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Substitution of Tongkol Fish Bone Meal in Tempeh Nugget Products as an Alternative Food Rich in Protein and Calcium for Toddlers

Substitusi Tepung Tulang Ikan Tongkol pada Produk Nugget *Tempe sebagai Makanan Alternatif Kaya Protein dan Kalsium untuk Balita*

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ABSTRACT

Background: One approach to preventing stunting is the provision of supplemental feeding (PMT). Tongkol fish bones are an underutilized waste product. An innovation in utilizing fish bone waste involves processing it into flour for inclusion in tempeh nugget formulations.
Objectives: This study aims to develop a protein- and calcium-rich food source to support stunting prevention efforts among toddlers.
Methods: This study employed an experimental design with quantitative analysis. A completely randomized design (CRD) was used with four factorial treatments and two replications. The ratios of Tongkol fish bone meal to wheat flour were 0:20 g, 5:15 g, 7:13 g, and 9:11 g. Chemical analysis was conducted to evaluate the nutritional content of tempeh nuggets, while organoleptic testing was employed to identify the optimal tempeh nugget formulation.
Results: The selected formulation (F1, 25%) provided 84.8 kcal energy, 6 g protein, 4.15 g fat, 7.66 g carbohydrates, and 638.66 mg calcium per 100 g. A serving size of 7 pieces (50 g) contained 129 kcal energy, 6 g protein, 6 g fat, 11 g carbohydrates, and 292 mg calcium.
Conclusions: Tempeh nuggets enriched with fish bone flour can be considered a viable source of protein and calcium, meeting nutritional claim thresholds.

INTRODUCTION

Globally, the prevalence of stunting in toddlers was 21.9% in 2018, according to the World Health Organization, while in Southeast Asia, it reached 25%[1]. In Indonesia, the prevalence of stunting was 24.4% in 2021, with DKI Jakarta Province reporting 16.8% and the South Jakarta area at 15.7%[2]. Although the prevalence in the capital city is lower than the national average, it still does not meet the government's target, necessitating further efforts to reduce or prevent stunting.

One effective strategy is the provision of supplemental feeding (PMT) using local foods. Toddlers often experience difficulties eating, showing a preference for snacks or food purchased outside the home. To address this, it is crucial to provide additional, nutritionally dense foods tailored to their needs. Animal-based foods, particularly those sourced from fisheries, are high-quality sources of nutrients that can significantly contribute to improving community nutrition[3]. Fishery resources, such as Tongkol, offer a rich source of animal protein. Tongkol fish bones, often discarded as waste, can be processed into flour rich in protein and calcium. This flour can be used in various food products, including nuggets—a favorite food among children. By modifying traditional nugget recipes to include Tongkol fish bone flour, a high-protein and calcium-rich alternative can be developed[3].

Research conducted by Septiansyah in 2020 reported Indonesia's marine fish productivity at 2,752,838 tons, with Tongkol contributing 31.2%, followed by skipjack (26.1%), mackerel (17.2%), shark (14.1%), and various other fish (10.7%)[4]. Data from the Ministry of Maritime Affairs and Fisheries shows that Tongkol, skipjack, and tongkol (TCT) are the types of fish most frequently consumed by Indonesians, accounting for 16.45% of total fish consumption. Mackerel, often referred to as "small Tongkol" due to its blackish-white flesh, is a familiar taste for the Indonesian palate[3]. Tongkol (Euthynnus affinis) has a high nutritional value, containing 26% protein, 2% fat, omega-3 fatty acids, and significant amounts of essential mineral salts[4]. Skipjack Tongkol bone waste is composed of major constituent compounds such as calcium oxide, phosphate, and carbonate. This waste can be processed into flour, which

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contains high levels of calcium and calcium phosphate, making it a superior source of calcium compared to other forms[4]. Long-term calcium deficiency can lead to suboptimal bone structure formation and interfere with growth during critical developmental stages[5]. Fish bone flour offers several advantages, including practicality, extended shelf life, and versatility, as it can be processed into various popular food products, such as nuggets[6].

Tempeh nuggets are a food product derived from tempeh, a traditional fermented soybean product made by utilizing various types of molds. Tempeh retains most of the nutrients found in soybeans during the fermentation process, which enhances the digestibility of its protein. As a result, tempeh is considered a high-protein food. Many studies have shown that tempeh serves as an economical source of protein for children in developing countriess[7]. According to Novelina's research in 2010, transforming tempeh into nuggets can significantly increase its added value[8]. The nutritional content of tempeh nuggets is not diminished during processing; instead, the product's nutritional value is enhanced, owing to its high protein and low fat content[9]. This study aims to develop tempeh nuggets enriched with calcium by incorporating Tongkol fish bone flour, creating a nutritious product that is especially appealing to toddlers and the community at large.

METHODS

This study employed a Completely Randomized Design (CRD) experimental approach with four substitution levels of Tongkol fish bone meal: F0 (0%), F1 (25%), F2 (35%), and F3 (45%). The research was conducted from November to February 2023. The production of Tongkol fish bone meal and the analysis of proximate and calcium content were carried out at the Nutrition Laboratory, Faculty of Health Sciences, University of Muhammadiyah Prof. Dr. Hamka, Limau, South Jakarta, and the Saraswanti Indo Genetech Laboratory, Bogor. To ensure the validity and reliability of the proximate and calcium analyses performed on the tempeh nuggets, all procedures followed standard laboratory methods. Nutritional parameters measured included water, ash, protein, carbohydrate, fat, and calcium content. The process of making tempeh nuggets substituted with Tongkol fish bone flour involved the following steps, as illustrated in Figure 1:


1. Preparation of Materials


2. Mixing Ingredients


3. Molding the Nugget Dough into a tar shape measuring 4-5 cm


4. Steam for 30 minutes at a temperature of 95°C


5. Making Nugget Coating with Eggs, Wheat Flour, and Breadcrumbs


6. Nuggets Ready to be Fried

Figure 1. The process of making fish bone flour tempeh nuggets

Strict quality control, including equipment calibration, was applied to maintain the accuracy and reliability of the results. This study employed an experimental design with a quantitative approach, using a Completely Randomized Design (CRD) with four factors and two replications. The comparison levels between Tongkol fish bone flour and wheat flour were 0:20 g, 5:15 g, 7:13 g, and 9:11 g. Various proportions of mackerel bone meal (0%, 25%, 35%, and 45%) were tested to evaluate their effects on the quality and nutritional value of tempeh nuggets. The aim was to identify the optimal concentration of mackerel bone meal that could enhance protein and calcium content without compromising organoleptic qualities such as aroma, taste, and texture. The 0% level served as the control, while the other levels were increased incrementally to observe changes resulting from the addition of mackerel bone meal. The materials used in this study included tempeh obtained from Kebayoran Market, Tongkol fish bones from a market in West Jakarta, and wheat flour purchased from a grocery store in Kebayoran Market. These ingredients were chosen for their high nutritional content. Tempeh,

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in particular, contains unsaturated fatty acids that help counteract the harmful effects of sterols in the body, serves as a potential source of vitamin B and minerals, and contains antioxidants beneficial for combating free radicals. Organoleptic testing of the tempeh nuggets utilized a hedonic scale (1–2) and hedonic quality scale (1–5). To ensure consistent assessments from each panelist, training and clear descriptions of the evaluation criteria were provided. Validity and reliability were maintained through careful selection of panelists, the inclusion of a large number of panelists, repetition of assessment sessions, statistical analysis, and regular training. This rigorous approach ensured objective and credible product evaluations. The panel consisted of 75 individuals: 20 mothers of toddlers, 20 toddlers, and 35 students from the University of Muhammadiyah Prof. Dr. Hamka (UHAMKA). Criteria for toddler participants included residing in the South Jakarta area and being aged 3–5 years. Adults aged 18–45 years participated in the hedonic quality test. Toddlers were included because the tempeh nugget product was designed as a supplementary food for children aged 3–5 years. Individuals who did not meet the location or age criteria or had health conditions that could be affected by product consumption (e.g., allergies) were excluded from the study. Regarding research ethics, all procedures adhered to established ethical standards. Approval was obtained from the Health Research Ethics Committee (Non-Medical) of the University of Muhammadiyah Prof. Dr. Hamka (KEPKK-UHAMKA), with ethics approval number 03/22.12/02163 issued on December 9, 2022. This approval ensured that the research was reviewed and deemed ethically compliant. The data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) software. The Kruskal-Wallis test was employed to determine significant differences among the groups. If differences were identified, Dunn's Post Hoc Test was conducted to further analyze the data. This test is particularly suitable for small sample sizes and non-normally distributed data, allowing for the identification of differences between unpaired samples.

RESULTS AND DISCUSSIONS

Based on the results of the organoleptic test, this study involved four formulas: Formula F0, Formula F1, Formula F2, and Formula F3. Each formula was tested to assess sensory attributes such as taste, aroma, texture, and appearance. The detailed results of the organoleptic test for each formula are presented in Table 1.

Table 1. Hedonic Quality Test of Tempeh Nugget with Tongkol Fish Bone Meal

Parameter	Mean±SD				p-value
	F0 (0%)	F1 (25%)	F2 (35%)	F3 (45%)	
Texture	3.18±0.884[b]	3.00±0.981[b]	2.62±0.828[a]	2.51±0.690[a]	<0.001*
Taste	3.49±0.573[b]	3.31±0.767[b]	2.31±0.979[a]	2.11±0.832[a]	<0.001*
Aroma	3.50±0.050[b]	3.38±0.049[b]	3.01±0.070[b]	2.89±0.104[b]	<0.001*
Color	3.50±0.050[b]	3.38±0.049[b]	3.01±0.070[a]	2.89±0.104[a]	<0.001*

*) *Kruskal Wallis* test, significant if p-value<0.05

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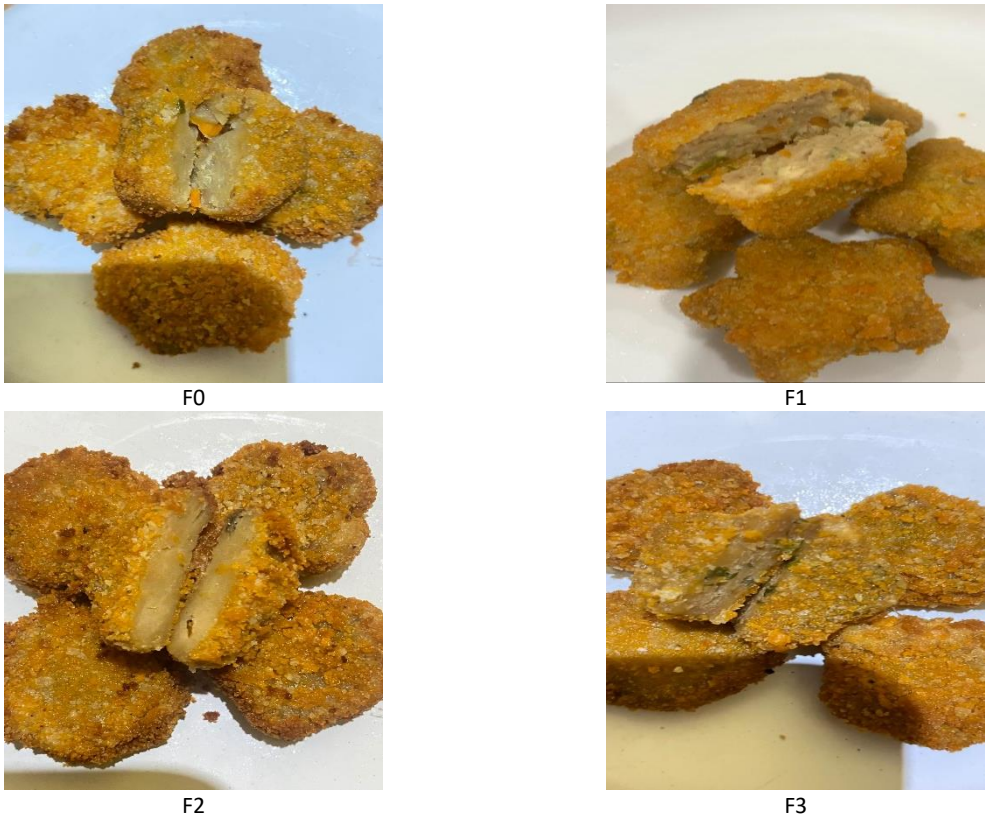

Figure 3. Tempeh nuggets Formula F0, F1, F2, F3

Texture

As shown in Table 1, the texture of the four treatments (F0, F1, F2, and F3) exhibited significant differences. Notably, F1 achieved the highest texture score with an average value of 3.00, indicating a non-hard texture, whereas F3 had the lowest score at 2.51, indicating a slightly hard texture. The differences are attributed to the substitution of Tongkol fish bone flour for wheat flour, which affects the texture properties. Texture refers to the tactile quality of a surface, encompassing attributes such as hardness, softness, roughness, or smoothness. It is influenced by various physical stimuli, including pressure, dryness, and moisture. According to research by Heridiansyah (2014), texture is the sensation of pressure felt with the tongue or fingertips and is affected by factors such as consistency, thickness, and smoothness[10]. This study supports findings by Merta (2020)[11], who demonstrated that reducing Tongkol fish bone flour decreases air content in nuggets, thereby affecting texture. Deasy, Dewi, and Susanto (2013) also found that texture characteristics are determined by water content, fat content, carbohydrates, and proteins[12]. Bunta (2013) further emphasized that calcium-rich fish bone flour results in harder products[13]. Consequently, as the concentration of fish bone flour increased, the texture of the tempeh nuggets became harder.

Flavor

Significant differences in taste were also observed across the four treatments (F0, F1, F2, and F3). F1 achieved the highest taste score, with an average value of 3.31, rated as "delicious," while F3 had the lowest score at 2.11, rated as "not delicious." The reduced panelist preference for higher concentrations of Tongkol fish bone flour can be attributed to the distinctive flavor of the fish bone flour, which overpowered other ingredients. Taste is a response to chemical stimuli detected by taste buds, with distinct receptors for sweetness, saltiness, sourness, and bitterness[14]. The tongue can detect sweetness at the tip, saltiness at the tip and sides, sourness at the edges, and bitterness at the back. In this study, the higher the concentration of mackerel bone flour, the stronger the fish bone flavor, leading to decreased panelist preference. As stated by[15], the concentration of Tongkol fish bone meal significantly affects panelists' preference for the taste of the modified food product, primarily due to the dominance of the strongly flavored fish. According to research conducted by Hastuti in 2016, as cited in Ardin's research, the taste of a product depends on the composition of the ingredients used. In the case of nuggets, the main ingredients, such as meat and mixed spices, influence the taste and may lead to a decrease in overall palatability[16,17]. The findings of this study indicate that increasing the percentage of mackerel bone meal in nuggets does not correlate proportionally with the percentage of meat. On the contrary, a higher concentration of mackerel bone meal is more likely to negatively affect the meat, tempeh, and spices in the nuggets, ultimately compromising the sensory quality of the final product.

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Aroma

Based on Table 1, the aroma characteristics of the four treatments (F0, F1, F2, and F3) showed significant differences, particularly between F1 and F3, and F1 and F0. The highest sensory score for aroma was observed in treatment F3, with an average value of 3.50 (easily detectable), while the lowest was an average of 3.07 (slightly detectable). This outcome can be attributed to the small amounts of Tongkol fish bone flour added to the tempeh nuggets compared to wheat flour. Aroma is defined as anything detectable by the olfactory sense that produces a smell. Odorous substances, when carried by air, enter the olfactory network in the nose, allowing individuals to perceive these substances as distinct aromas. Food aromas arise from the synthesis of volatile molecules, which may occur due to enzyme-mediated processes or independently of them. In this study, as the proportion of Tongkol bone flour increased, fewer aromas were detected by panelists, likely due to the strong fishy smell imparted by the bone flour. This observation aligns with Deswita's 2019 findings, which stated that bone flour contributes a dominant fishy odor to tempeh nuggets. Similarly, Merta (2020) noted that increasing Tongkol bone flour in the dough decreases the meaty aroma of nuggets[18,19]. Processed Tongkol bones, however, lack a pungent odor, which explains why they fail to enhance panelists' preferences. According to Nile (2017), panelists' preference for the aroma of nuggets tends to decrease as the number of additional ingredients in the dough increases[19]. The Indonesian National Standard (SNI) 01-6638-2002 explains that the aroma of nugget products harmonizes with the composition of ingredients used in their preparation, including spices and other additives.

Color

Based on Table 1, the color characteristics of the four treatments (F0, F1, F2, and F3) showed significant differences, particularly between F2 and F0, and between F3 and both F0 and F2. The highest sensory score for color was observed in treatment F1, with an average value of 3.38 (moderately strong), while the lowest was an average of 2.89 (strong). This result is likely due to the relatively small amount of Tongkol fish bone flour added to the tempeh nuggets compared to wheat flour. Color is the first impression perceived and evaluated by panelists. According to Florentinus Gregorius (1997), color is the primary organoleptic element in food presentation, assessed visually to form an initial impression[20]. Attractive colors can draw panelists or customers to test a product. This finding aligns with research conducted by Ayu Rahmawati, Safitri, and Ardin, who reported that the addition of Tongkol fish bone flour did not significantly impact the organoleptic characteristics, including the color of cookies, soy milk, and karasi cakes[21,22,17]. Ketaren (1986) highlighted that frying can alter product color, with factors such as frying duration, temperature, and the chemical composition of the food's surface influencing the intensity of the color produced[23]. According to Merta (2020), the brownish-yellow color in nuggets results from the Maillard reaction, a non-enzymatic process. This reaction occurs between amino groups in proteins—primarily from chicken meat—and simple carbohydrates in wheat flour during frying[11]. Rusdin (2015) elaborated that the Maillard reaction is a complex process involving the interaction between reducing sugars and amino groups in proteins, producing melanoidin compounds that impart a brown color to food[24].

Determination of Selected Formula for Tempe Nuggets as a Source of Protein and Calcium

The determination of the selected formula was conducted using the Exponential Comparison Method (MPE). Each parameter tested in this study was given equal weight of 25%. Then, each formula was assigned a ranking number from 1 to 4 based on the average value obtained. The total score was calculated by adding the results of the multiplication between the ranking and the weight of each parameter[25]. In MPE, the formula or treatment with the lowest total score was considered the optimal choice. Based on the calculation, it was found that the formula chosen for the Tongkol bone flour tempeh nugget product was Formula 1, as it had the lowest total score.

Table 2. Hedonic Test Method to Determine the Selected Formula of Tempe Nuggets as a Source of Protein and Calcium

Parameters	Weight	Alternative Component Scores							
		F0		F1		F2		F3	
		Rank	Score	Rank	Score	Rank	Score	Rank	Score
Texture	40%	1	0.4	2	0.8	3	1.2	4	1.6
Flavor	30%	1	0.3	2	0.6	3	0.9	4	1.2
Aroma	20%	1	0.2	2	0.4	3	0.6	4	0.8
Color	10%	1	0.1	2	0.2	3	0.3	4	0.4
Total Score		**1**		**2**		**3**		**4**	

It can be seen from the data in Table 2 that the overall value of the hedonic quality level of the panelists was obtained from each different parameter: texture, flavor, aroma, and color. The value for each parameter is the overall result of each, which is then multiplied by the respective weighting. The parameters in the formulation are added together to calculate the average. The average obtained from the hedonic quality test is then summed according to the formulation to derive the final results.

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Table 3. The Average Values Obtained from the Hedonic Quality Test

Indicator (Overall)	Formulation			
	F0	F1	F2	F3
Likes	34	33	26	25
Dislikes	6	7	14	15
Total	**40**	**40**	**40**	**40**

Based on Table 3, the formula with the lowest score was F3, followed by F2. The product with the highest score was F0, which was liked by 34 people and disliked by 6 people. Meanwhile, F1 was liked by 33 people and disliked by 7 people. This shows that toddlers preferred the tempeh nugget product with the addition of Tongkol fish bone flour in formula F1, followed by F0.

Nutritional Content of Selected Formula Tempe Nuggets

The three tested nugget formulas—Formula 1 (25%), Formula 2 (35%), and Formula 3 (45%)—revealed that nuggets with Formula 1 (25%) were the best. In other words, Formula 1 can be accepted better than the other formulas. Nuggets with Formula 1 contain the following nutrients: 258.77 kcal/100 g of energy, 113.91 kcal/100 g of energy from fat, 23.68 g/100 g of carbohydrates, 12.53 g/100 g of protein, 12.65 g/100 g of fat, 4.72 g/100 g of unfried fat, 47.64% water content, 3.48% ash content, and 584.87 mg/100 g of calcium.

Protein Content

The protein content in the selected tempeh nugget products is 12.53 grams per 100 g. According to BPOM claims in 2016, a food product is considered a source of protein if it provides 20% of the Nutrition Label Reference (NLF) per 100 g (in solid form), or 5.2 g, and is considered high in protein if it provides 35% of the NLF per 100 g (in solid form)[26] . Tempeh nugget products can meet the protein source claim because they contain 12.53 g per 100 g. Protein, unlike other macronutrients such as carbohydrates and lipids, plays a more significant role in the production of biomolecules than as a source of energy (contributing to body structure)[27]. According to Adani's research in 2017, insufficient protein intake can lead to linear growth disorders and result in stunting[28].

Fat Content

From the results of the laboratory analysis, two values for fat content were obtained: one for fried nuggets and one for unfried nuggets. The highest fat content was found in fried tempeh nuggets, with 12.65 g per 100 g, compared to unfried nuggets, which contained 4.72 g per 100 g. The frying process affects the fat content of the nuggets. When the nuggets are fried, the water in them evaporates, allowing some oil to seep into the nuggets and fill the empty spaces previously occupied by water. The amount of oil absorbed to soften the center of the nugget corresponds to the amount of water that evaporates. The thicker the center layer of the nugget, the more oil it will absorb. This study is in line with the research conducted by Ayu in 2009[29].

Calcium Levels

The calcium content in the selected tempeh nugget products is 584.87 mg per 100 g. According to BPOM's nutritional claims in 2016, a food product is considered a source of calcium if it provides 15% of the NLF per 100 g (in solid form), or around 97.5 mg, and is considered a "high" source if it provides twice that amount[26]. Tempeh nugget products can meet the claim of being a source of calcium because they contain 584.87 mg per 100 g. Ninety-nine percent of calcium in the human body is found in the bones, making calcium an essential element for human health. Additionally, according to Clements' research in 2014, biological fluids such as blood serum, body cells, extracellular fluid, and intracellular fluid contain up to 1% calcium[30]. Calcium deficiency during the growth phase can reduce bone hardness in the bone formation process. Furthermore, rickets can result from calcium deficiency in childhood, as it disrupts the development of bone structure, and severe deficiency can stunt growth. According to research[31], calcium intake is crucial for optimal child growth.

The advantages of this study are that the tempeh nugget products made from Tongkol fish bone flour have high protein and calcium content. The study used the RAL method, proximate analysis, and valid organoleptic tests, which showed that the F1 formula (25%) has good acceptability in taste, texture, aroma, and color. This product supports the prevention of stunting by increasing the nutritional intake of toddlers locally and economically, with a production cost of only IDR 1,400 per serving. Meanwhile, the disadvantages of this study include the suboptimal processing method for eliminating the fishy smell.

Strength and Limitation of Research

In this study, the main strength lies in the innovation of tempeh nugget products made with Tongkol fish bone flour, which offers high nutritional value, particularly in terms of protein and calcium. The variations in formulas with four different treatments allow researchers to clearly assess the differences in organoleptic quality and nutritional content. The results of the organoleptic test, which showed the F1 treatment (25%) as the most preferred, indicate the potential for this recipe to be accepted by the market.

However, this study also has some weaknesses. First, the product has an unpleasant aroma, which may reduce consumer appeal. This highlights the need for further processing strategies to reduce or eliminate the fishy odor of Tongkol bone flour. Second, there were challenges in the questionnaire completion process, which was less conducive, and the texture assessment indicators were imprecise.

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CONCLUSIONS

The organoleptic test showed that F1 (25%) had the highest panelist acceptance due to its delicious taste, tender texture, non-fishy aroma, and attractive color. Further research should focus on improving processing methods to reduce the fishy smell, such as soaking in lime or using fermentation techniques. Enhancing research methodology, including more detailed questionnaires and a conducive evaluation environment, will help obtain accurate data. Future studies could also explore different processing techniques or additives to improve the organoleptic and nutritional quality of tempeh nuggets.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

DCU: conceptualization, methodology, data curation, investigation, writing-original draft, project administration; MS: supervision, formal analysis, validation, writing-review & editing, funding acquisition; NRM: resources, data curation, visualization, writing-review & editing.

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