shaping and molding into biscuits. The final product from this combination also exhibited a sturdy biscuit structure, resisted crumbling, and had a physical appearance similar to that of a typical biscuit(Akhsanitaqwim et al., 2024; Barakat et al., 2025; L. Liu et al., 2022).

In contrast, formulations with ratios of 10:90, 20:80, 30:70, and 40:60 failed to produce moldable biscuits. Dough with a high patin fish paste content tended to be too soft, wet, and unable to maintain its shape when molded. Figure 1 shows a visual of the Mung Bean Flour and Patin Fish Paste Toddler Biscuits.

Figure 1. Visual of Green Bean Flour and Patin Fish Paste Toddler Biscuits

Color Sensory

Figure 2. Sensory assessment of color attributes of toddler biscuits made from mung bean flour and catfish paste with various formulation proportions. The graph shows that panelists' preference levels tended to be high in all treatments, with the highest percentage in the KHIP8020 formulation (90%) and the lowest in the KHIP6040 (70%). Statistical tests (p = 0.309) indicated no significant differences between formulations regarding color attributes.

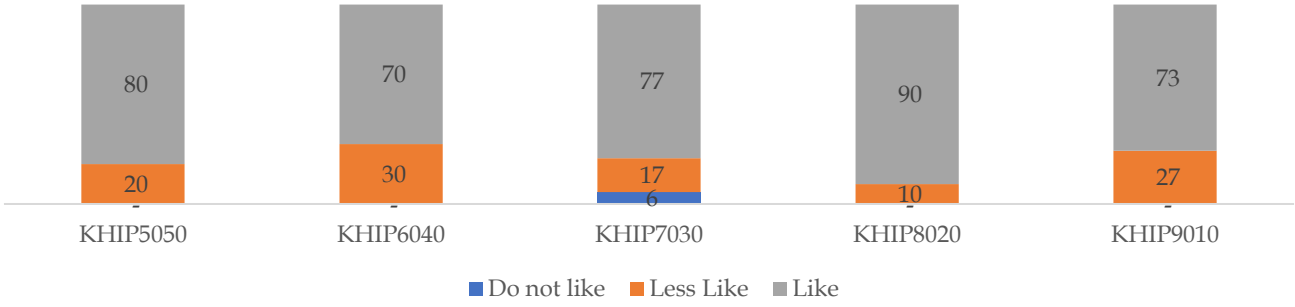

Figure 2. Color Sensory of Toddler Biscuits Made from Green Bean Flour and Patin Fish Paste

Interestingly, the KHIP8020 formulation with 80% mung bean flour and 20% catfish paste achieved the highest preference rating. This indicates that the predominance of mung bean flour produces brighter and more visually appealing biscuit colors compared to other formulations, which tend to produce darker colors. The main pigment in mung beans is chlorophyll, which degrades into yellowish-brown pheophytin during the baking process. This reduction in chlorophyll can affect the product's brightness. However, at higher proportions, mung bean flour still provides a natural color impression that panelists prefer. In addition to the influence of natural pigmentation, the baking process also triggers the Maillard reaction between catfish protein and reducing sugars, as well as caramelization, both of which contribute to the formation of brown color in bakery products. Several studies have reported that the intensity of the Maillard reaction is proportional to protein content and baking temperature, so formulations with a higher proportion of catfish paste have the potential to produce darker colors (Barakat et al., 2025; El Hosry et al., 2025; B. A. L. Fitri et al., 2025; Melini et al., 2024).

Additionally, the presence of flavonoids and polyphenols in mung beans also influences color changes during thermal processing. These compounds can condense to form dark brown polymers, which decrease brightness and increase the browning index(Huang et al., 2022). Thus, panelists' preferences for biscuit color were influenced by the balance of the proportions of mung bean flour and catfish paste, as well as the dynamics of natural pigment changes and non-enzymatic browning reactions during baking.

Aroma Sensory

Figure 3. Sensory assessment of the aroma of biscuits based on mung bean flour and catfish paste. Panelists' preference levels ranged from 67% to 90%, with the highest value in the KHIP8020 formulation (90%), followed by KHIP5050 (87%) and KHIP9010 (83%). The KHIP7030 formulation showed the lowest preference level (67%) and the largest number of panelists who stated that they did not like it. Statistical tests showed that the differences between treatments were not significant (p = 0.136; p > 0.05), indicating that all formulations were still acceptable in terms of aroma.

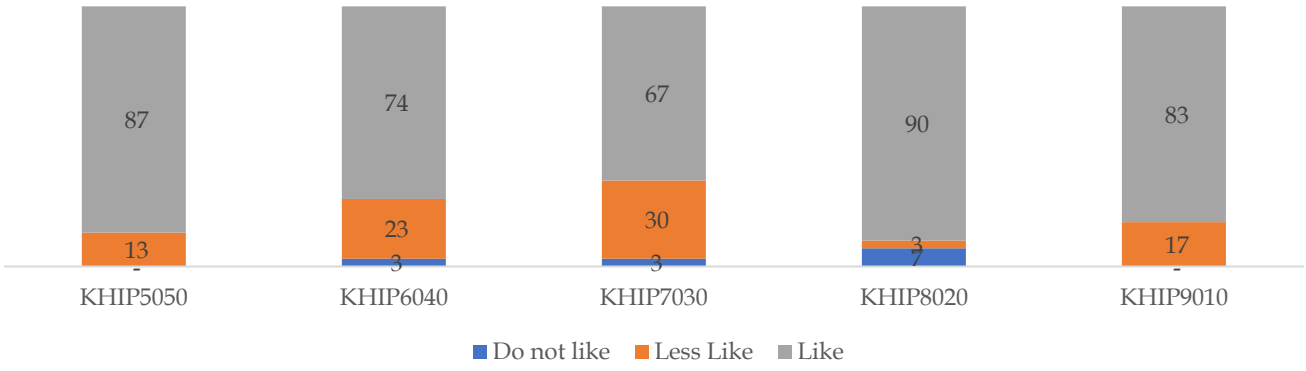

Figure 3. Aroma Sensory of Toddler Biscuits Made from Green Bean Flour and Patin Fish Paste

The predominance of mung bean flour in the formulation (as in KHIP9010) has the potential to produce a "beany" aroma due to the presence of hexanal. However, the roasting process has been shown to reduce the concentration of this compound, while increasing the formation of Maillard compounds such as pyrazines, ketones, and esters, which give a roasted and sweet impression. Recent metabolomics studies also reported an increase in the volatile compounds 2-methoxy-3-isobutyl pyrazine, 2,3-butanedione, and 1,2-hexanedione after roasting, while hexanal levels were significantly reduced, resulting in a more controlled unpleasant aroma(Sun et al., 2025).

On the other hand, catfish paste contributes aroma components through protein and lipid degradation during heating, producing branched aldehydes (3-methylbutanal, 2-methylbutanal), alcohols (2-methyl-1-butanol), and furans (e.g., 2-pentylfuran). These compounds contribute to the characteristic "meaty" or "nutty" aroma. However, if the proportion is too high (as in KHIP6040 or KHIP7030), the fish volatile compounds can exceed the sensory detection threshold, resulting in a fishy aftertaste that reduces panelists' preference. Conversely, a moderate amount of fish paste, as in KHIP8020, can enrich the aroma complexity without causing a strong aftertaste, resulting in the highest hedonic scores.(Jiang et al., 2022; M. Liu et al., 2022).

Thus, the balanced proportions of mung bean flour and patin fish paste proved to be a key factor in producing a desirable biscuit aroma. The balanced formula not only suppressed the unpleasant aroma of the beans but also avoided the excessive fishy aroma of the fish, creating a suitable aroma profile that was more acceptable to panelists.

Texture Sensory

Figure 4. Panelists' preference level for the texture of toddler biscuits made from mung bean flour and patin fish paste. Formulations with a higher proportion of mung bean flour (KHIP9010 and KHIP8020) showed a better level of acceptance, with 84% and 77% of panelists expressing liking. Conversely, increasing the proportion of patin fish paste (KHIP7030 and KHIP6040) decreased the preference, with only 63% and 40% of panelists expressing liking, respectively. Differences between formulations showed a significant tendency ($p = 0.001$; $p < 0.05$) that the higher the proportion of mung bean flour, the crispier the texture produced and the more panelists preferred it, while increasing the patin fish paste correlated with decreased acceptance due to a softer and less crispy texture.

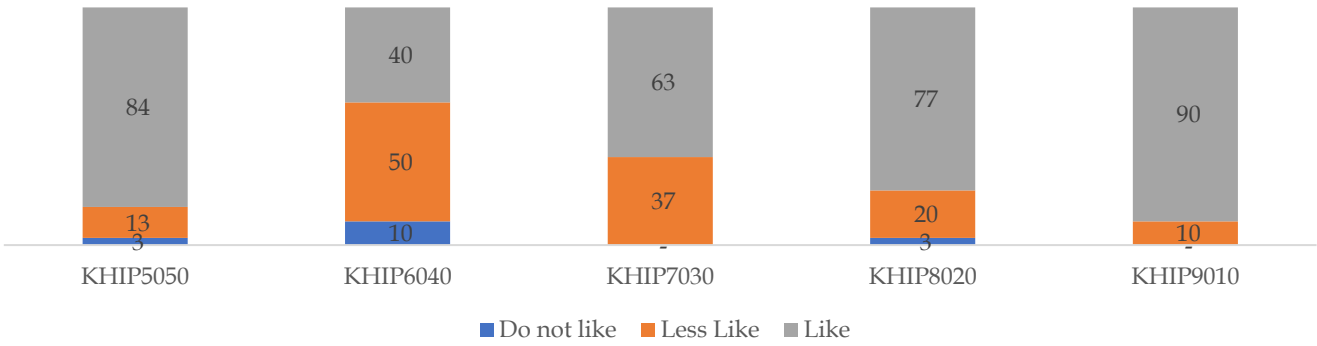

Figure 4. Texture Sensory of Toddler Biscuits Made from Green Bean Flour and Patin Fish Paste

Formulations with a high proportion of mung bean flour (e.g. KHIP9010 and KHIP8020) produce a crispier, drier, and crunchier texture, because a stable starch-protein structure is formed during baking, and not too much water remains bound in the dough, according to the preferences of sensory panelists(Aslan & Isik, 2024). Previous research shows that mung bean flour is known to be rich in protein, starch, and minerals, with a protein content of ~20–30% of its dry weight, making it an effective natural binding agent in the manufacture of dry cake and biscuit products(Barakat et al., 2025). Likewise, another study succeeded in making gluten-free biscuits made from mung bean flour with a ratio of up to 60% mung bean flour (a combination of bean flour and other flours) which produced good texture and sensory acceptance(Fathonah et al., 2020).

Formulations with a higher proportion of patin fish paste (KHIP6040, KHIP7030) tend to have a softer or chewier texture, due to the higher animal protein and fat/water content. Water acts as a plasticizer, and the animal protein in fish can weaken the starch-protein network structure and increase moisture, reducing the final crispiness of the product.(Nawaz, Li, et al., 2021). Studies on whole fish powder (WFP) have shown that adding large amounts of fish protein increases unbound water and disrupts the starch-protein network, resulting in a softer, less dense texture. Conversely, at lower protein proportions (around 5%), there is a strong

starch-protein interaction, so the texture remains relatively stable and desirable(Nawaz, Khalifa, et al., 2021).

Taste Sensory

Figure 5. Sensory assessment of toddler biscuits based on mung bean flour and catfish paste (KHIP). Formulations KHIP5050 and KHIP9010 showed the highest level of preference, with 87% of panelists stating "like" and none stating "dislike". In contrast, KHIP7030 obtained the lowest level of acceptance with 13% of panelists stating "dislike" and only 67% stating "like". Formulation KHIP6040 also showed a low trend, with only 53% of panelists stating "like" and 40% stating "less like". Meanwhile, KHIP8020 showed an increase to 77% of panelists stating "like". Statistical tests showed a significant difference between formulations (p = 0.019), confirming that variations in the proportion of mung bean flour and catfish paste had a significant effect on taste preference.

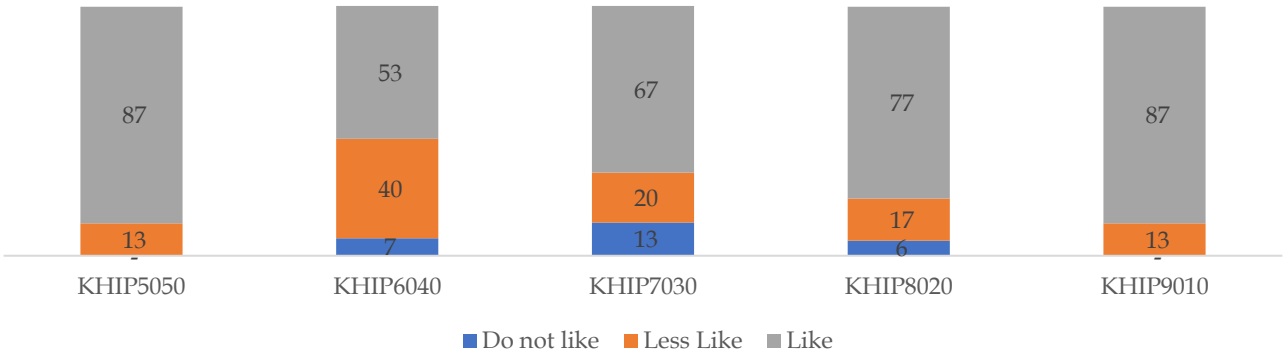

Figure 5. Taste Sensory of Toddler Biscuits Made from Green Bean Flour and Patin Fish Paste

Mung beans contain oxidized lipid compounds like hexanal and ketones, which contribute to the "beany" aroma that consumers dislike. Thermal processes like roasting or baking produce Maillard reactions that form compounds like pyrazine, 2,3-butanedione, and 2-hydroxypyridine, which enhance caramel, creamy, and nutty aromas while reducing hexanal content(Sun et al., 2025).

Fish paste is rich in peptides and amino acids (especially glutamate and aspartate) that contribute to the umami flavor, and volatile sulfur-nitrogen compounds, if not properly processed, can impart a fishy aroma. Processing processes such as pasteurization, baking, or dewatering can reduce the fishy odor and produce a more balanced umami aroma(Prabawa et al., 2020).

KHIP5050 biscuits combine a balanced content of mung bean and fish paste. This is because the thermal baking process allows the formation of pyrazines and ketones from mung beans (reducing hexanal and caramel aromas), while simultaneously extracting the umami flavor from the fish protein. Therefore, 87% of panelists liked it due to the balanced combination of nutty, creamy, and slightly umami aromas. Roasting increases the formation of positive aroma compounds such as pyrazines and ketones, while reducing the offensive aldehyde (hexanal) from mung beans. Proper processing of fish protein—for example, through controlling temperature, pH, or heating time—can suppress sulfur-nitrogen compounds that cause fishy aromas, while enhancing the umami flavor from amino acids such as glutamate and aspartate(Prabawa et al., 2020; Sun et al., 2025).

Table 1. Results of the De Garmo test on five KHIP biscuit formulations based on mung bean flour and patin fish paste. Formulation KHIP5050 (50% mung bean flour: 50% patin fish paste) obtained the highest total score (3.33) with an effectiveness value (NE) of 0.75 and was determined as the best treatment. In contrast, KHIP6040 showed the lowest score (0.29; NE 0.03), indicating a low level of panelist acceptance. Formulations KHIP8020 and KHIP9010 were still quite preferred with total scores of 3.13 (NE 0.81) and 2.98 (NE 0.64), respectively, while KHIP7030 ranked fourth with a total score of 0.70 (NE 0.20). These results indicate that a balanced proportion between mung bean flour and patin fish paste provides the best sensory quality compared to the dominance of one ingredient.

Table 1. Results of the De-Garmo Test to Determine the Best Proportion of KHIP Biscuits, Mung Bean Flour and Patin Fish Paste

Formulation KHIP Biscuits	NE	Total NP	Rank
KHIP5050	3.33	0.75	1
KHIP6040	0.29	0.03	5
KHIP7030	0.70	0.20	4
KHIP8020	3.13	0.81	2
KHIP9010	2.98	0.64	3

Proximate Content of KHIP Biscuits Mung Bean Flour and Patin Fish Paste

This table 2 shows the differences in nutritional content between PMT Toddler biscuits and KHIP5050 biscuits formulated from a mixture of 50% mung bean flour and 50% catfish paste. KHIP5050 biscuits have higher energy (479.45 kcal) than PMT biscuits (453.3 kcal), as well as a significant increase in protein (16.81% vs. 9.6%) and fat (27.77% vs. 14.3%). In contrast, carbohydrate content is lower (40.57% vs. 71.55%). The moisture content of KHIP5050 is higher (11.53% vs. 2.18%), while the ash content is also increased (3.33% vs. 2.5%), indicating better mineral content. These results confirm that KHIP5050 is more energy and protein dense, although the high moisture content has implications for product shelf life.

Table 2. Proximate Content of Toddler Biscuits

Nutrient	Biscuit (%)	
	Toddler Biscuits	KHIP5050 Biscuits
Energy	453.3	479.45
Carbohydrate	71.55	40.57
Protein	9.6	16.81
Fat	14.3	27.77
Moisture	2.18	11.53
Ash	2.5	3.33

The energy value of food is greatly influenced by the composition of macronutrients, especially fat, carbohydrates and protein, where fat contributes the highest energy at 9 kcal/gram, while carbohydrates and protein each contribute 4 kcal/gram(Rolls, 2017). The high energy content of KHIP5050 biscuits may be attributed to the use of fat- and protein-rich ingredients such as catfish paste and legume flour (e.g., mung bean or cowpea), which generally contain significant amounts of lipids(Mouafo et al., 2024; Rachmawati et al., 2025). In addition, if KHIP5050 biscuits are formulated with additional oil or other fat sources (such as shortening or margarine), this also contributes significantly to increasing the total energy of the product(Goubgou et al., 2021).

This high energy content is a key advantage of RUTF (Ready to Use Therapeutic Food) products, as their primary goal is to provide a dense intake of energy and nutrients in small amounts for children experiencing acute malnutrition. This aligns with the WHO criteria for KHIP, which requires a minimum energy intake of 520–550 kcal/100 grams of product(Food and Agriculture Organization of the United Nations & World Health Organization, 2022). In contrast, PMT Toddler biscuits are likely adapted for supplementary feeding programs with sufficient energy content but not as high as RUTF, because the target is for healthy toddlers who need additional nutritional support, not nutritional therapy for severe malnutrition(Fetriyuna et al., 2023; Rimbawan et al., 2024).

In terms of protein, KHIP5050 biscuits experienced a significant increase of up to 16.81%, almost double that of PMT Balita biscuits which contain 9.6% protein, p. The main contribution to this high protein content comes from the basic ingredients used, namely a combination of mung bean flour and patin fish paste. Mung beans (Vigna radiata) are one of the plant sources rich in protein(Anyiam et al., 2025; F. Wang et al., 2021). Meanwhile, catfish (Pangasius sp.) is a source of animal protein which is known to have a complete amino acid profile and high biological value(Fitria et al., 2024; Sokamte et al., 2020).

The carbohydrate content in KHIP5050 is recorded as lower, at only 40.57%, compared to 71.55% in PMT biscuits. This decrease is consistent with the substitution of carbohydrate-rich ingredients (wheat flour) with protein and fat sources. In the KHIP5050 formulation, substituting wheat flour (the main carbohydrate source) with protein- and fat-rich alternatives resulted in a significant decrease in carbohydrate content. This is generally consistent with the pattern in wheat flour substitution studies. Other studies have shown that biscuits made from composite flour have a higher protein content (~12.4%) than biscuits based on wheat flour (~10.4%)(Shaji et al., 2024). Another study showed that whole wheat biscuits enriched with vegetable protein resulted in significant reductions in carbohydrates, fat, and energy in overweight women, as well as triggering a better metabolic response(Kanata et al., 2024).

The fat content also showed a sharp increase, from 14.3% in PMT biscuits to 27.77% in KHIP5050, reflecting the significant contribution of catfish lipids to the formulation. This is likely due to the addition of lipid-rich ingredients such as peanuts and fish, both of which are known to be rich in fat, especially unsaturated fatty acids such as omega-3 from fish and monounsaturated fats from peanuts. Peanuts generally have a high fat content, reaching 40–50%. Therefore, if the formulation includes peanut flour, the lipid contribution can be significant in the final formulation(Moharana et al., 2020; Sahasakul et al., 2022). Likewise, the addition of fish often increases the total lipid content of the final product. While some fish products are processed to remove fat (delipidification), many retain their natural lipid content, especially when the focus is on increasing nutritional value(Abraha et al., 2018).

The moisture content of KHIP5050 biscuits is higher, at 11.53%, compared to PMT biscuits at only 2.18%, which can affect the product's shelf life and crispness. With a high moisture content (11.53%), KHIP5050 may have a softer texture and lose crispness more quickly when exposed to environmental humidity.

In studies, biscuits with moisture contents ranging from 2.10 to 7.46% cause water absorption during storage and affect texture quality. Conversely, PMT with a low moisture content (2.18%) has a more stable foundation for crispness(Asadi et al., 2022). KHIP5050 biscuits have a much higher water content and this has the potential to result in initial favorable viscosity and softness, but reduces overall resistance to oxidation and microbes(Kumari et al., 2021).

Finally, the resulting ash content reached 3.33%, which is higher than that of PMT Toddler biscuits, which is only 2.5%. This indicates that KHIP5050 biscuits have a higher mineral content and have the potential to provide better micronutrients for consumers, especially toddlers who are an important target group in nutritional food interventions. Previous studies have shown that biscuits made from a mixture of wheat flour and bean flour significantly increase ash content, with values higher than the control (100% wheat)(Iahtisham-Ul-Haq et al., 2024).

Zinc and Fe Content of KHIP Biscuits, Green Bean Flour and Patin Fish Paste

Figure 6 shows a zinc content of 3.41 mg/100 g, slightly higher than KHIP5050 (3.16 mg/100 g). A more significant difference is seen in the iron content, where PMT Balita biscuits contain 10.07 mg/100 g while KHIP5050 only contains 6.31 mg/100 g. This difference indicates that PMT Balita biscuits have greater potential to support meeting iron needs for anemia prevention, while both formulations can be considered good sources of zinc.

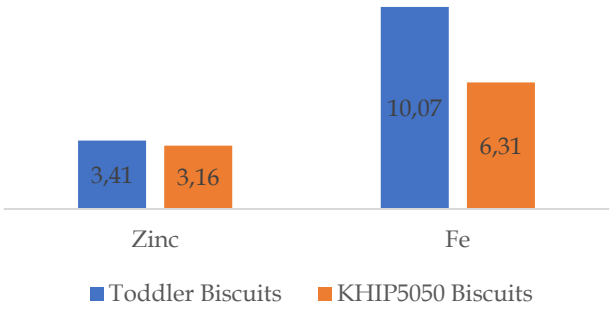

Figure 6. Fe and Zinc content in toddler biscuits

Zinc plays a vital role in supporting enzyme function, growth, and the immune system in children, so its presence in both biscuit formulations has significant nutritional value. Zinc in fish is generally present in a form that is easily absorbed by the body, and its availability is not significantly inhibited by mineral-binding compounds like phytate(Devarshi et al., 2024; Maares & Haase, 2020). A recent study showed that consumption of both marine and freshwater fish was positively correlated with the zinc status of children in malnutrition-prone areas(Byrd et al., 2022). In contrast, green beans, although they contain quantitative zinc, have most of their zinc bound by phytic acid (phytate), forming a complex that reduces solubility and intestinal absorption; traditional processing interventions such as soaking, fermentation, and sprouting or the use of phytase can reduce phytate and increase zinc bioavailability(Abera et al., 2023; Chondrou et al., 2024).

Several reviews and observational studies have shown that zinc deficiency is one of the most common micronutrient malnutrition problems worldwide. In children in low- and middle-income countries, zinc deficiency significantly limits growth (including stunting), increases the risk of infections and chronic diarrhea, and contributes to cognitive impairment. Furthermore, zinc deficiency also exacerbates the risk of infections and increases mortality during pregnancy and early life(Hussain et al., 2022; Lowe et al., 2024). A comparative study of malnourished and healthy children showed that zinc deficiency was more common in malnourished children, with an odds ratio of approximately 3.9 times greater. This means that zinc deficiency is closely linked to severe malnutrition(Ahsan et al., 2021).

Meanwhile, the Fe (iron) content shows a quite striking difference. PMT Toddler Biscuits contain 10.07 mg of Fe/100 g, significantly higher than KHIP5050 biscuits, which only contain 6.31 mg/100 g. This indicates that the PMT Toddler formulation has the potential to contribute significantly to meeting daily iron requirements, which is crucial for preventing iron deficiency anemia in toddlers. The iron in fish is mostly heme iron, which has a higher bioavailability (15–35%) than non-heme iron from plant sources (2–20%)(Kalman et al., 2025; Piskin et al., 2022). The presence of animal protein can also increase the absorption of non-heme iron from other foods through the meat factor effect. The meat factor effect of meat, poultry, and fish increases non-heme iron absorption, a mechanism thought to be related to peptide/cysteine and luminal factors(Consalez et al., 2022; Piskin et al., 2022). Meanwhile, Fe in green beans is non-heme iron, which has lower absorption and is susceptible to being inhibited by phytate, tannins, and polyphenols(Idris et al., 2025). The presence of animal protein from catfish can increase the absorption of non-heme Fe from green beans, so that overall mineral availability increases(Piskin et al., 2022; Sulaiman et al., 2021).

Iron plays a vital role in hemoglobin formation, oxygen transport, energy metabolism, and brain development. Iron deficiency can lead to iron deficiency anemia, which can lead to decreased learning ability, behavioral problems, and a reduced immune system. Recent studies confirm that iron deficiency in early life is

closely linked to stunting because it interferes with bone growth and soft tissue development (H S et al., 2024; Oktarina et al., 2024).

The higher Fe content in PMT for toddlers means this product has the potential to be more effective in supporting hemoglobin status and reducing the risk of anemia, which is a contributing factor to stunting and underweight. 64 Conversely, the lower Fe content in KHIP5050 needs to be balanced with a fortification strategy or the selection of Fe-rich raw materials to support the prevention of these nutritional problems (Piskin et al., 2022).

Amino Acid Profile of Mung Bean Flour and Patin Fish Paste Toddler Biscuits

Table 3 shows a comparison of amino acid levels between PMT Toddler biscuits and KHIP5050 biscuits. Almost all types of amino acids, both essential and non-essential, experienced an increase in KHIP5050. The most prominent increases were in lysine (from 1.88% to 9.86%), leucine (6.68% to 13.80%), and methionine (0.50% to 2.26%). Glutamic acid levels were relatively stable in both formulations. These data indicate that the combination of mung bean flour and catfish paste in KHIP5050 significantly enriches the protein quality of the biscuits, primarily by increasing essential amino acids that are important for children's growth and development.

Table 3. Amino Acid Profile of Toddler Biscuits

Amino Acid	Biscuit (%w/w)	
	Toddler Biscuits	KHIP5050 Biscuits
Alanine	3.24	7.62
Arginine	2.83	7.46
Aspartic Acid	5.25	15.22
Glycine	3.49	6.42
Glutamate Acid	28.40	27.93
Histidine*	4.30	5.31
Ileucine*	2.81	6.30
Cystine	0.86	0.81
Leucine*	6.68	13.80
Lysine*	1.88	9.86
Methionine*	0.50	2.26
Trytophane*	0.97	1.59
Valine*	3.17	7.44
Phenylalanine*	4.82	10.17
Proline	9.52	10.48
Serine	4.82	8.83
Threonine*	2.74	5.53
Tyrosine	2.23	4.12

*) Essencial Amino Acid

KHIP5050 biscuits are composed of 50% mung bean flour and 50% patin fish paste, a nutritionally complementary combination. Mung bean flour is a source of vegetable protein with relatively high levels of certain amino acids, particularly lysine, arginine, and leucine, but relatively low levels of methionine(Idris et al., 2025; Yanti et al., 2023). On the other hand, catfish as a source of animal protein is rich in complete amino acids, including methionine, leucine, valine, and phenylalanine, and has high protein bioavailability because the digestibility of fish protein is generally >90%(Parikh et al., 2022). Several studies have reported that stunted children tend to have lower circulating levels of essential amino acids, so dietary interventions that increase EAAs may help improve linear growth(Furuta et al., 2021; Maulidiana & Sutjiati, 2021).

The abundant lysine in green beans is strengthened by lysine from catfish, so that in KHIP5050 the levels increase drastically(Fitria et al., 2024; Hidayaturrahmah et al., 2025; Idris et al., 2025; Yanti et al., 2023). Lysine plays an important role in collagen synthesis and bone formation; increased lysine in the KHIP5050 formulation may contribute to potential stunting prevention(Gunarathne et al., 2025). The common methionine deficiency in plant proteins is offset by the contribution of catfish, raising the methionine content from 0.50% to 2.26%(Fitria et al., 2024; Hidayaturrahmah et al., 2025; Idris et al., 2025; Yanti et al., 2023). Methionine has a dual function, namely as a supporter of tissue synthesis during growth and as a methyl donor (S-adenosylmethionine) which can influence gene expression through DNA/histone methylation, both of these mechanisms are relevant for growth recovery in malnourished toddlers(Endrinikapoulos et al., 2023; Gkiouleka et al., 2025).

Mung beans and catfish both provide branched-chain amino acids (BCAAs), particularly leucine, which is known to be a key trigger for mTORC1 pathway activation and muscle protein synthesis. Providing foods or formulations rich in leucine from plant (mung bean flour) and animal (catfish) sources can enhance anabolic signaling and aid weight recovery in underweight/wasting toddlers when combined with adequate energy and protein intake(S. A. Fitri et al., 2024; Furuta et al., 2021; Rehman et al., 2023; Tarahi, 2024).

Phenylalanine (Phe) and tryptophan (Trp) are found in plant protein sources such as mung beans and animal protein sources such as catfish/pangasius. These two aromatic amino acids are important precursors for neurotransmitters that play a role in appetite regulation, so that the adequacy or supplementation of proteins containing Phe/Trp has the potential to influence energy intake and support nutritional recovery. Trp is the main precursor of serotonin, while Phe can be metabolized to tyrosine, which is necessary for the synthesis of catecholamines (dopamine, noradrenaline). Serotonin is primarily involved in appetite regulation and energy homeostasis; catecholamines/dopamine are related to reward and motivation to eat, so the intake of precursors (Trp, Phe) can functionally influence food intake(Pertea et al., 2025; Salamanca et al., 2022; van Galen et al., 2021;

Xu et al., 2025). Reviews and composition studies show that mung beans are rich in protein with an amino acid profile that includes phenylalanine and tryptophan, making them a suitable source of neurotransmitter precursors(Tarahi, 2024; Yanti et al., 2023). Composition studies on Pangasius show a complete amino acid profile including Phe and Trp. Fish as an animal protein source also provides superior bioavailability and co-factors (iron, vitamins) that support neurotransmitter synthesis(Chakma et al., 2022; Junianto & Syauqibik, 2025).

Fatty Acid Profile of Green Bean Flour and Patin Fish Paste Toddler Biscuits

The fatty acid profile of KHIP5050 biscuits (50% mung bean flour and 50% patin fish paste) showed higher saturated and unsaturated fatty acid content compared to PMT Balita biscuits. MUFA content, especially oleic acid (omega-9), and PUFA including essential fatty acids (linoleic acid and linolenic acid) were more dominant in KHIP5050. In addition, KHIP5050 biscuits contained EPA, DHA, and arachidonic acid (AA) which were not detected in PMT Balita biscuits, confirming their contribution in providing long-chain PUFAs important for children's growth and development (Table 4).

Table 4. Fatty Acid Profile of Toddler Biscuits

Fatty Acid	Toddler Biscuits	Biscuit (%) KHIP5050 Biscuits
Saturated Fatty Acids	7.83	16.20
Unsaturated Fatty Acids	6.51	11.57
Polyunsaturated Fatty Acids	1.67	2.58
Monounsaturated Fatty Acids	4.84	8.99
Omega 3 Fatty Acids	0.07	0.18
Omega 6 Fatty Acids	1.59	2.39
Omega 9 Fatty Acids	4.80	8.72
Arachidonic Acid (AA)	ND	0.06
Docosahexaenoic Acid (DHA)	0.01	0.02
Eicosapentaenoic Acid (EPA)	0.01	0.03
linoleic acid	1.59	2.31
Linolenic Acid	0.05	0.13
Oleic acid	4.80	8.71
C 10:0 (Capric Acid)	0.01	0.29
C 12:0 (Lauric Acid)	0.05	2.08
C 14:0 (Myristic Acid)	0.17	1.37
C 15:0 (Pentadecanoic Acid)	0.01	0.06
C 16:0 (Palmitic Acid)	6.79	9.72
C 18:0 (Stearic Acid)	0.70	2.06
C 20:0 (Arachidic Acid)	0.05	0.08

Mung bean flour is generally low in total fat but rich in linoleic acid (C18:2, omega-6) as the dominant fatty acid while catfish has a significant proportion of MUFA especially oleic and also contains long-chain omega-3 (EPA, DHA) this shows that KHIP5050 biscuits have higher PUFA, EPA/DHA, and AA content than PMT Toddler biscuits. Mung beans (Vigna radiata) have a relatively low total fat content compared to other grains, but lipid fraction analysis shows the dominance of unsaturated fatty acids especially linoleic acid (C18:2) and n-3 precursors (α-linolenic acid). In addition, mung bean seeds are rich in antioxidant phytochemicals (e.g. vitexin, isovitexin, and proanthocyanidin) which have the potential to protect PUFA from oxidation during processing and storage. Therefore, the use of mung bean flour in biscuit formulation can increase the contribution of linoleic acid and ALA precursors to the fatty acid profile of the final product without significantly increasing the total fat content of the product(Desta et al., 2024; Rodríguez Madrera et al., 2024). Catfish (Pangasius sp.) is a source of animal fat, especially long-chain omega-3 PUFA such as EPA and DHA, as well as arachidonic acid (AA) which is important for the development of the central nervous system(Rahman et al., 2023).

A metabolomics study of children in Malawi found that stunting was closely associated with low serum levels of omega-3 and omega-6 polyunsaturated fatty acids (PUFAs). Both are essential fats for growth and development. Children with stunting showed lower levels of PUFAs, neurosteroid sulfates (important for brain development), carnitine, and the amino acid γ-glutamyl(Semba et al., 2017).

Omega-3 fatty acids (ALA, DHA, EPA) cannot be synthesized by the body and must be obtained from the diet. They play a critical role in brain development, including neurogenesis, neuron migration, synaptogenesis, and neurotransmission. In very low birth weight infants, higher intakes of PUFAs, including DHA and AA, were associated with better cognitive and motor scores at 12 months of age, with positive trends up to 24 months, although some did not reach statistical significance(Gsoellpointner et al., 2023).

Long-chain omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are essential components for central nervous system development. DHA specifically accumulates in the phospholipid membranes of neurons, particularly during the critical period of brain development (late gestation through the first two years of life) and plays a key role in synapse formation, neuronal plasticity, and neural signal transmission. A recent systematic review and meta-analysis showed that DHA supplementation in early life may benefit several aspects of cognitive development, although results across studies are

heterogeneous. These findings reinforce the relevance of adequate EPA and DHA in the diet, particularly in children at risk of developmental delays due to malnutrition(Hu et al., 2024).

Apart from its function in the brain, EPA and DHA also function as precursors of bioactive lipid mediators such maresins, protectins, and resolvins that control the resolution of inflammation. Consuming EPA and DHA may lower the risk of tissue damage from chronic inflammation by modulating monocyte immunological responses and lowering the synthesis of proinflammatory mediators, according to clinical research. For undernourished children under five, who typically have recurring infections and an increased inflammatory response, this impact is especially pertinent (Szabó et al., 2020).

Arachidonic acid (AA) is an omega-6 fatty acid stored as part of the phospholipids of cell membranes, including neuronal membranes. AA plays a role in maintaining membrane fluidity and facilitating the function of receptors and membrane proteins. Furthermore, AA is a major precursor of eicosanoids such as prostaglandins and leukotrienes, which mediate various aspects of the immune response, from vasodilation to immune cell migration. In the context of malnourished children, the presence of AA in the diet is important for supporting the integrity of nerve cell membranes while maintaining the ability to modulate immunity against pathogens(B. Wang et al., 2021).

Consuming adequate amounts of MUFAs helps the absorption of fat-soluble vitamins (A, D, E, and K) by increasing micelle formation in the small intestine. Oleic acid, a major component of MUFAs, plays a role in the formation of triglycerides, which transport these vitamins through the chylomicron pathway. This process is crucial for undernourished children, whose fat-soluble vitamin status is often low due to low total dietary fat intake(El Aoud et al., 2024).

Conclusion

Although formulations dominated by mung bean flour (ratio 80:20 and 90:10) were equally well-received by panelists, toddler biscuits made with a formula of 50% mung bean flour and 50% catfish paste (KHIP5050) turned out to be the best in terms of sensory quality. Compared to regular toddler PMT biscuits, KHIP5050 biscuits feature a number of nutritional advantages. KHIP5050 cookies are richer in fat (27.77%), protein (16.81%), and calories (479.45 kcal). Furthermore, the amino acid profile of these cookies is richer, particularly in important amino acids like methionine, leucine, and lysine. They also have a better fatty acid profile, with a higher proportion of MUFA and PUFA, as well as EPA, DHA, and AA that aren't found in regular biscuits. However, compared to regular toddler PMT biscuits, KHIP5050 biscuits have less iron and more water. This suggests that these biscuits could be a nutrient-dense food product to combat toddler malnutrition, although more advancements in shelf life and mineral fortification are required.

Acknowledgments
This research would not have been possible without the support and contributions of various parties. We express our deepest gratitude to the Poltekkes Kemenkes Banjarmasin for the facilities and resources provided, which enabled us to conduct this research. We also thank all the panelists who took the time to participate in the sensory quality testing, as well as the research team who collaborated closely at every stage of this study.

Author Contributions
Conceptualization, SA., and ZD; methodology, SA., and ZD. and SA., and ZD; formal analysis, SA., and ZD and SA., and ZD; investigation, SA., and ZD. and SA., and ZD; resources, SA., and ZD. and SA., and ZD; writing—preparation of original draft, SA., and ZD; writing—reviewing and editing, SA., and ZD. and SA., and ZD; visualization, SA., and ZD; supervision, SA., and ZD; project administration, IKN; obtaining funding, SA., and ZD and SA., and ZD. All authors have read and approved the published version of the manuscript

Funding
No Funding

Conflicts of Interest
The authors declare no conflict of interest

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