

# Nutritional, Sensory, and Consumer Preference Analysis of Milkfish Fortified with Shrimp Waste Flour

Julia Agustina<sup>1\*</sup>, Rahmat Dhandy<sup>2</sup>, Amelia Dwi Nugrahaini<sup>3</sup>, Elis Rahmawati Mar'atus Sholihah<sup>4</sup> and Andi Muhammad Ismail<sup>5</sup>

<sup>1</sup>Agribusiness Management Department, Politeknik Negeri Jember; [julia.agustina@polije.ac.id](mailto:julia.agustina@polije.ac.id)

<sup>2</sup>Agribusiness Management Department, Politeknik Negeri Jember; [rahmat.dhandy@polije.ac.id](mailto:rahmat.dhandy@polije.ac.id)

<sup>3</sup>Agribusiness Management Department, Politeknik Negeri Jember; [amelia.dwi@polije.ac.id](mailto:amelia.dwi@polije.ac.id)

<sup>4</sup>Agribusiness Management Department, Politeknik Negeri Jember; [elis\\_rahmawatims@polije.ac.id](mailto:elis_rahmawatims@polije.ac.id)

<sup>5</sup>Agribusiness Management Department, Politeknik Negeri Jember; [andi\\_m\\_ismail@polije.ac.id](mailto:andi_m_ismail@polije.ac.id)

\* Correspondence: [julia.agustina@polije.ac.id](mailto:julia.agustina@polije.ac.id)

**Abstract:** Shrimp and milkfish are major aquaculture commodities in Sidoarjo; however, shrimp processing produces substantial by-products rich in protein, minerals, and bioactive compounds. Utilizing these by-products as fortifying ingredients for milkfish pempek supports circular-economy practices and enhances functional food development. Three pempek formulations containing 0%, 10%, and 15% shrimp waste flour were prepared and evaluated. Proximate analysis followed AOAC standard methods, while sensory evaluation was performed by 20 semi-trained panelists using a five-point hedonic scale. Data were analyzed using ANOVA and Tukey's HSD ( $p < 0.05$ ). Fortification significantly increased protein and ash contents while reducing moisture and carbohydrate levels. The 10% substitution (Product B) provided balanced nutritional enhancement and obtained the highest sensory scores, particularly for texture and color. In contrast, the 15% formulation exhibited lower acceptability due to intensified crustacean aroma and coarser texture. A 10% substitution level optimizes both nutritional quality and sensory acceptance, supporting sustainable utilization of shrimp by-products.

**Keywords:** milkfish pempek, fortification, proximate analysis, nutritional quality

**Citation:** J. Agustina, R. Dhandy, A. D. Nugrahaini, Elis R. M. Sholihah and A. M. Ismail, "Nutritional, Sensory, and Consumer Preference Analysis of Milkfish Fortified with Shrimp Waste Flour", *TEFA*, vol. 3, no. 1, pp. 26–32, Jan. 2026.

Received: 20-12-2025

Accepted: 28-01-2026

Published: 31-01-2026



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## 1. Introduction

Sidoarjo Regency is one of the leading aquaculture centers in East Java, particularly known for its high production of shrimp and milkfish. Milkfish (*Chanos chanos*) is widely cultivated due to its adaptability, rapid growth, and high protein content, making it suitable for the development of various value-added products. Pempek, a traditional fish-based product originating from South Sumatra, has become increasingly popular across Indonesia because of its distinctive chewy texture, savory flavor, and formulation versatility [1]. This growing popularity creates opportunities for product innovation using locally available aquatic resources.

Shrimp, another major aquaculture commodity in Sidoarjo, generates substantial amounts of by-products—especially heads and shells—during processing. These materials are often discarded, contributing to environmental waste despite their considerable nutritional and economic potential. Previous studies have demonstrated that shrimp waste is rich in chitin, protein, minerals (calcium, phosphorus, magnesium), and bioactive compounds such as astaxanthin, which exhibits strong antioxidant activity [2]. Additionally, the high glutamic acid concentration in shrimp heads offers potential as a natural flavor enhancer, supporting the shift toward natural rather than synthetic additives in processed foods [3]. Therefore, underutilized shrimp waste represents a promising raw material for developing functional fortified foods.

Food fortification involves adding or substituting nutrient-rich ingredients to improve the nutritional value of a product [4]. Incorporating shrimp waste flour into pempek is consistent with circular economy principles and supports sustainable food production systems [5]. By converting shrimp processing by-products into value-added flour, producers can minimize waste, enhance resource efficiency, and develop nutritious functional foods that meet consumer demand for healthier products. Previous studies indicate that shrimp-based ingredients can enhance protein and mineral content in fish

products without negatively affecting sensory quality when used at appropriate levels [6]. Thus, shrimp waste flour has the potential to improve both nutritional composition and market competitiveness of milkfish pempek.

Beyond nutritional benefits, this research supports the development of the Agribusiness Teaching Factory (TEFA) at PSDKU Sidoarjo. The production of fortified milkfish pempek serves as a hands-on learning platform for students, integrating concepts of agro-industrial management, product innovation, quality assurance, and entrepreneurship. TEFA-based education has been shown to strengthen students' problem-solving skills, managerial competencies, and industry readiness [7]. Through student business units and practical production activities, pempek innovation also contributes to local economic development by transforming regional aquatic resources into market-oriented agro-industrial products.

Therefore, the development of milkfish pempek fortified with shrimp waste flour is not only relevant for improving food quality and sustainability but also enhances educational innovation through TEFA implementation. This study aims to analyze the nutritional characteristics, sensory attributes, and consumer acceptance of fortified milkfish pempek, thereby providing scientific evidence to support its potential commercialization as a sustainable, high-value, and locally based functional food product.

## 2. Materials and Methods

### 2.1. Materials

Milkfish (*Chanos chanos*) fillets were sourced from a local fish market in Sidoarjo, East Java, Indonesia. Shrimp waste (heads and shells) was collected from small-scale processing units in the same area. The waste materials were washed, boiled in a pressure cooker at 90°C for 2 hours, dried at 121°C for 60 minutes, and ground into fine flour. The resulting flour was then sieved through a 100-mesh filter to ensure uniform particle size [8]. These procedures were applied to obtain shrimp waste flour with a smooth texture comparable to commercial flour. Additional ingredients—including tapioca flour, garlic, salt, broth powder, and sugar—were purchased from local suppliers.

### 2.2. Research approach

This study consisted of two main phases: (1) proximate analysis of milkfish pempek formulations and (2) sensory evaluation by semi-trained panelists. Three formulations were prepared with varying shrimp waste flour levels: 0% (Product A), 10% (Product B), and 15% (Product C).

#### 2.2.1. Proximate analysis

The first phase involved an experimental laboratory approach to determine the macronutrient composition of the samples, including protein, fat, carbohydrates, fiber, moisture, and ash content. The ingredients used in each formulation are presented in Table 1.

**Table 1.** Formulation of milkfish pempek

Ingredients	Type of Treatment		
	Product A (0%)	Product B (10%)	Product C (15%)
Milkfish (g)	250	250	250
Shrimp waste flour (g)	0	16	24
Tapioca flour (g)	160	144	136
Ice water (ml)	100	100	100
Eggs (g)	40	40	40
Garlic (g)	10	10	10

Ingredients	Type of Treatment		
	Product A (0%)	Product B (10%)	Product C (15%)
Salt (g)	5	5	5
Broth (g)	1.5	1.5	1.5
Sugar (g)	2.5	2.5	2.5

All proximate analyses were conducted in triplicate for each formulation. Analyses followed AOAC [9] official methods :

- 1) **Moisture:** AOAC 925.10 (Oven drying at 105°C)
- 2) **Ash:** AOAC 923.03 (Muffle furnace at 550°C)
- 3) **Crude protein:** AOAC 2001.11 (Kjeldahl method  $N \times 6.25$ )
- 4) **Crude fat:** AOAC 920.39 (Soxhlet extraction)
- 5) **Carbohydrates:** calculated by difference ( $100 - \% \text{ moisture} - \% \text{ protein} - \% \text{ fat} - \% \text{ ash}$ )

### 2.2.2. Sensory evaluation

The second phase involved sensory testing using 20 semi-trained panelists with prior experience in evaluating fish-based processed foods. All panelists were screened for allergies to fish or seafood. Sensory testing followed ISO 4121:2003 guidelines and the procedures described by Civille and Carr [10].

Testing was conducted in individual booths with neutral white lighting and controlled temperature ( $24 \pm 1^\circ\text{C}$ ). Each panelist received coded samples using randomized three-digit codes, and rinsing with warm water was required between evaluations.

### 2.2.3. Hedonic Test

A five-point hedonic scale (Table 2) was used to measure panelists' preference levels.

**Table 2.** Hedonic scale with numerical scale

Hedonic Term	Score
Strongly Like	5
Like	4
Neutral	3
Dislike	2
Strongly Dislike	1

The evaluated attributes included taste, aroma, texture, color/appearance, aftertaste, and suitability for regular consumption.

### 2.3. Statistical analysis

Proximate and sensory data were analyzed using Analysis of Variance (ANOVA) in SPSS version 16.0 for Windows to determine the effects of shrimp waste flour addition. When significant differences were detected ( $p < 0.05$ ), Tukey's Honest Significant Difference (HSD) test was applied. Results were presented as mean values accompanied by letter notations indicating significant differences among treatments.

## 3. Results and Discussion

### 3.1. Subsection

Proximate analysis was conducted to determine the basic chemical composition of fortified pempek, including moisture, ash, protein, fat, and carbohydrate content. This

analysis is essential for evaluating the nutritional characteristics and overall quality of fish-based processed products..

**Table 3.** Proximate composition of milkfish pempek fortified with shrimp waste flour

Treatment	Water (%)	Ash (%)	Lipid (%)	Protein (%)	Carbohydrate (%)
Product A (0%)	65.18 a	1.04 a	0.38 a	7.91 a	25.49 a
Product B (10%)	63.65 b	2.00 b	0.39 a	10.92 b	24.24 b
Product C (15%)	62.03 c	2.39 c	0.34 a	11.0 b	23.04 c

### 3.1.1. Water content/moisture

Water content/moisture decreased as the level of shrimp waste flour increased, ranging from 65.18% in Product A to 63.65% in Product B and 62.03% in Product C. This trend reflects the higher protein and fiber content of shrimp waste flour, which enhances water-binding capacity and reduces free moisture in the final product [12].

Lower moisture levels also influenced textural attributes, as formulations with higher protein content tended to produce a firmer gel structure during cooking. This aligns with findings that increased protein availability promotes stronger gel matrix formation, thereby improving chewiness and elasticity [13,14]. Conversely, higher moisture levels in the control product contributed to a softer and less cohesive texture.

### 3.1.2. Ash content

Ash content increased significantly with fortification, from 1.04% in Product A to 2.00% in Product B and 2.39% in Product C. The higher ash values indicate greater mineral content contributed by shrimp shells, which are naturally rich in calcium, magnesium, and phosphorus [15,16].

However, elevated mineral levels may negatively affect sensory perception, potentially causing a slightly gritty or coarse mouthfeel at high substitution levels. This observation is consistent with previous studies on crustacean-based and calcium-fortified products [17]. Thus, optimizing mineral content is crucial to balance nutritional enhancement and textural acceptability.

### 3.1.3. Lipid content

Lipid content did not differ significantly across treatments, suggesting that shrimp waste flour contributed only minimal fat originating from residual tissues attached to the exoskeleton. Although present in small quantities, these lipids play a role in flavor release and mouthfeel, as they act as carriers of volatile compounds [11,18].

### 3.1.4. Protein content

Protein content increased markedly with fortification, rising from 7.91% (Product A) to 10.92% (Product B) and 11.00% (Product C). This confirms the effectiveness of shrimp waste flour as a natural protein-enhancing ingredient, consistent with prior studies demonstrating high-quality protein in crustacean by-products [4,11].

The increased protein level also contributes to functional benefits, such as improved gel strength and texture, supporting its potential application in fortified fish products aligned with circular economy principles. This indicates that consuming pempek daily can meet the body's protein needs. The average adult protein requirement is 60-65 grams per day, so the protein benefits of shrimp head flour provide beneficial health benefits[5].

### 3.1.5. Carbohydrate content

The carbohydrate Carbohydrate content decreased as shrimp waste flour was added, primarily due to the reduced proportion of tapioca flour, which is rich in starch. Since shrimp waste flour contains minimal starch but higher levels of protein, minerals, and fiber, its substitution naturally lowers total carbohydrate content [19].

This trend aligns with findings that replacing starchy components with seafood by-product flours yields a measurable reduction in carbohydrate levels in processed foods.

### 3.2. Sensory evaluation

Sensory evaluation assessed consumer acceptance of the fortified pempek based on taste, aroma, texture, color, and aftertaste. Table 4 presents the mean scores obtained from the hedonic test.

**Table 4.** Summary of average scores from organoleptic testing

Assessment Aspects	Treatment		
	Product A	Product B	Product C
Taste	4.15 a	4.05 b	3.50 c
Aroma	3.75 a	3.80 a	3.40 b
Texture	3.80 b	4.00 a	3.65 c
Color/Appearance	4.10 b	4.20 a	3.70 c
Aftertaste	3.90 a	3.85 a	3.55 b

#### 3.2.1. Taste

Product B (10%) performed slightly below Product A but significantly higher than Product C. This indicates that moderate substitution enhances flavor depth without introducing overpowering marine or mineral notes, which were more pronounced in the 15% formulation. Similar declines in taste preference at higher shrimp flour concentrations have been reported in related studies [20].

This finding suggests that an optimal substitution threshold is necessary to enhance nutritional value while maintaining desirable sensory characteristics.

#### 3.2.2. Aroma

Product B obtained the highest aroma score (3.80), statistically comparable to Product A (3.75), whereas Product C recorded the lowest. Higher concentrations of shrimp waste flour intensify the release of volatile compounds such as aldehydes, ketones, and amino acids, which may produce a stronger crustacean aroma [21].

Although moderate levels enhance savory aroma through glutamic acid and natural shrimp volatiles, excessive addition may introduce overly intense or unfamiliar notes, reducing consumer acceptance.

#### 3.2.3. Texture

Texture scores differed significantly across treatments. Product B had the highest score (4.00), followed by Product A and Product C. The improved texture in Product B may be attributed to the balanced interaction between protein and moisture, producing a more elastic and cohesive structure.

In contrast, Product C exhibited a coarser texture, likely resulting from excess minerals and fiber that can disrupt gel formation, creating a slightly gritty sensation [17,21].

#### 3.2.4. Colour/appearance

Product B achieved the highest color score (4.20), indicating a visually appealing

appearance. Carotenoid pigments in shrimp waste flour contribute to an attractive orange hue when used in moderation [22].

However, excessive fortification resulted in darker coloration in Product C due to Maillard reactions occurring during flour preparation, which reduced its visual appeal [11].

### 3.2.5. After taste

Aftertaste scores for Products A and B were similar and higher than Product C. The decline in aftertaste acceptance for the 15% formulation is likely due to stronger residual mineral and chitin flavors, commonly reported in high-fortification crustacean-based products.

Overall, the sensory results clearly indicate that shrimp waste meal influences consumer perception across a range of attributes. A 10% substitution level: Improves texture elasticity, enhances color brightness, maintains acceptable flavor and aroma, avoids gritty or strong aftertaste.

In contrast, the 15% formulation negatively impacts sensory quality, particularly flavor, aroma, and texture, due to the more intense crustacean characteristics and mineral content.

Therefore, 10% fortification is the most balanced and acceptable formulation for consumers, aligning nutritional enhancement with sensory appeal and supporting the sustainable use of shrimp by-products.

## 4. Conclusions

The results of this study demonstrate that the addition of shrimp waste flour effectively enhances the nutritional quality of milkfish pempek. Fortification at the 10% level significantly increased protein and mineral (ash) content while simultaneously reducing moisture and carbohydrate levels, producing a more desirable texture and appearance compared with both the control (0%) and the higher substitution level (15%).

Sensory evaluation further confirmed that the 10% formulation (Product B) achieved the highest overall acceptance, particularly in taste, texture elasticity, and color. In contrast, the 15% formulation was less preferred due to its stronger crustacean aroma, intensified mineral notes, and coarser texture, which negatively affected consumer acceptability.

Overall, a 10% substitution level represents the optimal balance between nutritional enhancement and sensory desirability, supporting the use of shrimp waste flour as a functional, sustainable ingredient in fish-based products. These findings contribute to efforts to minimize aquaculture waste and promote circular-economy-based food innovation..

**Funding:** The authors are thankfull to Research and Community Service Center of State Polytechnic of Jember for the Research Grant.

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