

Fortification of Wet and Instant Noodles with Snakehead Fish (*Channa striata*) Flour to Overcome Protein Malnutrition in Toddlers

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Abstract Protein malnutrition remains a significant issue, particularly among toddlers, leading to stunted and wasted growth. *Channa striata* (snakehead fish), a protein-rich freshwater fish widely available in Indonesia, presents a potential solution. This study aimed to analyze the effect of snakehead fish flour substitution on physicochemical characteristics of wet and instant noodles. Wet and instant noodles were prepared by substituting up to 10% of wheat flour with snakehead fish flour. The physicochemical properties, including yield, water absorption, moisture content, texture, protein, and amino acid composition, were then analyzed. The results showed that fortification with snakehead fish flour did not significantly affect the yield, water absorption, moisture content, or texture of the noodles. However, instant noodles, regardless of substitution level, exhibited lower yield and higher water absorption compared to wet noodles, which was mainly attributed to structural changes during the frying process. Notably, protein and amino acid content significantly increased in noodles with snakehead fish flour substitution compared to the control. These findings suggest that incorporating snakehead fish flour into noodle products can enhance their nutritional profile, offering a practical solution to overcome protein malnutrition in toddlers.

Keywords *Channa striata*, Protein Malnutrition, Snakehead Fish Flour, Noodle Fortification, Amino Acid Content

1. Introduction

Malnutrition remains a global issue, with cases rising annually. Approximately 45% of global child mortality in children under five is attributed to inadequate nutrition, with an estimated 149 million children experiencing stunting (low height for age) and 45 million suffering from wasting (low weight for height) [1]. Indonesia also faces significant malnutrition challenges; in 2022, an estimated 21.6% of children under five were stunted, and 7.7% were wasted [2]. Adequate energy intake and high-quality protein are crucial for children's linear growth. Essential amino acids like lysine, leucine, and tryptophan support growth and cognitive development [3]. Lack of protein intake in toddlers will lead to metabolic disorders that can have long-term effects. Toddlers can experience underweight, stunting, and a decreased immune system making them more susceptible to disease [4].

Snakehead fish (*Channa striata*), *haruan* or *gabus* in Indonesia, presents a potential solution to overcome this problem in Indonesia. This freshwater fish, abundant in the country, boasts a high protein content which is a valuable source of protein throughout the Asia Pacific region. In Indonesia, this fish is highly valued and commercially in

demand, contributing to food security. It is traditionally consumed as salted fish, boiled, steamed, or processed into filtrate and oil. Additionally, snakehead fish is rich in amino acids, with the highest concentrations found in two essential amino acids (leucine and lysine) and three non-essential amino acids (aspartic acid, glutamic acid, and alanine). These amino acids promote the growth of body tissues, muscles, organs, the immune system, and improve brain and nervous system function [5, 6]. To enhance its nutritional accessibility, processing snakehead fish into fish flour is a practical approach since fish flour is widely recognized as a nutrient-rich ingredient, providing good source of digestible energy and essential minerals, essential vitamins, and protein with a high biological value [7]. Previous studies have also shown that snakehead fish flour meets the quality requirements of fish meal based on the Indonesian National Standard (SNI 01-2715-1996) and hence it can be used as a supplement or substitute for several foods [8].

Addressing protein malnutrition in toddlers requires food products with high protein content that are popular among people. Noodles are one of the most commonly consumed foods across all age groups in Indonesia. Noodles are a worldwide food that has been distributed to 80 countries, China is the country with the highest consumption of instant noodles, followed by Indonesia, Japan and Vietnam [9]. Noodles have become people's choice because it's easy to serve and can be turned into various kinds of dishes with rich flavors. However, frequent consumption of instant noodles may be associated with increased risk of metabolic disease due to its high-calorie content and high concentration of refined carbohydrates, fats, and sodium [10].

Despite previous studies highlighting the high protein content and essential acids in snakehead fish, limited study exists on its potential as a flour substitute in wet and instant noodles. Here, this study aims to analyze the effect of snakehead fish flour substitution on physicochemical characteristics of wet and instant noodles.

2. Materials and Methods

2.1. Sample Preparation

The noodle preparation was done by mixing wheat flour, snakehead fish flour, salt, baking soda, and mineral water according to the specified formulations (Table 1). Five formulations (F0–F4) with varying levels of snakehead fish flour were prepared (0%, 2.5%, 5%, 7.5%, 10%). The mixing process continued until all ingredients were fully combined. The dough was then left to rest in a bowl for 30 minutes to allow proofing. After proofing, the dough was rolled into sheets and molded into noodle strands using a noodle maker. The molded noodles were then placed on an aluminium tray and steamed for 10 minutes. Following the

steaming process, wet noodles were obtained. To produce instant noodles, the wet noodles were deep-fried at 140–150°C for 90 seconds. Additionally, both wet and instant noodles underwent a boiling test, where wet noodles were boiled for 90 seconds, while instant noodles were boiled for 180 seconds.

Table 1. Formulation of snakehead fish flour substitution on wet and instant noodles

Ingredient	Formula (g)				
	F0	F1	F2	F3	F4
Snakehead fish flour	0	3.1	6.3	9.4	12.5
Wheat flour	125	121.9	118.8	115.6	112.5
Salt	1	1	1	1	1
Baking soda	0.1	0.1	0.1	0.1	0.1
Mineral water	55	55	55	55	55

2.2. Yield

The yield of the wet and instant noodle products was calculated based on the gravimetric method. The dough weight of the noodles will be measured as the initial weight. After that, weighing is conducted again after the noodle product is finished as the final weight. The yield of the noodles produced will be calculated using the following formula: the final weight (g) divided by the initial weight (g), then multiplied by 100 to obtain the percentage yield.

2.3. Water Absorption

The water absorption value was obtained by reducing the weight after the noodle product was cooked (W_2) by the weight before the noodle product was cooked (W_1) and then dividing by the initial weight (W_1) and then multiplying by 100.

2.4. Moisture Content

The moisture content analysis of noodle products was conducted using the gravimetric method. Initially, an aluminum dish is dried in an oven at 105°C for 30 minutes before being used as a sample container. The test was performed in duplo. The sample will be weighed as much as 3 grams, and then put into the oven at 105°C for 12 hours. After the oven, the sample will be weighed. The moisture content was calculated by determining the percentage of weight loss after drying, which was obtained by subtracting the final weight from the initial weight, dividing the result by the initial weight, and then multiplying by 100.

2.5. Texture

The textures of the final products of wet noodles and instant noodles were analyzed with a texture analyzer. A

total of 5 strands of noodles with a length of 7 to 10 cm were randomly taken for measurement. The parameters tested with the texture analyzer were hardness force (N) and elastic (N/mm²). Three replications were conducted for each formulation of wet noodles and instant noodles.

2.6. Protein and Amino Acid Content

Analysis of protein and amino acid levels was conducted by Saraswanti Indo Genetech Laboratory. The samples sent are control instant noodle samples (F₀) and snakehead fish flour substitution instant noodle samples that have the best quality compared to other substitution formulas.

2.7. Statistical Analysis

The data from each analysis was done in duplo or triplo. ANOVA or Analysis of Variance and student t-test were used to determine the differences of each data. Statistical analysis was performed with SPSS software. Results with $p < 0.05$ were concluded as significantly different.

3. Results and Discussion

3.1. Yield

Figure 1 illustrates the appearance of noodles formulated with snakehead fish flour substitution from different formulations. The visual comparison between F₀ (control) and F₄ (the highest substitution level) highlights the effects of snakehead fish flour on noodle characteristics such as color, texture, and overall appearance.



Figure 1. Noodles formulated with snakehead fish flour substitution: F₀ (0%), F₁ (2.5%), F₂ (5%), F₃ (7.5%), F₄ (10%)

The yield result is obtained from the comparison between the initial weight before processing to the final product. The calculation of the yield value can be used to measure the efficiency of the noodle production process, including the weight lost due to the processing process [11]. A high yield value indicates that the raw material

undergoes optimal processing, while a low yield value indicates weight loss due to the production process or other external factors. Based on Table 2, there is no difference in the yield value between the formulas of the two noodle treatments. This shows that the difference in the percentage of substitution of snakehead fish flour does not affect the yield value. However, the different treatments (wet noodles and instant noodles) have different yield values. Instant noodles tend to have a lower yield value compared to wet noodles. This result can be influenced by the frying treatment of instant noodles, which reduces the moisture content of the final noodle product. The high-temperature frying process can cause evaporation of the moisture content in the instant noodles [12]. The reduction in moisture content due to frying causes the instant noodle product's final weight to be lower than that of wet noodles that only go through the steaming process and are directly boiled.

Table 2. Yield analysis of wet and instant noodles made from different formulations

Formula	Yield (%)	
	Wet noodle	Instant noodle
F ₀	93.87 ± 2.18 ^a	83.92 ± 2.97 ^{a*}
F ₁	95.98 ± 1.22 ^a	83.76 ± 3.83 ^{a*}
F ₂	94.85 ± 2.03 ^a	81.88 ± 8.04 ^{a*}
F ₃	95.10 ± 0.43 ^a	86.46 ± 1.25 ^{a*}
F ₄	94.41 ± 1.56 ^a	90.22 ± 3.90 ^{a*}

Data are presented as mean ± standard deviation. Different superscripts denote significant differences among formulations analyzed by one-way analysis of variance and asterisk (*) indicate significant differences between wet and instant noodles within the same formulation analyzed by student t-test at $p < 0.05$.

3.2. Water Absorption

Water absorption analysis is conducted to determine the water absorption capacity of the product when it is boiled. When boiling, the noodles will absorb water to make the noodles expand and increase in weight, and hence it represents the degree of expansion of noodles during cooking [13]. Based on the water absorption value contained in Table 3, the substitute formula of snakehead fish flour into noodle products does not significantly affect the water absorption value. However, there was a significant difference between the wet noodle and instant noodle treatments on the water absorption value. The water absorption value of instant noodles is higher than that of wet noodles. The higher water absorption of instant noodles is due to the porous structure formed during frying. High temperatures cause rapid water evaporation, creating capillaries and widening pores, which enhance water uptake during rehydration. Additionally, protein denaturation and starch gelatinization further contribute to this structural change, making instant noodles more absorbent than wet noodles [14].

Table 3. Water absorption of wet and instant noodles made from different formulations

Formula	Water absorption (%)	
	Wet noodle	Instant noodle
F0	41.85 ± 3.04 ^a	65.54 ± 11.90 ^{a*}
F1	41.56 ± 1.38 ^a	53.94 ± 2.29 ^{a*}
F2	38.70 ± 0.41 ^a	56.47 ± 1.92 ^{a*}
F3	42.29 ± 0.92 ^a	53.21 ± 2.67 ^{a*}
F4	38.25 ± 0.47 ^a	50.52 ± 1.45 ^{a*}

Data are presented as mean ± standard deviation. Different superscripts denote significant differences among formulations analyzed by one-way analysis of variance and asterisk (*) indicate significant differences between wet and instant noodles within the same formulation analyzed by student t-test at $p < 0.05$.

3.3. Moisture Content

The moisture content value is very important because it can determine the quality, shelf life, and physical characteristics of a food product [15]. High moisture content can increase the risk of food product spoilage. Conversely, lower moisture content indicates longer shelf life. Through the moisture content analysis results (Table 4), it can be concluded that there is no significant difference in the moisture content value between formulations. This indicates that the amount of snakehead fish flour substitution does not influence the moisture content of the noodles. However, the treatment of noodles has a significant effect. Wet noodles tend to have a higher moisture content value compared to instant noodles. This can be caused by several factors. One of them is the difference in the manufacturing process, where wet noodles do not go through a drying or frying process like instant noodles. Without the frying process, the moisture content in wet noodles does not decrease. In addition, wet noodles also have higher water absorption during the boiling process compared to instant noodles.

Table 4. Moisture content of wet and instant noodles made from different formulations

Formula	Moisture content (%)	
	Wet noodle	Instant noodle
F0	51.98 ± 0.85 ^a	46.34 ± 1.12 ^{a*}
F1	52.47 ± 0.57 ^a	45.15 ± 1.37 ^{a*}
F2	52.96 ± 1.15 ^a	45.48 ± 0.21 ^{a*}
F3	52.33 ± 0.04 ^a	45.11 ± 0.11 ^{a*}
F4	52.29 ± 0.77 ^a	46.20 ± 0.69 ^{a*}

Data are presented as mean ± standard deviation. Different superscripts denote significant differences among formulations analyzed by one-way analysis of variance and asterisk (*) indicate significant differences between wet and instant noodles within the same formulation analyzed by student t-test at $p < 0.05$.

The higher water absorption is due to the flexibility of the molecular structure of wet noodles, in contrast to the tighter molecular structure of instant noodles due to frying.

The molecular structure of wet noodles causes intermolecular bonds and hydrogen bonds to bind more easily with water. Another factor is associated with the hygroscopic nature of wet noodles, which is closely related to starch and gluten. Hydroxyl groups from starch and gluten can bind with water molecules to form hydrogen bonds. In addition, the hygroscopic nature triggers a gelatinization reaction between starch granules and water molecules. In the boiling process, the starch granules of wet noodles can easily form bonds with water molecules, which causes the moisture content of wet noodles to be higher. In contrast to wet noodles, the frying process of instant noodles can cause structural changes in starch granules that reduce the gelatinization ability of starch and the ability to bind water molecules [16, 17].

3.4. Texture

Based on Table 5, the amount of snakehead fish flour substitution and the difference in noodle treatments did not have a significant effect on the hardness value of the noodles. However, the hardness of both noodle treatments decreased along with the increase in the amount of snakehead fish flour substitution. The hardness value of the noodles can be influenced by the amount of gluten, which the higher the gluten content, the harder of the noodles will also be [18]. Noodles substituted with snakehead fish flour had a decrease in the amount of gluten contained in the noodle dough. The protein contained in snakehead fish flour is unable to form a gluten chain because the main protein content is different from that of wheat flour. The high albumin content in snakehead fish flour is more soluble in water and has difficulty forming strong interchain bonds like proteins in wheat flour that form gluten.

Table 5. Hardness and elastic parameters of wet and instant noodles made from different formulations

Formula	Hardness (N)		Elastic (N/mm ²)	
	Wet noodle	Instant noodle	Wet noodle	Instant noodle
F0	0.23 ± 0.05 ^a	0.15 ± 0.05 ^a	0.02 ± 0.01 ^a	0.02 ± 0.00 ^a
F1	0.23 ± 0.03 ^a	0.26 ± 0.10 ^a	0.03 ± 0.00 ^b	0.04 ± 0.01 ^a
F2	0.20 ± 0.05 ^a	0.47 ± 0.28 ^a	0.03 ± 0.01 ^b	0.07 ± 0.04 ^a
F3	0.16 ± 0.02 ^a	0.15 ± 0.00 ^a	0.02 ± 0.00 ^a	0.02 ± 0.00 ^a
F4	0.17 ± 0.03 ^a	0.14 ± 0.10 ^a	0.02 ± 0.00 ^a	0.02 ± 0.00 ^a

Data are presented as mean ± standard deviation. Different superscripts denote significant differences among formulations analyzed by one-way analysis of variance and asterisk (*) indicate significant differences between wet and instant noodles within the same formulation analyzed by student t-test at $p < 0.05$.

Meanwhile, the elastic parameter measures the ability of the sample to return to its initial shape after applying pressure or force. The elasticity of noodles is strongly influenced by the gluten content, which is composed of gliadin and glutenin proteins. Glutenin plays a role in creating polymers composed of disulfide bonds, while gliadin is a monomer that can interact with glutenin through hydrogen bonds. The interaction between gliadin and glutenin contributes to the texture and elasticity of the noodles [19]. Snakehead fish flour used in the noodle formulation does not contain gliadin and glutenin which form gluten, so the elasticity of noodles using snakehead fish flour should be reduced compared to noodles with wheat flour. Based on the research conducted, it can be concluded that the difference in treatment between wet noodles and instant noodles does not significantly affect the elasticity of the noodles. The difference in the amount of substitution or formulation of snakehead fish flour also does not affect instant noodle products. This shows that the protein content in snakehead fish flour does not affect the formation of gluten in the noodles produced, so the elasticity value of the noodles shows no significant difference. However, the elasticity values of F1 and F2 were higher than those of the other formulations in wet noodle products. This can be influenced by several factors, such as better starch gelatinization or measurement errors in the formula.

3.5. Protein and Amino Acid Content

The optimal formulation among F1-F4 was selected and compared to F0, which served as the control without snakehead fish flour substitution. Yield, water absorption, moisture content, and texture analysis showed no significant differences across the various substitution levels. Therefore, F4, which contained the highest percentage of snakehead fish flour, was chosen for further analysis of its protein and amino acid content. The protein content analysis of instant noodle samples F0 and F4 is presented in Table 6, showing that F4 had a significantly higher protein content than F0. This indicates that substituting snakehead fish flour in instant noodles effectively enhances their protein content. As a macronutrient, protein is essential for the body in large quantities, playing a crucial role in enzyme and hormone metabolism for immune function. It also supports cell and tissue maintenance. In toddlers, protein is particularly vital for cell formation and overall growth. Sufficient protein intake during this stage ensures optimal tissue development [20].

Table 6. Protein content of instant noodles made from different formulations

Formula	Protein content (%)
F0	9.40 ± 0.06
F4	14.13 ± 0.19*

Data are presented as mean ± standard deviation. Asterisk (*) indicates significant differences between different formulations analyzed by student t-test at $p < 0.05$.

The test results of essential amino acid content in instant noodle samples F0 and F4 are in Table 7. All essential amino acid content in instant noodle sample F4 is higher than that of F0. This shows that the substitution of snakehead fish meal into instant noodle products has a significant effect on essential amino acid content. Essential amino acids are amino acids that cannot be produced by the human body so it can only be obtained from the food consumed. The types of essential amino acids are phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, valine, and tryptophan. The amino acids phenylalanine and tryptophan have a role in the formation of chemical substances in the brain to regulate communication between nerve cells. The amino acid histidine helps in maintaining the myelin sheath to keep the signals sent by the nerves going smoothly. In addition, the amino acid histidine is also a neurotransmitter in the immune system that regulates the response to allergies or infections. The amino acid isoleucine plays a role in the immune system, isoleucine will produce hemoglobin, energy regulation, and muscle metabolism. The amino acid leucine helps in wound healing, regulates blood sugar levels, and produces growth hormone. The amino acid lysine plays a role in the formation of hormones, enzymes, and the immune system. Amino acid methionine is needed in the body's cellular metabolism, methionine will help biosynthesize in glutathione to prevent oxidative stress, reduce DNA damage, and reduce carcinogenic reactions. Threonine amino acid is a component of collagen and elastin, threonine amino acid functions in improving the immune system, fat metabolism, and sleep patterns. Valine amino acid functions in muscle growth and energy production [21]. All essential amino acids in the instant noodles are significantly increased when snakehead fish meal is substituted for the instant noodles.

Table 7. Essential amino acid content of wet and instant noodles made from different formulations

Essential amino acid	Content (mg/kg)	
	F0	F4
L-Phenylalanine	1989.65 ± 0.52	4118.72 ± 4.23*
L-Histidine	923.49 ± 1.68	2400.52 ± 5.16*
L-Isoleucine	467.94 ± 1.06	2339.70 ± 0.69*
L-Leucine	2096.51 ± 10.83	6835.94 ± 24.42*
L-Lysine	577.56 ± 0.08	4876.42 ± 9.63*
L-Methionine	57.55 ± 0.02	141.96 ± 0.06*
L-Threonine	789.55 ± 0.54	2715.78 ± 7.28*
L-Valine	671.85 ± 0.22	2739.90 ± 4.36*
L-Tryptophan	707.50 ± 8.22	1050.16 ± 21.76*

Data are presented as mean ± standard deviation. Asterisk (*) indicates significant differences between wet and instant noodles analyzed by student t-test at $p < 0.05$.

The test results of non-essential amino acid content in instant noodle samples F0 and F4 are in Table 8. All non-

essential amino acid content in instant noodle sample F4 is higher than F0. This shows that the substitution of snakehead fish meal into instant noodle products has a significant effect on non-essential amino acid content. Non-essential amino acids are amino acids that can be formed by the body through the synthesis process. Non-essential amino acids arginine, aspartic acid, and glutamic acid can accelerate the wound healing process in the body [22]. In addition, glutamic acid is the component that gives savory taste [23]. The non-essential amino acid profiles of the noodles formulated with snakehead fish flour showed similar composition reported for snakehead fish meat [24]. Glutamic acid, proline, glycine, and alanine were present at the highest concentrations compared to other non-essential amino acids. Therefore, the incorporation of snakehead fish flour effectively retained the characteristic amino acid profile of the fish in the noodle products.

Table 8. Non-essential amino acid content of wet and instant noodles made from different formulations

Non-essential amino acid	Content (mg/kg)	
	F0	F4
L-Arginine	1834.40 ± 23.19	4258.70 ± 15.42*
L-Alanine	1423.90 ± 2.38	5872.82 ± 28.79*
L-Proline	4693.76 ± 6.41	10514.46 ± 33.64*
L-Aspartic Acid	2059.96 ± 2.74	7324.66 ± 33.16*
L-Glutamic Acid	11499.95 ± 73.26	27973.00 ± 149.98*
Glycine	2793.24 ± 11.85	7919.32 ± 19.92*
L-Serine	2073.04 ± 2.74	4931.43 ± 11.56*
L-Tyrosine	775.08 ± 8.14	1327.86 ± 1.17*
L-Cystine	2291.26 ± 1.58	4566.78 ± 2.34*

Data are presented as mean ± standard deviation. Asterisk (*) indicates significant differences between wet and instant noodles analyzed by student t-test at $p < 0.05$.

4. Conclusions

The results indicate that substituting snakehead fish flour did not significantly alter the overall yield, water absorption, moisture content, or texture of the noodles. While processing differences influenced certain parameters, such as a lower yield in instant noodles, higher water absorption in instant noodles, and increased moisture content in wet noodles, these variations are primarily attributable to the processing methods rather than the substitution itself. Importantly, noodles containing snakehead fish flour exhibited significantly higher levels of protein, essential amino acids, and non-essential amino acids compared to the control samples. Therefore, incorporating snakehead fish flour into noodle formulations offers a promising approach to enhance protein content and nutritional value, which could be beneficial in addressing protein malnutrition in toddlers.

Open Contribution

Aditya Fuadi: Writing, Formal Analysis, Investigation, Data Curation. **Jasmine Bun:** Writing, Formal Analysis, Investigation, Data Curation. **Guntur Berlian:** Conceptualization, Reviewing, Methodology. **Asep Aripin:** Conceptualization, Reviewing, Methodology. **Diana Lo:** Supervision, Project Administration, Validation.

Open Data

All data generated or supported for this study are included in this article.

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