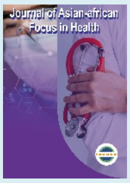

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Effect of Catfish (Clarias batrachus) Flour and Pre-Gelatinized Red Bean (Vigna angularis) Flour Substitution on the Saturated and Trans Fat Content of Dried Sponge Cake

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Abstract

*Stunting prevention requires not only nutritional intervention but also the development of practical, acceptable, and locally based functional food products for pregnant women. This study aimed to analyze the effect of substituting catfish flour (*Clarias batrachus*) and pregelatinized red bean flour (*Vigna angularis*) in dried sponge cake on saturated fat and trans-fat content, while positioning the product as a potential value-added innovation in maternal nutrition management. This study used an experimental design with a Completely Randomized Design consisting of three formulations and two replications. Formula A served as the control with 100% wheat flour, Formula B used 15% catfish flour and 20% pregelatinized red bean flour, and Formula C used 25% catfish flour and 10% pregelatinized red bean flour. Saturated fat and trans-fat contents were analyzed using laboratory fat analysis procedures, and the data were processed using the Kruskal-Walli's test. The results showed that saturated fat content decreased descriptively in the substitution formulas, with the lowest value found in Formula B at 2.91%, although the difference was not statistically significant ($p>0.05$). Trans fat content showed a significant difference among formulations ($p<0.05$), with Formula B producing the lowest value at 16.81%. These findings indicate that the combination of catfish flour and pregelatinized red bean flour, especially Formula B, can improve the lipid quality of dried sponge cake. The product has potential as a healthier local functional food innovation that supports maternal nutrition, food diversification, and stunting prevention strategies. Further sensory, shelf-life, and feasibility studies are needed before commercialization.*

Introduction

Stunting remains a major nutritional problem that affects child health, especially in developing countries. It reflects long-term growth failure caused by chronic nutritional deficiencies during critical periods of growth and development, particularly during the first 1,000 days of life. This period starts from pregnancy and continues until a child reaches two years of age. Nutritional problems during this stage can affect physical growth, cognitive development, immune function, and future productivity. According to the World Health Organization, stunting occurs when a child has a height-for-age value below minus two standard deviations of the WHO Child Growth Standards (Sadomo & Siwiendrayanti, 2023; Scheffler & Hermanussen, 2022; Moelyo et al., 2025; Karlsson et al., 2022; Chanyarungrojn et al., 2023; Nwankwo et al., 2024). In Indonesia, stunting prevalence has gradually declined in recent years. However, the rate remains higher than the threshold recommended by WHO. This condition shows that stunting

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still requires comprehensive, sustainable, and evidence-based intervention strategies (Shenoy et al., 2023; Azwar et al., 2026).

Stunting is closely related to maternal nutrition before and during pregnancy. Poor maternal nutritional status can increase the risk of fetal growth restriction, low birth weight, and impaired child growth after birth (Kabahenda & Stoecker, 2024; Rezaeizadeh et al., 2024; Marine et al., 2026). Therefore, improving the nutritional intake of pregnant women plays an important role in stunting prevention. Nutritional interventions should not only focus on sufficient energy intake but also on the quality of nutrients consumed. Protein, essential fatty acids, vitamins, and minerals are needed to support fetal growth and maternal health. At the same time, excessive intake of unhealthy fats, especially saturated fat and trans-fat, needs attention because it may increase the risk of metabolic disorders during pregnancy (Mititelu et al., 2024; Zupo et al., 2024).

Food safety also influences nutritional intervention efforts. Food safety has become a global issue that shapes health policy in both developing and developed countries. Foodborne diseases and food contamination remain important public health concerns. Food handlers need adequate knowledge of hygiene and sanitation because food safety practices affect the prevention of disease transmission through food, humans, the environment, and processing equipment (Sadomo & Siwiendrayanti, 2023; Sharif et al., 2024; Gebru et al., 2023; Saadat et al., 2024). Human factors, especially the behavior and personal hygiene of food handlers, play an important role in food contamination during processing and serving (Nurhayati et al., 2020). Therefore, the development of functional food products must consider not only nutritional value but also safe processing practices.

Stunting occurs when children experience growth failure due to chronic malnutrition over a long period, particularly during the first 1,000 Days of Life (HPK). This condition is marked by body length or height for age below minus two standard deviations from the child growth standards (WHO, 2020). Based on the 2018 Basic Health Research, the prevalence of stunting in Indonesia reached 30.8% (Ministry of Health of the Republic of Indonesia, 2018). This figure decreased to 24.4% in 2021 and 21.6% in 2022. However, it still remained above the WHO threshold of less than 20% (Ministry of Health of the Republic of Indonesia, 2022; WHO, 2022). In Central Java Province, stunting prevalence reached 20.8% in 2022. This rate indicates that stunting still needs serious attention, especially through nutrition-based prevention programs (Ministry of Health of the Republic of Indonesia, 2022).

One potential strategy to support maternal nutrition is the development of functional food products made from local ingredients. Catfish is one animal protein source that is widely available in Indonesia. According to Statistics Indonesia, catfish production as part of national aquaculture commodities exceeded 1 million tons per year in 2023, with annual growth. In Central Java, catfish production reached more than 150 thousand tons per year. This shows that catfish has strong potential as an accessible local food ingredient (Statistics Indonesia, 2023). Catfish also contains protein and unsaturated fatty acids, while its cholesterol content is relatively low. Fish glycogen decomposes faster than meat glycogen because it is unstable and easily converted into lactic acid through glycolysis (Ida Mardalena, 2017; Xu et al., 2026; Wang et al., 2026).

Although catfish has good nutritional potential, fish also has limitations as a food ingredient. Fish contains high moisture, around 80%, and has a pH close to neutral. These conditions make fish spoil easily and reduce its shelf life. Processing is needed to improve its nutritional value, taste, odor, appearance, and storage stability (Hasanah, 2020; Gantner & Kostyra, 2023). One processing method that can increase the value of catfish is drying. Drying can produce more

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stable products, including fish flour, which can be used as a substitute ingredient in food formulations (Kocatepe et al., 2011; Rasul et al., 2022; Mathew et al., 2022). Catfish flour can help improve the protein content of processed foods and create alternative products that are practical for daily consumption.

In addition to catfish, red beans are another local food ingredient with high nutritional potential. Red beans are a plant-based protein source and are widely available in Indonesia. According to Statistics Indonesia of Central Java Province, red bean production in Central Java reached 37,578 tons in 2020. Red beans belong to the legume group and contain starch that can be developed into resistant starch through precooking methods. Resistant starch relates to functional properties such as water holding capacity, oil holding capacity, and swelling capacity. These properties can influence the hypocholesterolemic potential of red bean flour. However, the use of red beans as a resistant starch source still faces challenges, especially because the preparation process takes a long time. One practical solution is to process red beans into semi-finished products such as precooked flour. The precooking process involves heating followed by cooling. This process increases retrograded starch and produces flour with higher resistant starch content. In practice, repeated autoclaving-cooling cycles can support this process (Lehmann et al., 2015; Faridah et al., 2022; Farooq & Yu, 2024; Wira etal., 2025; Rahman et al., 2025).

Mustikaningrum (2011) reported that peas soaked in 4.2% sodium bicarbonate solution for 8 hours and cooked for 145 seconds produced the lowest hardness and the highest rehydration ratio. This finding supports the importance of proper pretreatment in legume processing. Red bean flour, including precooked red bean flour, also has relatively low-fat content. Astuti et al. (2023) reported that the fat content of red bean flour ranged from around 1.56% to 2.21% per 100 grams of material. This low-fat content makes red bean flour suitable for the development of food products with lower fat characteristics. It also supports its use as a substitute ingredient in bakery products aimed at improving nutritional quality.

The combination of catfish flour and red bean flour has potential as an alternative food ingredient for pregnant women (Aminah et al., 2022). Catfish provides animal protein, while red beans contribute plant-based nutrients, resistant starch, and functional properties. This combination can support the development of local food products with better nutritional value. The fat profile of food products for pregnant women also needs attention. Saturated fat and trans-fat intake during pregnancy should be controlled because they are associated with higher risks of cardiovascular and metabolic health problems. Saturated fat and trans-fat can increase low-density lipoprotein levels in the blood. This process contributes to atherosclerosis and increases the risk of heart disease (World Health Organization, 2023; Yisahak et al., 2021).

This study selected dry sponge cake as the product model because it has lower moisture content and longer shelf life than moist cake products. Dry sponge cake generally has moisture content of around 3 to 5%, while moist sponge cake can reach 20 to 30%. Dry sponge cake is also familiar to many consumers, easy to consume, and suitable for product innovation (Syarbini & Indonesia, n.d.). The substitution of wheat flour with catfish flour and pregelatinized red bean flour is expected to improve the nutritional quality of dry sponge cake. This product may serve as a practical functional food that supports pregnant women's nutritional needs in stunting prevention efforts.

Several studies have examined the use of fish flour and legume flour in bakery products to improve nutritional quality, especially protein content, dietary fiber, and sensory characteristics. Previous findings show that catfish flour can increase the protein value of processed foods. Pregelatinized red bean flour can also increase resistant starch content and

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improve functional properties. However, most studies have focused on proximate composition, acceptability, and physical characteristics. Research on the combined effect of catfish flour and pregelatinized red bean flour on saturated fat and trans-fat content in bakery products remains limited.

Based on this gap, this study aimed to analyze the effect of substituting catfish flour and pregelatinized red bean flour in dry sponge cake formulations on saturated fat and trans-fat content. This study hypothesized that the incorporation of catfish flour and pregelatinized red bean flour could improve the lipid profile of dry sponge cake by reducing saturated fat and trans-fat levels compared with the control formulation. The findings are expected to provide scientific evidence for the development of healthier functional food products based on locally available ingredients. This product innovation may support maternal nutrition and contribute to stunting prevention efforts.

Method

Research Design

This study used an experimental research design with a Completely Randomized Design (CRD). The study applied one treatment factor, namely the substitution of catfish flour and pregelatinized red bean flour in dried sponge cake formulation. The purpose of this design was to determine the effect of different substitution levels on saturated fat and trans-fat content in the final product. The experiment consisted of three formulations, namely Formula A as the control formulation, Formula B with 15% catfish flour and 20% pregelatinized red bean flour, and Formula C with 25% catfish flour and 10% pregelatinized red bean flour. Each formulation was prepared in two replications, resulting in six experimental units. This design was selected because it allowed each treatment to receive the same processing conditions, while the main difference was only the level of flour substitution.

Tools and Materials

The materials used in this study were divided based on the preparation stage. Fresh catfish was used as the main material for producing catfish flour. Fresh red beans and $NaHCO_3$ solution were used for producing pregelatinized red bean flour. The ingredients used in the production of dried sponge cake consisted of catfish flour, pregelatinized red bean flour, wheat flour, chicken eggs, granulated sugar, margarine, vanilla, and baking powder. All ingredients were prepared before processing to ensure that each formulation followed the same production procedure.

The equipment used in this study was also grouped according to its function. The production of catfish flour used knives, cutting boards, steamers, blenders, basins, spoons, trays, a cabinet dryer, a grinder, and a 40-mesh sieve. The production of pregelatinized red bean flour used pots, basins, an autoclave, a cabinet dryer, trays, a grinder, spoons, brushes, and a 60-mesh sieve. The production of dried sponge cake used a digital scale, mixer, basin, plates, spatula, spoon, molds, baking trays, oven, and ziplock bags. The use of separate tools for each processing stage was intended to maintain product quality and reduce the possibility of cross-contamination during preparation and processing.

Production of Catfish Flour

The production of catfish flour in this study followed the procedure of Arvianto et al. (2016) with several controlled processing steps. Fresh catfish were cleaned by removing the gills and impurities. The fish were then washed thoroughly using clean water to remove remaining dirt and unwanted odor. After cleaning, the fish were steamed for approximately 25 minutes until

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fully cooked. Steaming was carried out to soften the fish meat and support the next processing stage. After steaming, the cooked fish were blended until a smooth texture was obtained. The blended fish was then spread evenly on trays and dried using a cabinet dryer at 50°C for 15 hours. Drying was conducted to reduce moisture content and improve the stability of the flour. After the drying process was completed, the dried fish was ground using a grinder until it formed flour. The flour was then sieved using a 40-mesh sieve to obtain a uniform particle size. The catfish flour was stored in clean and closed packaging before being used in the dried sponge cake formulation.

Production of Pregelatinized Red Bean Flour

The production of pregelatinized red bean flour referred to the procedure of Mustikaningrum (2011). Fresh red beans were first sorted and cleaned to remove damaged beans and foreign materials. The red beans were then soaked in $NaHCO_3$ solution using a red bean-to-water ratio of 1:3 for 8 hours. The soaking process was carried out to soften the bean structure, reduce hardness, and support the cooking process.

After soaking, the red beans were cooked using an autoclave for 145 seconds at 15 psi and 121°C. This heating process aimed to produce a precooked or pregelatinized structure. The cooked red beans were then dried using a cabinet dryer at 50°C for 18 hours. After drying, the red beans were ground using a grinder and sieved using a 60-mesh sieve to obtain fine flour with a uniform texture. The pregelatinized red bean flour was then stored in clean packaging before use.

Dried Sponge Cake Formulation

The dried sponge cake formulation used in this study was adapted from Prameswari et al. (2022). The formulation consisted of three treatments with different levels of catfish flour and pregelatinized red bean flour substitution. Formula A was used as the control because it contained 100% wheat flour without catfish flour or red bean flour substitution. Formula B used 65 g wheat flour, 15 g catfish flour, and 20 g pregelatinized red bean flour. Formula C used 65 g wheat flour, 25 g catfish flour, and 10 g pregelatinized red bean flour. The amount of chicken eggs, granulated sugar, margarine, vanilla, and baking powder was kept the same in all formulations to ensure that the observed differences came mainly from the flour substitution.

Table 1. Formula of Dried Sponge Cake with Catfish Flour and Pregelatinized Red Bean Flour Substitution

Composition	Formula A (0:0)	Formula B (15:20)	Formula C (25:10)
Wheat flour (g)	100	65	65
Catfish flour (g)	0	15	25
Red bean flour (g)	0	20	10
Chicken eggs (eggs)	2	2	2
Granulated sugar (g)	100	100	100
Margarine (g)	5	5	5
Vanilla (g)	2	2	2
Baking powder (g)	1	1	1

Production of Dried Sponge Cake

The production of dried sponge cake followed the procedure adapted from Prameswari et al. (2022). Eggs, granulated sugar, and vanilla were first mixed using a mixer at medium to high speed until the mixture became white, fluffy, and thick. After the mixture reached the desired

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texture, the mixer speed was reduced. Wheat flour, catfish flour, and pregelatinized red bean flour were then added gradually according to each formulation. The mixture was stirred until all ingredients were evenly combined.

Before baking, the oven was preheated at 150°C for approximately 10 minutes. The cake molds were greased with margarine to prevent the product from sticking during baking. The homogeneous batter was then poured into the prepared molds. The molds were placed in the oven and baked at 150°C for approximately 40 minutes until the sponge cake was fully cooked and had a yellowish-brown color. After baking, the dried sponge cake was removed from the oven and cooled at room temperature. The cooled products were then packed in ziplock bags to maintain quality before laboratory analysis.

The substitution levels were selected based on the formulation developed by Prameswari et al. (2022). These levels were adjusted to balance nutritional improvement, product acceptability, and processing feasibility. The same processing temperature, baking time, and ingredient quantities were applied to all treatments, except for the amount of wheat flour, catfish flour, and pregelatinized red bean flour.

Analysis of Saturated Fat and Trans Fat Content

The analysis of fat content was carried out using the Soxhlet extraction method as described by Fibri et al. (2014). This method works based on the principle of fat extraction using a nonpolar solvent, namely petroleum ether. A 2-gram sample from each dried sponge cake formulation was placed in the extraction apparatus. The extraction process was carried out for approximately 4 hours, followed by purification for 2 hours. The extracted residue was then dried until it reached a constant weight. The extracted fat was used for the determination of saturated fat and trans-fat content based on laboratory analytical procedures.

All analyses were conducted in duplicate to improve data reliability. Before measurement, the analytical instruments were calibrated according to laboratory standard operating procedures. This calibration process was conducted to ensure that the data obtained were accurate, consistent, and reproducible. The results of saturated fat and trans-fat content were then recorded for each formulation and compared among treatments.

Data Analysis

The data obtained from saturated fat and trans-fat analysis were processed using SPSS version 20. Before selecting the statistical test, the data were tested for normality and homogeneity. Normality was assessed using the Shapiro-Wilk test, while homogeneity of variance was assessed using Levene's test. The results showed that the data were not normally distributed and were not homogeneous. Therefore, the Kruskal-Walli's test was used to determine whether there were significant differences among the three formulations.

The level of significance used in this study was $p<0.05$. If the Kruskal-Walli's test showed a significant difference, further analysis was conducted to identify differences between treatment groups. The statistical analysis was used to determine whether the substitution of catfish flour and pregelatinized red bean flour affected saturated fat and trans-fat content in dried sponge cake.

Result and Discussion

Saturated Fat Content

The saturated fat content of dried sponge cake was analyzed to determine the effect of catfish flour and pregelatinized red bean flour substitution on the lipid profile of the product. The

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analysis was carried out on three formulations, namely Formula A as the control, Formula B with 15% catfish flour and 20% pregelatinized red bean flour, and Formula C with 25% catfish flour and 10% pregelatinized red bean flour. The results are presented as mean ± standard deviation from duplicate measurements.

Table 2. Saturated Fat Test Results

Percentage Composition of Catfish Flour and Pregelatinized Red Bean Flour	Mean Relative Saturated Fat Content (%)	P-Value
Formula A	4.81 ± 1.14^{a}	0.116
Formula B	2.91 ± 0.41^{a}	
Formula C	3.61 ± 1.37^{a}	

Description: Formula A = 100% medium protein wheat flour; Formula B = 15% catfish flour and 20% pregelatinized red bean flour; Formula C = 25% catfish flour and 10% pregelatinized red bean flour. The same superscript letters indicate no significant difference among treatments based on the Kruskal-Wallis test at $p<0.05$.

Based on Table 2, the highest mean saturated fat content was found in Formula A, which was the control formulation, at 4.81 ± 1.14%. The lowest mean saturated fat content was found in Formula B at 2.91 ± 0.41%. Formula C had a mean saturated fat content of 3.61 ± 1.37%. These results show that the substitution formulas had lower saturated fat content than the control formula. Formula B showed the greatest reduction among all treatments.

The decrease in saturated fat content in Formula B and Formula C may be related to the nutritional characteristics of the substituted ingredients. Pregelatinized red bean flour has relatively low-fat content, while catfish flour contains fat that is mostly composed of unsaturated fatty acids. Therefore, the use of these two ingredients can reduce the relative contribution of saturated fat in the final product. This finding is consistent with the role of red bean flour as a low-fat ingredient and the potential of fish-based ingredients to improve the fat quality of food products.

According to Waluyo et al. (2021), parboiling treatment in red beans can increase resistant starch content and reduce oil absorption capacity. Lower oil absorption capacity may help reduce fat retention in processed food products. This condition may explain why Formula B, which contained the highest proportion of pregelatinized red bean flour, produced the lowest saturated fat content. In this study, Formula B used 20% pregelatinized red bean flour, while Formula C used only 10%. The higher amount of pregelatinized red bean flour in Formula B may have contributed to the lower saturated fat value.

However, the Kruskal-Walli's test showed a p-value of 0.116, which means that there was no significant difference in saturated fat content among the three formulations at $p<0.05$. This result indicates that the substitution of catfish flour and pregelatinized red bean flour did not significantly affect saturated fat content in dried sponge cake. Although the values showed a decreasing trend, the difference was not strong enough statistically.

The non-significant result may be influenced using the same amount of margarine and eggs in all formulations. Margarine and eggs are important fat sources in bakery products. Since these ingredients were kept constant across Formula A, Formula B, and Formula C, their contribution to saturated fat may have reduced the visible effect of flour substitution. Sartika (2008) stated that saturated fat content in bakery products is strongly influenced by the type and amount of

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added fat, such as margarine. Therefore, changing the flour composition alone may not be enough to produce a statistically significant decrease in saturated fat content.

Although the statistical result was not significant, the descriptive trend remains important. Formula B and Formula C both showed lower saturated fat content than Formula A. This result suggests that the substitution of wheat flour with catfish flour and pregelatinized red bean flour has potential to improve the lipid quality of dried sponge cake. Among the two substitution formulas, Formula B showed the most favorable saturated fat result because it had the lowest mean saturated fat content.

Trans Fat Content

The trans-fat content of dried sponge cake was analyzed to determine whether flour substitution affected the presence of trans fat in the product. The same three formulations were tested, namely Formula A as the control, Formula B with 15% catfish flour and 20% pregelatinized red bean flour, and Formula C with 25% catfish flour and 10% pregelatinized red bean flour. The results are presented in Table 3.

Table 3. Trans Fat Test Results

Percentage Composition of Catfish Flour and Pregelatinized Red Bean Flour	**Mean Relative Trans Fat Content (%)**	**P-Value**
Formula A	30.07 ± 3.34^{a}	0.024
Formula B	16.81 ± 7.75^{b}	
Formula C	21.34 ± 1.77^{a}	

Description: Formula A = 100% medium protein wheat flour; Formula B = 15% catfish flour and 20% pregelatinized red bean flour; Formula C = 25% catfish flour and 10% pregelatinized red bean flour. Different superscript letters indicate a significant difference among treatments based on the Kruskal-Wallis test at $p<0.05$.

Based on Table 3, the highest mean trans-fat content was found in Formula A at 30.07 ± 3.34%. Formula B had the lowest mean trans-fat content at 16.81 ± 7.75%, while Formula C had a mean value of 21.34 ± 1.77%. These results show that both substitution formulas had lower trans-fat content than the control formula. The largest decrease was found in Formula B.

The Kruskal-Walli's test showed a p-value of 0.024, which means that there was a significant difference in trans-fat content among the three formulations at $p<0.05$. This result indicates that the substitution of catfish flour and pregelatinized red bean flour significantly affected trans-fat content in dried sponge cake. The superscript letters in Table 3 show that Formula B was significantly different from Formula A and Formula C. Meanwhile, Formula A and Formula C had the same superscript letter, which indicates that the difference between these two formulations was not statistically significant.

The lower trans-fat content in Formula B may be linked to the higher proportion of pregelatinized red bean flour. Red bean flour has low fat content and does not undergo hydrogenation. Therefore, it does not contribute greatly to trans-fat formation. Pregelatinization changes the starch structure through heating and cooling, but it does not create industrial trans-fat. Waluyo et al. (2021) explained that parboiling can increase resistant starch and change the functional characteristics of red bean flour. These changes may support lower fat absorption and better lipid quality in the final product.

Catfish flour may also contribute to the improvement of the product's fat profile. Although catfish contains fat, much of its fat is naturally present as unsaturated fatty acids. Natural

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animal-based trans-fat is generally lower than industrial trans-fat produced through hydrogenation (WHO, 2018; Vékony et al., 2026; Ali et al., 2026). Therefore, the use of catfish flour in the formulation did not increase trans-fat content. Instead, when combined with pregelatinized red bean flour, it helped produce a better lipid profile than the control formula.

Formula B showed better results than Formula C. This difference may be caused by the higher amount of pregelatinized red bean flour in Formula B. Formula B contained 20% pregelatinized red bean flour, while Formula C contained only 10%. Although Formula C contained more catfish flour, its trans-fat content was higher than Formula B. This suggests that pregelatinized red bean flour may have a stronger role in reducing the relative trans-fat content of the product than catfish flour. This result supports the selection of Formula B as the best formulation in terms of trans fat reduction.

The significant reduction in trans-fat content has important nutritional implications. Trans fat intake should be limited because it is associated with increased cardiovascular and metabolic health risks. This issue is especially relevant for pregnant women because maternal fat intake can affect pregnancy outcomes and long-term child health. Excessive intake of saturated fat and trans-fat during pregnancy is not recommended because it may contribute to lipid and glucose metabolism disorders, preeclampsia, gestational diabetes, and preterm birth. Khaire et al. (2020) stated that maternal dietary fat composition is a modifiable factor that plays an important role in pregnancy outcomes and long-term health.

Implications of Local Functional Food Innovation for Maternal Nutrition Management

The central contribution of this study is not limited to showing that catfish flour and pregelatinized red bean flour can alter the lipid profile of dried sponge cake. Its broader contribution lies in demonstrating how locally available food resources can be transformed into a managed product innovation with potential relevance for maternal nutrition. From a management perspective, these finding matters because food innovation should not stop at laboratory formulation. It must be understood as a complete value creation process that links raw material selection, product design, production control, consumer acceptance, health positioning, and distribution strategy. The use of catfish and red beans supports the logic that local resources can become strategic inputs when firms or community-based producers develop the capability to process them into stable, acceptable, and nutritionally relevant products. This view aligns with the resource-based perspective, which argues that firms gain advantage when they can organize valuable resources into productive capabilities (Barney, 1991; Nayak et al., 2023; Varadarajan, 2023). In this study, catfish and red beans are not merely ingredients. They represent local resource potential that can be converted into a differentiated food product when supported by proper formulation, processing, quality control, and market positioning.

This paper also strengthens the argument that functional food development should be treated as a strategic management issue. Functional foods fail only because they contain beneficial ingredients. They succeed when the product offers credible health relevance, practical consumption value, acceptable sensory quality, stable production, and a clear market identity. Zhao et al. (2025) and Ketkaew et al. (2024) argued that the functional food market grows when health benefits meet consumer demand and product usability. Ghosh et al. (2024) further showed that functional food innovation requires the integration of science, technology, market knowledge, and firm strategy. The present study fits within this body of work because it moves beyond conventional bakery formulation and introduces a nutritional purpose into a familiar product category. Dried sponge cake is not positioned as a medical intervention. It is positioned as a food product that may support healthier dietary options for pregnant women. This

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distinction is important. A food product can support nutritional goals, but it should not claim clinical outcomes without further intervention-based evidence.

The study also contributes to the management of local food diversification. Indonesia has abundant catfish and red bean resources, yet abundance alone does not create product value. Many local commodities remain underutilized because they are sold as raw materials with limited processing, branding, and market differentiation. Hart's natural-resource-based view emphasizes that competitive advantage can emerge when firms manage natural resources through product stewardship and sustainable development (Hart, 1995). In this context, processing catfish into flour and red beans into pregelatinized flour reflects a product stewardship approach. It extends the utility of perishable and seasonal materials into a more stable intermediate product. Kocatepe et al. (2011) showed that processing can change the proximate characteristics and usability of fish-based products, while Hasanah (2020) and Arvianto et al. (2016) demonstrated the potential of catfish flour in bakery-type products. The implication for managers is clear. Local ingredient innovation requires processing systems that can reduce perishability, control quality, and create consistent inputs for scalable production.

The role of pregelatinized red bean flour is especially important for product development strategy. Legume-based flour has managerial relevance because it allows firms to improve product functionality while differentiating the product from ordinary wheat-based bakery items. Mustikaningrum (2011) showed that pretreatment can improve the processing qualities of legumes, while Lehmann et al. (2002) explained the role of heating and cooling in resistant starch formation. Waluyo et al. (2021) further reported that parboiling can increase resistant starch and affect functional characteristics such as oil absorption. Astuti et al. (2023) also showed that red bean flour has low fat characteristics and can support functional food development. These studies support the practical implication of this paper: managers can use pregelatinized legume flour not only as a nutritional substitute but also as a formulation tool that changes product structure, fat interaction, and functional value. This is useful for food firms that aim to create healthier bakery products without depending only on imported or high-cost functional ingredients.

The results also carry strong implications for product portfolio management. Bakery products often face criticism because they are associated with sugar, refined flour, and added fat. However, this study shows that bakery products can be reformulated into more purposeful food products when ingredient substitution follows a clear nutritional and managerial logic. Prameswari et al. (2022) showed that substitution in traditional cake products can be used to improve nutritional and product characteristics. The present study extends this idea by focusing on lipid quality, especially saturated fat and trans-fat. This is significant because firms that produce bakery products increasingly face pressure to offer healthier choices, not only products that taste good. Sartika (2008) highlighted the health concerns related to saturated and trans fatty acids, and WHO (2018) strengthened the global urgency of reducing industrial trans-fat intake. Therefore, bakery producers need to manage fat sources, flour composition, processing method, and product claims as part of an integrated product strategy. Reformulation is not only a technical decision. It is a strategic decision that affects brand credibility, consumer trust, and long-term market access.

From a maternal nutrition perspective, the implication must be framed carefully. Stunting prevention requires complex interventions that include maternal nutrition, infant feeding practices, sanitation, healthcare access, household food security, and education. This study does not prove that dried sponge cake prevents stunting. It offers a product-level contribution that may support a broader maternal nutrition strategy. This distinction is essential for scientific

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and managerial credibility. Black et al. (2013), Bhutta et al. (2013), and Victora et al. (2008) showed that maternal and child undernutrition requires integrated and evidence-based interventions during critical growth periods. Dewey and Begum (2011) also emphasized the long-term consequences of stunting for human development. Kinshella et al. (2021) argued that maternal health needs stronger attention within the first 1,000 days agenda. The practical implication is that this product should be viewed as one possible component in a broader nutrition program, not as a stand-alone solution. Managers, public health actors, and food entrepreneurs should avoid exaggerated claims and instead position the product as a locally based, healthier snack option for pregnant women.

The focus on saturated fat and trans-fat also has managerial significance because maternal food products must balance nutrient adequacy with metabolic risk control. Khaire et al. (2020) argued that maternal fat intake has implications for pregnancy complications and long-term offspring health. Yisahak et al. (2021) showed that maternal dietary patterns in early pregnancy relate to neonatal outcomes. Cohen et al. (2023) added that poorer maternal diet quality during pregnancy may relate to less favorable metabolic outcomes in offspring. Jasińska-Melon et al. (2022) also highlighted the need to monitor trans fatty acids in diets intended for pregnant and breastfeeding women. These studies support the relevance of developing maternal food products that do not merely increase calories or protein but also consider fat quality. For management practice, this means product development teams should not evaluate maternal food products through single-nutrient logic. A product can be high in protein yet still poorly positioned if its fat profile, sugar content, food safety, and acceptability are weak. The current study provides a useful starting point by placing lipid quality within the product development conversation.

The study's implication for innovation management is also important. Food innovation is rarely linear. It requires sensing consumer needs, seizing product opportunities, and transforming operational routines. Teece (2007) described dynamic capabilities as the firm's ability to sense, seize, and transform in response to opportunities and changes. In this study, the opportunity is the need for practical, local, and healthier food products for pregnant women. The seizing activity appears in the formulation of dried sponge cake with catfish flour and pregelatinized red bean flour. The transformation challenge lies in moving from laboratory formulation to standardized production, consumer testing, packaging, costing, certification, and market distribution. Firms or community enterprises that want to commercialize this product must develop routines for raw material sourcing, flour production, moisture control, batch consistency, sensory evaluation, shelf-life monitoring, and nutritional labeling. Without these routines, the product will remain a promising formulation but not a reliable market offering.

The consumer side cannot be treated as secondary. A food product designed for health will fail if consumers perceive it as strange, unpleasant, expensive, unsafe, or inconvenient. Costa and Jongen (2006) argued that consumer-led food product development requires firms to integrate consumer needs early in the innovation process. Grunert (2005) showed that perceptions of quality and safety shape food demand. Verbeke (2005) found that consumer acceptance of functional foods depends on cognitive and attitudinal factors, while Verbeke (2006) warned that consumers are not always willing to sacrifice taste for health. Bech-Larsen and Grunert (2003) also showed that perceived healthiness differs across consumers and product contexts. For this study, the management implication is direct. The product should not be marketed only as a scientific formulation. It must be tested through sensory acceptance, perceived naturalness, willingness to pay, purchase intention, and trust in health information. Pregnant women may value nutrition, but they still make food choices based on taste, familiarity, price, convenience, and safety.

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This point becomes more important because functional food acceptance depends on the relationship between the ingredient, the carrier product, and the claimed benefit. Urala and Lähteenmäki (2007) showed that attitudes toward functional foods evolve when consumers see clear and believable benefits. Ronteltap et al. (2007) argued that perceived benefit, perceived risk, and trust influence acceptance of technology-based food innovations. Baker et al. (2022) further synthesized evidence that consumer acceptance of functional foods is shaped by product characteristics, individual factors, trust, perceived effectiveness, and communication. These findings matter because catfish flour in a sweet bakery product may create mixed consumer responses. Some consumers may value the protein content and local ingredient identity. Others may worry about fishy aroma, texture, or product freshness. Therefore, management decisions should include deodorization control, texture optimization, packaging communication, and clear explanation of the product's nutritional purpose. The product must make sense to consumers, not only to researchers.

The strongest practical implication concerns positioning. The product should be positioned as a locally sourced functional snack for maternal nutrition, not as a medicine and not as a generic cake. Porter and Kramer (2011) argued that firms can create shared value by aligning business growth with social needs. This study provides a concrete context for shared value creation. A firm or food enterprise can build a marketable product from local catfish and red beans while supporting maternal nutrition goals. However, shared value requires discipline. It must be supported by measurable nutrition quality, responsible claims, affordable pricing, and an accessible distribution model. If the product becomes too expensive for the intended maternal segment, its social value weakens. If the health claim exceeds the evidence, its credibility weakens. If the supply chain cannot maintain quality, its market value weakens. Therefore, the product strategy should connect nutrition evidence, production economics, and consumer affordability.

The supply chain implications are also substantial. Catfish and red beans are locally available, but local availability does not automatically guarantee stable quality. Catfish is highly perishable, and fish-based flour requires careful drying, grinding, storage, and odor control. Red beans require sorting, soaking, heating, drying, and milling consistency. Trienekens and Zuurbier (2008) emphasized that quality and safety standards in the food industry have become central because modern food supply chains are increasingly interconnected and risk sensitive. Luning and Marcelis (2009) argued that food quality management must combine technological and managerial principles. This study therefore implies that producers must develop quality assurance systems before product expansion. They need raw material specifications, supplier selection criteria, process control sheets, moisture monitoring, packaging standards, storage procedures, and batch records. These managerial systems determine whether the product can move from experimental production to commercial production.

Food safety must receive the same attention as nutrition. A product intended for pregnant women carries a higher responsibility because the consumer group is nutritionally and biologically sensitive. Sadomo and Siwiendrayanti (2023) emphasized that hygiene and sanitation are important in preventing foodborne disease transmission, while Nurhayati et al. (2020) highlighted the role of food handler behavior and personal hygiene in contamination risk. This means that the managerial value of the product depends on safe production practices. Producers should apply Good Manufacturing Practices, sanitation standard operating procedures, and hazard-based controls. The use of fish-based flour requires strict attention to drying temperature, moisture reduction, storage, microbial safety, and rancidity prevention. Without these controls, the nutritional advantage of the product can be weakened by safety risk. In food management, safety is not an operational detail. It is part of the value proposition.

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The study also opens an opportunity for small and medium enterprises, local cooperatives, and community-based food producers. Catfish farmers and red bean producers can gain more value if their commodities enter processed food supply chains rather than remaining as raw materials. This supports local economic upgrading. However, upgrading requires coordination among producers, processors, universities, laboratories, health offices, and distribution partners. The product cannot scale through informal production alone. It needs a managed local food system. This is consistent with the innovation system view in which product development depends on linkages among knowledge institutions, producers, market actors, and policy support. For practical implementation, universities can support formulation and testing, SMEs can manage production, local governments can support certification and training, and maternal health programs can support education and distribution. The product therefore has relevance not only as a food formula but also as a local innovation model.

The discussion also shows why formulation management should become more rigorous in future work. The present study gives an important signal, but managers should not move directly from laboratory results to broad commercialization. They need a staged development process. The next stage should test sensory acceptance, protein content, total energy, sugar content, dietary fiber, shelf life, microbial quality, packaging stability, cost per serving, and consumer willingness to pay. The product should also be tested with the target users, especially pregnant women, because maternal food acceptance can differ from general consumer acceptance. A product that works technically may fail commercially if it does not match the eating habits, taste preferences, income level, and trust concerns of the target group. This is why food innovation requires both laboratory evidence and market evidence. Functional value must be validated through consumer relevance.

This study also has implications for responsible health communication. The product may support healthier food development, but it should not be presented as a direct anti-stunting product unless clinical or program evaluation evidence supports that claim. The more defensible claim is that the product uses local ingredients and shows potential to improve lipid quality in a bakery product intended to support maternal nutrition. This form of communication protects scientific integrity and reduces the risk of misleading consumers. It also supports long-term brand trust. Grunert (2005), Verbeke (2005), and Baker et al. (2022) all show that food choice depends heavily on trust, perceived quality, and perceived benefit. Therefore, the communication strategy should use clear language, transparent nutrition information, and cautious claims. For example, managers may emphasize local ingredients, improved formulation, and suitability as an alternative snack, while avoiding claims that promise disease prevention or guaranteed pregnancy outcomes.

The broader theoretical implication is that health-oriented food innovation in developing-country contexts should be understood as a strategic capability that joins nutrition science with management science. Many nutrition studies stop at nutrient composition. Many management studies discuss innovation without enough product-level evidence. This study sits between those fields. It shows that a product formulation can become a site of strategic value creation when it links local resources, nutritional improvement, consumer needs, and production feasibility. Barney (1991), Hart (1995), Teece (2007), and Porter and Kramer (2011) provide a useful theoretical foundation for understanding this contribution. The product uses local resources, addresses a social nutrition concern, requires dynamic capability to scale, and offers a possible shared-value pathway. This is the main management contribution of the paper.

In practical terms, the most promising direction is to develop the selected substitution formula into a prototype for controlled product development. The next managerial task is not only to

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confirm the lipid profile but to build a viable product system around it. That system must include supplier contracts, flour standardization, production flow, quality control, packaging design, pricing strategy, consumer education, and distribution channels. Possible channels include maternal health programs, local food SMEs, school or community nutrition initiatives, clinics, pharmacies, and digital marketplaces. Each channel requires a different value proposition and compliance requirement. For example, distribution through health programs requires stronger nutrition evidence and institutional approval. Distribution through retail requires packaging appeal, shelf stability, and price competitiveness. Distribution through SMEs requires simple processing procedures and cost control. The product's future depends on the alignment between scientific value and managerial execution.

The main lesson for this field is that local functional food development must move beyond the language of substitution. Substitution is only the technical entry point. The strategic question is how substitution creates value, for whom, through what production system, and with what evidence. This study suggests that catfish flour and pregelatinized red bean flour can support the development of a dried sponge cake with a more favorable lipid direction. Yet the managerial contribution becomes stronger when this formulation is linked to maternal nutrition needs, local commodity upgrading, responsible health positioning, food safety management, and consumer-led product development. Future research should therefore combine experimental food analysis with sensory science, business feasibility, supply chain analysis, and intervention design. Only then can local ingredient innovation become a credible, scalable, and socially relevant food management strategy.

Conclusion

This study concludes that the substitution of catfish flour and pregelatinized red bean flour in dried sponge cake has practical potential for developing a healthier local functional food product for maternal nutrition management. Although the reduction in saturated fat content was not statistically significant, the substitution formulas showed a lower saturated fat tendency than the control. More importantly, the substitution significantly reduced trans-fat content, with Formula B, consisting of 15% catfish flour and 20% pregelatinized red bean flour, producing the most favorable result. These findings indicate that combining locally available animal and plant-based ingredients can improve the lipid quality of bakery products while supporting product diversification for pregnant women. From a management perspective, this study highlights the importance of transforming local food resources into value-added products through evidence-based formulation, quality control, and responsible health positioning. Further research should examine sensory acceptance, protein content, shelf life, production feasibility, and consumer willingness to purchase so that this product can be developed into a scalable functional food innovation that supports broader maternal nutrition and stunting prevention strategies.

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