

PHYSICAL AND CHEMICAL CHARACTERISTICS OF FISH FLOUR MADE FROM ALBUMIN EXTRACTION BY PRODUCTS OF *Channa* GENUS FISH

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Abstract

The albumin extraction process from the *Channa* genus, namely giant snakehead (*Channa micropeltes*) and snakehead fish (*Channa striata*), produces by-products in the form of residual fish meat that still contains protein and various other important nutrients. This study aimed to determine the physical and chemical characteristics and amino acid profiles of fish meal produced from the albumin extraction by-products of snakehead fish and snakehead fish. The research method was experimental with two treatments: snakehead fish meal and snakehead fish meal made from albumin extraction by-products. Data were analyzed using an independent t-test. The highest yield was obtained using a 63 µm sieve. Giant snakehead and snakehead flours had yields of 40.45% and 37.56%, respectively. Giant snakehead and snakehead flours showed L* values of 76.83 and 72.68, hue values of 83.60 and 80.89, chroma values of 24.60 and 23.18, solubility values of 21% and 22%, and swelling power values of 1.09% and 0.85%, respectively. Their chemical compositions were 76.97% and 77.96% protein, 10.37% and 13.53% moisture, 3.36% and 3.49% ash, 7.12% and 1.74% fat, and 2.15% and 0.27% carbohydrate, respectively. The total amino acid content was lower in giant snakehead flour than in snakehead flour, with values of 72.32% and 87.23%, respectively. These findings indicate that snakehead flour produced from albumin extraction by-products has more favorable nutritional characteristics than giant snakehead flour. Snakehead flour also has a higher total amino acid content, supporting its potential use as a protein-rich ingredient derived from fish-processing by-products.

Keywords: *Channa micropeltes*, *Channa striata*, extraction waste, giant snakehead, snakehead

Karakteristik Fisik dan Kimia Tepung Ikan Berbahan Hasil Samping Ekstraksi Albumin Ikan Genus *Channa*

Abstrak

Proses ekstraksi albumin dari genus *Channa*, yaitu ikan toman (*Channa micropeltes*) dan ikan gabus (*Channa striata*) menghasilkan produk samping berupa daging ikan sisa yang masih mengandung protein dan berbagai zat gizi penting lainnya. Penelitian ini bertujuan untuk menentukan karakteristik fisik, kimia, dan profil asam amino dari tepung ikan yang dihasilkan dari produk samping ekstraksi albumin ikan toman dan ikan gabus. Metode penelitian bersifat eksperimen dengan dua perlakuan, yaitu tepung ikan toman dan gabus berbahan hasil samping ekstraksi albumin. Data dianalisis menggunakan uji t independen. Rendemen tertinggi pada ukuran ayakan 63 µm, yaitu tepung ikan toman 40,45% dan tepung ikan gabus 37,56%. Karakteristik fisik tepung ikan toman dan ikan gabus secara berturut-turut adalah: L* 76,83 dan 72,68; *hue* 83,60 dan 80,89; *chroma* 24,60 dan 23,18; kelarutan 21% dan 22%; *swelling power* 1,09% dan 0,85%. Komposisi kimia berturut-turut adalah: protein 76,97% dan 77,96%; kadar air 10,37% dan 13,53%; abu 3,36% dan 3,49%; lemak 7,12% dan 1,74%; karbohidrat 2,15% dan 0,27%. Total asam amino pada tepung ikan toman 72,32% dan tepung ikan gabus 87,23%. Tepung ikan gabus berbahan hasil samping ekstraksi albumin menunjukkan sifat fisik dan kimia yang lebih baik serta kandungan total asam amino yang lebih tinggi dibandingkan tepung ikan toman.

Kata kunci: *Channa micropeltes*, *Channa striata*, gabus, limbah ekstraksi, toman

INTRODUCTION

The economic importance of the *Channa* genus, particularly snakehead (*Channa striata*) and giant snakehead (*Channa micropeltes*), is reflected in Indonesia's fisheries production statistics from 2020 to 2024. The annual production of snakehead will increase steadily from 61,154 tons in 2020 to 69,473 tons in 2024. In 2024, South Kalimantan and South Sumatra were the leading producing provinces, contributing 13,776 tons and 11,515 tons, respectively. In comparison, giant snakehead production was substantially higher throughout the same period, although the annual output showed slight fluctuations, reaching 494,950 tons in 2020, 456,936 tons in 2021, 462,970 tons in 2022, 472,086 tons in 2023, and 480,723 tons in 2024. South Sumatra remains the largest producer of giant snakehead in 2024, accounting for 73,108 tons, followed by South Kalimantan with 61,795 tons. These production figures highlight the abundance and economic significance of the *Channa* genus as a valuable freshwater fishery resource in Indonesia (KKP, 2025).

Snakehead and giant snakehead are economically important freshwater fish species that are recognized for their high nutritional and functional value. Both species are extensively utilized as food fish, raw materials for processed fish products, and ingredients in nutraceutical and health supplement formulations because of their high protein and albumin content. The growing demand for functional foods is accompanied by increasing consumer awareness of the health benefits of nutrient-rich diets. Fish of the genus *Channa*, commonly known as snakehead fish, have high nutritional value. Snakehead and giant snakehead fish contain high levels of fatty acids, particularly palmitic and oleic acids. These species also contain essential amino acids, such as glutamic acid and lysine. In addition, they provide important minerals such as calcium, iron, and phosphorus. Giant snakehead contains 3.6147 g/dL albumin, whereas snakehead contains 3.3076 g/dL albumin (Fitriyani *et al*., 2020). Snakehead and giant snakehead also show comparable soluble protein levels, with both species containing 0.803 mg/mL soluble protein (Alviodinasyari *et al*., 2019).

Previous studies have indicated that albumin contributes to immune function. Albumin and immunoglobulin G (IgG) are the major plasma components. IgG in serum albumin functions as an antibody and exhibits anti-inflammatory properties (Niga *et al*., 2022). Proteins also support immune responses and tissue repair. When incorporated into a balanced diet, high-quality protein intake can support optimal growth and may help reduce the risk of stunting (Fikawati *et al*., 2021). Albumin extract is considered a functional food because of its high albumin and protein content (Sari & Rahmawati, 2022). Fish albumin can be extracted using a semi-vacuum extractor without the addition of solvents. This extraction process produces albumin extract as the main product and residual fish flesh as a byproduct. Albumin is a water-soluble plasma protein. Residual fish flesh contains protein, particularly myofibrillar protein, and other nutrients. Therefore, this by-product can be processed into fish meal. Fish meal is a dry solid product produced by removing most of the water and part or all of the fat from the fish material.

Fish meal is a concentrated, dry protein product. Producers commonly use fish flesh intended for consumption as raw material. Fish meal can serve as an intermediate ingredient in processed foods such as meatballs, nuggets, biscuits, and instant porridge. Processing snakehead fish into fish meal can extend its shelf life, facilitate incorporation into food formulations, and improve its nutritional value. Snakehead fish meal reportedly contains 11.05% moisture, 79.62% protein, 4.93% fat, 5.13% ash, 0.66% fiber, 363 kcal energy, and 0.70% albumin (Permatasari *et al*., 2021). (Dewantara *et al*., 2019) reported that snakehead fish meal contained 4.13% moisture, 88.27% protein, 5.83% fat, 3.80% ash, and 2.07% carbohydrates. Niga *et al*. (2022) reported that snakehead fish meal contained 9.26% moisture, 85.80% protein, 2.06% fat, 2.67% ash, and 0.21% carbohydrates.

The yield of fish meat remaining after albumin extraction from striped and giant snakehead fish ranged from 46.8% to 46.9%. This by-product has been utilized in the production of fish nuggets and shredded fish (Sari & Khairina, 2021; Sari & Rahmawati, 2022). Processing this residual fish meat into fish flour offers several advantages, including extendedend shelf life, incorporation into food formulations, and improved nutritional value. As an intermediate food ingredient, fish flour has broad applications in the manufacture of products such as fish balls, nuggets, biscuits, instant porridge, and other processed food.

Previous studies have extensively described the physical and chemical characteristics of fish flour produced from fresh fish meat; however, information regarding fish flour produced from the by-products of albumin extraction from the *Channa* genus remains unavailable. Therefore, the present study aimed to evaluate the physical and chemical characteristics, as well as the amino acid profile, of fish flour produced from the residual fish meat generated during albumin extraction from the *Channa* genus. The novelty of this study lies in the application of a zero-waste approach by converting the by-product of albumin extraction into fish flour with physical and chemical characteristics that comply with Indonesian National Standard (SNI).

MATERIALS AND METHODS

The main raw materials were giant and common snakehead fish. Both species were obtained from the Gambut Market in Banjar Regency, South Kalimantan, Indonesia. The giant snakehead had an average weight of 1250 ± 50 g and an average length of 52 ± 1.73 cm. The snakehead had an average weight of 1133 ± 58 g and an average length of 47.67 ± 2.52 cm. Both fish species were subjected to albumin extraction. The extraction process produced albumin extract as the main product and residual fish flesh as a by-product. The residual fish flesh was then processed into fish flour. The main equipment used for fish flour production included a temperature-controlled stove oven (Oven Hock No. 3, Indonesia) and a dry grinder (200G Powder Grinder, Indonesia).

Albumin extraction and fish flour production were conducted at the Laboratory of Raw Materials for Fishery Product Technology, Faculty of Fisheries and Marine Sciences, Lambung Mangkurat University, Banjarbaru, Indonesia. Fish flour quality analyses were conducted at the Animal Nutrition and Feed Laboratory, Faculty of Agriculture, Lambung Mangkurat University, Integrated Laboratory of Lambung Mangkurat University, and Integrated Laboratory of IPB University.

Production of Albumin Extract

Albumin extracts from giant snakehead and snakehead were prepared according to Sari and Rahmawati (2022). The fish were cleaned by removing the scales, viscera, gills, fins, and head. The fish flesh was washed under running water and drained of excess water. The fish flesh was scored to facilitate albumin release during the extraction process. Lime extract (0.5% w/v) was added at a rate of 5 mL per 1 kg of fish flesh. The fish flesh was marinated for approximately 3 min to reduce the fishy odor. The marinated flesh was then washed and drained. Albumin extraction was conducted at 60°C for 10–12 h without the

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addition of solvents. The liquid released during the first 2 h was discarded because it mainly contained water from fish flesh. The albumin-containing extract was identified by its slightly sticky texture. The albumin extraction process was completed approximately 10 h after the initial 2 h phase.

Production of Fish Flour

Fish flour was produced according to the method described by Sari *et al*. (2014), with modifications. The raw material consisted of residual fish flesh obtained from albumin extraction of the giant snakehead fish and the snakehead fish. The residual fish flesh was separated from the bones and skin. The flesh was then shredded and spread evenly on an oven tray to a thickness of approximately 0.5 cm. The drying process was conducted at 50°C for approximately 5 h. During drying, the fish flesh was stirred after the first two hours. The flesh was then stirred every 30 min until the drying process was complete. Gentle manual pressing was performed during drying to prevent clumping. The dried fish flesh was then cooled to room temperature. The cooled material was then ground using a dry grinder. The ground material was then sieved through 230-, 200-, 120-, 60-, 50-, and 35-mesh sieves to determine the fish flour yield based on particle size.

Test Parameters

The observed parameters included the yield, physical properties, chemical composition, and amino acid profile. Yield was determined according to (AOAC, 2005). The physical properties included color, solubility, and swelling power. The color was measured according to Setyawardani *et al.* (2022). Solubility and swelling power were measured according to the method described by Muchlisyiyah *et al*. (2016). Chemical analyses comprised the determination of protein content (BSI, 2006), moisture content (BSI, 2015), ash content, fat content, carbohydrate content (calculated by difference, 100% minus the sum of other components), and amino acid profile (AOAC, 2005).

Yield

The fish flour yield was calculated as the ratio of the fish flour weight to the residual fish flesh weight. The yield was calculated using Equation 1.

$$\%\text{yield} = \frac{\text{fish flour weight}}{\text{residual fish flesh weight}} \times 100 \quad (1)$$

Physical Analysis

Color

The color was measured using the CIE color scale with a Minolta CR-400 Chromameter. The measurements were performed using the CIELAB system. This analysis determined the color changes after processing. The CIELAB system consists of three parameters: The L* value indicates lightness and ranges from 0, which represents black, to 100, which represents white. The a* value represents the green-to-red spectrum of the sample. The b* value represents the blue-to-yellow spectrum of the color. The color reader was turned on before the measurement. The sensor was placed on the surface of the sample. The test button was pressed to obtain L*, a*, and b* values. Each sample was measured at three different points on its surface. Hue and chroma values were calculated using Equations 2 and 3 (Kamal-Eldin *et al*., 2020)

$$\text{Hue } (h°) = \tan^{-1}\left(\frac{a^*}{b^*}\right) \quad (2)$$

$$\text{Chroma } (C^*) = \sqrt{(a^2 + b^2)} \quad (3)$$

Solubility and swelling power

Solubility indicates the ability of fish flour to dissolve in water. Swelling power indicates the ability of fish flour to absorb water and expand its volume. A 100 g sample of fish flour was placed in a pre-weighed test tube. Distilled water (10 mL) was then added. The mixture was vortexed for 10 s. The sample was incubated in a water bath at 85°C for 30 min, with occasional stirring. The samples were then cooled in ice water until they reached ambient temperature. The suspension was centrifuged at 2,000 rpm for 30 min using a Frontier 5000 Series centrifuge (type: FC5706). The supernatant was transferred to a pre-weighed dish and dried in an oven until a constant weight was obtained. The weight of the dried supernatant was recorded as w_1. The remaining residue in the test tube was weighed and recorded as *ws*. The swelling power and solubility were calculated using Equations 4 and 5, respectively.

$$\text{Swelling power (\%)} = \frac{\text{Ws}}{0.1\times(100\%\text{-W1})} \quad (4)$$

$$\text{Solubility (\%)} = \frac{\text{W1}}{0.1} \times 100 \quad (5)$$

Chemical Analysis
Protein

The protein content was determined using the Kjeldahl method. A 2 g sample was placed in a digestion flask. Two catalyst tablets, 15 mL H_2SO_4, and 3 mL H_2O_2 were added to the flask. The mixture was then digested at 410 °C for 2 h. After digestion, the samples were cooled to room temperature. Subsequently, distilled water (50 mL) was added to the mixture. Distillation was conducted using 25 mL of 4% H_3BO_3 until the distillate turned yellow in color. The distillate was titrated with 0.2 N HCl until the color changed from green to grey. The nitrogen and protein contents were calculated using Equations 6 and 7, respectively.

$$\text{N (\%)} = \frac{(\text{A}-\text{B}) \times 14.008}{\text{C}} \quad (6)$$

A = sample titration volume
B = blank titration volume
C = sample weight

$$\text{Protein (\%)} = \text{N(\%)} \times 6.25 \quad (7)$$

Moisture

Moisture content was determined by oven-drying. A 5 g sample was placed in a dish and dried at 105 °C for 12 h using a Memmert UN110 Universal Oven. The dishes were then cooled in a desiccator for 30 min and weighed. The moisture content was calculated using Equation 8.

$$\text{Moisture (\%)} = \frac{(\text{A}-\text{B})}{\text{A}} \quad (8)$$

A = initial weight
B = dry weight

Ash

The ash content was determined using a muffle furnace. An empty dish was preheated in an oven, cooled for 30 min, and weighed again. A 5 g sample was placed in a dish. The samples were incinerated in two stages. The first stage was conducted at 450 °C. The second stage was conducted at 550 °C for 2–3 h using a muffle furnace (type 1300). After ashing, the dishes were cooled in a desiccator and weighed. The ash content was calculated using Equation 9.

$$\text{Ash (\%)} = \frac{\text{ash weight}}{\text{sample weight}} \times 100 \quad (9)$$

Fat

The fat content was determined using the Soxhlet method. A 1–2 g sample was wrapped in filter paper with cotton and dried at 80 °C for approximately 1 h. The dried sample was placed in a Soxhlet apparatus connected to a pre-weighed fat flask containing boiling stones. Extraction was conducted using petroleum ether or another fat solvent for approximately 6 h. The solvent was then distilled. The fat extract was dried at 105 °C, cooled in a desiccator, and weighed until a constant weight was achieved. The fat content was calculated using Equation 10.

$$\text{Fat (\%)} = \frac{\text{W2}-\text{W1}}{\text{W}} \times 100 \quad (10)$$

W = sample weight
W1 = weight of the flask and boiling stones before extraction
W2 = weight of the flask and boiling stones after extraction

Carbohydrate

The carbohydrate content was calculated using the by-difference method. The calculation used protein, moisture, ash, and fat content as the measured proximate components. The carbohydrate content was calculated using Equation 11.

$$\text{Carbohydrate (\%)} = 100\% - (\text{Protein (\%)} - \text{moisture (\%)} - \text{ash (\%)} - \text{fat (\%)}) \quad (11)$$

Amino Acid Profile

The amino acid profile was analyzed using HPLC with a Shimadzu LC-2070 Series system. A 3 mg sample was crushed and hydrolyzed with 1 mL of 6 N HCl solution. The sample was heated at 110°C for 24 h. After hydrolysis, the sample was cooled and transferred to a 50 mL evaporator flask. The residue was rinsed with 2 mL 0.01 N HCl. The rinsing step was repeated two to three times. The sample was then evaporated using a rotary evaporator for 15–30 min. The dried sample was dissolved in 5 mL 0.01 N HCl. The solution was filtered using a Millipore filter paper. Derivatization was performed using 30 µL of derivatization solution. The derivatization solution was prepared by mixing the potassium borate buffer with the sample at a 1:1 ratio (v/v). The mixture was then combined with an ortho-phthalaldehyde solution at a 5:1 ratio. The final mixture was filtered through a Whatman filter paper. A 5 µL aliquot was injected into the HPLC system for analysis. The separation required approximately 25 min. Amino acid concentrations were calculated using a standard chromatogram prepared under the same conditions. The amino acid content was calculated using Equation 12.

$$\text{Amino acid (\%)} = \frac{A \times C \times FP \times MW}{B \times D} \times 100 \quad (12)$$

A = sample area
C = standard amino acid concentration (0.5 µmol/mL)
FP = dilution factor (5 mL)
MW = molecular weight of each amino acid
B = standard area
D = sample weight

Data Analysis

Data were analyzed using an independent *t*-test to compare the two treatments: giant snakehead and snakehead fish flour. Physical and chemical analyses were performed in triplicate. The physical analyses included color, solubility, and swelling power measurements. The chemical analyses included protein, moisture, ash, fat, and carbohydrate content. Amino acid profiles were qualitatively and quantitatively analyzed. This analysis was performed on one sample from each treatment group. Therefore, the amino acid data are presented descriptively.

RESULTS AND DISCUSSION

Yield

Yield is an important indicator of processing efficiency in fishery products. Yield describes the proportion of raw material converted to the final product (Nurfitriyani *et al*., 2024). The processing efficiency increases when a higher proportion of the raw material is retained as the product. Therefore, a high yield improves the economic value of fishery-based products (Senduk *et al*., 2022). Each species was prepared using 15 kg of fresh fish. Giant snakehead and snakehead each produced 10 kg of fish flesh, corresponding to a flesh yield of 66.67%. The albumin extraction process produced 1.5 L of albumin extract, corresponding to an extraction yield of 15%. This process also generates residual fish flesh as an extraction by-product. The residual flesh weighed 4.69 kg for giant snakehead and 4.68 kg for snakehead, corresponding to yields of 46.9% and 46.8%, respectively. The residual flesh was further processed into fish flour. The residual flesh of the giant snakehead produced 1.37 kg of fish flour, corresponding to a 29.21% yield of fish flour. The residual Snakehead dual flesh also produced 1.37 kg of fish flour, corresponding to a yield of 29.27%.

The fish meal yield is influenced by several processing factors, including drying, grinding, and sieving. In addition, the proportion of edible fish flesh significantly affects the final fish meal yield. In snakehead fish, the fillet accounts for approximately 47% of the total body weight (Niga *et al*., 2022). Similarly, in giant snakehead, flesh constitutes approximately 44% of the total body weight, resulting in a fish meal yield of 92.49% (Fakhriah, 2019). The yields of giant snakehead and snakehead flour based on particle size are presented in Table 1.

Table 1 Yield of giant snakehead and snakehead flour based on particle size

Mesh size		Giant snakehead flour		Snakehead flour	
(μm)	(Mesh)	Weight (g)	Yield %	Weight (g)	Yield %
63	230	68.33±1.53	39.55±0.96	64.00±1.00	37.62±0.42
75	200	48.00±2.00	27.78±1.12	39.33±1.15	23.12±0.53
125	120	31.33±1.53	18.14±0.90	30.33±0.58	17.83±0.58
250	60	21.00±1.73	12.15±0.93	24.00±1.00	14.10±0.43
300	50	3.33±0.58	1.93±0.33	11.67±1.53	6.85±0.80
500	35	0.77±0.40	0.44±0.23	0.80±0.35	0.47±0.21

Yield Based on Particle Size

Particle-size-based yield observations were conducted to determine the particle-size distribution of the fish flour. The results showed that the largest proportion of particles from both fish species was retained on the 63 μm sieve (230 mesh). The yield of giant snakehead flour was 68.33±1.53 g (39.55±0.96%), whereas that of snakehead flour was 64.00±1.00 g (37.62±0.42%). These findings suggest that the majority of particles from both species were retained on the coarser sieves, indicating that the fish flour particles were relatively coarse. Fish flour contains high protein levels and has a complex matrix. This protein-rich matrix may reduce the grinding efficiency and limit the formation of finer particles. In general, fish flour has a dry texture with relatively uniform and fine particles. Particle size may also depend on nutritional components, particularly crude fiber, fat, and protein content (Purnamasari *et al.*, 2018).

A reduction in sieve size (e.g., 500 μm or 35 mesh) resulted in a lower fish flour yield. The yield of giant snakehead flour was 0.77±0.40 g (0.44±0.23%), whereas that of snakehead flour was 0.80±0.35 g (0.47±0.21%). These results suggest that only a small proportion of particles were classified as very fine. The particle size can influence the sensory properties of processed products containing fish flour. However, Rahmaniar *et al.* (2023) reported that 60-, 80-, and 100-mesh particle sizes of snakehead fish flour did not significantly affect the moisture, protein, fat, ash, water absorption capacity, or oil absorption capacity.

Physical and Chemical Properties

The physical and chemical characterization used fish flour from the fraction with the highest yield, namely, the 63 μm fraction. The physical parameters included color, solubility, and swelling power of the starch. The chemical parameters, including protein, moisture, ash, fat, carbohydrate, and amino acid contents, are presented in Table 2.

Color

The L* value represents the lightness of the product. This value ranges from 0 to 100, where 0 indicates black and 100 indicates white color. Giant snakehead flour had an L* value of 76.83±0.03, whereas snakehead flour had an L* value of 72.68±0.51, respectively. The independent *t*-test indicated a significant difference between the two fish flours. The higher L* value of the giant snakehead flour indicates a lighter color than that of the snakehead flour. Visually, both fish flours showed an off-white to ivory appearance; however, the giant snakehead flour appeared lighter than the snakehead flour. A previous study reported that biscuits fortified with 10% eel flour exhibited a higher lightness value (L* = 63.45±0.21) than those fortified with 50% eel flour (L* = 53.75±0.92). The decrease in the L* values with increasing proportions of eel flour was associated with a darker biscuit color (Wulandari *et al.*, 2019).

The a* value represents the green-to-red spectrum. Positive values (0 to 80) indicate red hues, while negative values (0 to −80) indicate green hues (Fadlilah *et al.*, 2022) Giant snakehead flour had an a* value

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Table 2 Summary of physical and chemical properties of giant snakehead and snakehead flour

Parameters	Giant snakehead flour	Snakehead flour
Color		
L*	76.83±0.03[a]	72.68±0.51[b]
a *	2.74±0.07[a]	3.68±0.02[b]
b *	24.45±0.08[a]	22.88±0.26[b]
Hue	83.60±0.17[a]	80.89±0.14[b]
Chroma	24.60±0.06[a]	23.18±0.27[b]
Solubility (%)	21.00±1.00[a]	22.00±1.73[a]
Swelling power (%)	1.09±0.46[a]	0.85±0.20[a]
Protein (%)	76.97±0.46[a]	77.96±0.25[b]
Moisture (%)	10.37±0.13[a]	13.53±0.13[b]
Ash (%)	3.36±0.03[a]	3.49±0.03[b]
Fat (%)	7.12±0.10[a]	1.74±0.16[b]
Carbohydrate (%)	2.15±0.75[a]	0.27±0.04[b]

Different superscript letters in the same row indicate significant differences ($p<0.05$)

of 2.74±0.07, whereas snakehead flour had an a* value of 3.68±0.02. The independent *t*-test indicated a significant difference between the two fish flours. The higher a* value of the snakehead flour indicates greater redness than that of the giant snakehead flour. The b* value represents the blue-to-yellow region of the color spectrum. Positive values (0–70) indicate yellow, whereas negative values (0 to −70) indicate blue. Positive b* values indicate yellowness, whereas negative b* values indicate blueness (Nanda *et al*., 2023). Giant snakehead flour had a b* value of 24.45±0.08, whereas snakehead flour had a b* value of 22.88±0.26. The independent *t*-test indicated a significant difference between the two fish flours. The higher b* value of giant snakehead flour indicates greater yellowness than that of the snakehead flour.

Hue was calculated from a* and b* values. Hue indicates the dominant color position in the color spectrum, such as red, green, yellow, blue, and violet (Handayani *et al*., 2022). Giant snakehead flour had a hue value of 83.60±0.17, whereas snakehead flour had a value of 80.89±0.14. The independent *t*-test indicated a significant difference between the two fish flours. Based on the color classification reported by Tager *et al*. (2021), both values fall within the yellow-red range. However, visual observations showed that both fish flours appeared ivory white. The Hue angle represents a color characteristic based on the light reflected from an object. In a previous study, biscuits fortified with eel flour exhibited hue angle values ranging from 14.9±0.99 to 22.15±0.78 (Wulandari *et al*., 2019). Increasing the proportion of eel flour fortification affected the Hue angle, resulting in a darker biscuit color. The yellowish-brown color observed in biscuits fortified with fish protein concentrate has been attributed to the Maillard reaction between reducing sugars and free amino acids (Abraha *et al*., 2018).

Chroma represents the color saturation or intensity. It ranged from 0 to 100%. Higher chroma values indicate more vivid colors, whereas lower values indicate duller or less-saturated colors (Dakhi *et al*., 2024). Giant snakehead flour had a chroma value of 24.60±0.06, whereas snakehead flour had a value of 23.18±0.27. The independent *t*-test indicated a significant difference between the two fish flours. These low chroma values correspond to the pale and weakly saturated appearances of both fish flours. Color is an important quality indicator of fish flour. Color differences may reflect variations in chemical composition and heat-induced reactions during processing. The protein contents of giant snakehead and snakehead flours were 76.97% and 77.96%, respectively. Fish flour with a high protein content generally exhibits a light brown to yellowish color. In contrast, excessive darkening may indicate a deterioration in quality due to Maillard reactions during heating (Farida *et al.*, 2024). The addition of 5–15% tilapia fish flour to biscuits increased the chroma values (Chambó *et al.*, 2017).

Solubility and swelling power

Solubility describes a material's ability to dissolve in water. Swelling power describes the ability of flour to absorb water and expand its volume. This property is commonly expressed as the amount of water absorbed by 1 g of material under high-temperature conditions with excess water (Ansharullah & Hermanto, 2021). Giant snakehead flour had a solubility of 21.00±1.00%. The solubility of snakehead flour was 22.00±1.73%. The independent *t*-test indicated no significant difference between the two fish flours (Table 2). The comparable solubility values may be related to the similar particle size characteristics and protein-rich matrix structure of both fish flours. The particle size of fish flour from both species tended to be relatively coarse, with most particles being large. Fish flour contains a complex and elastic protein matrix that may limit water penetration and solubilization (Purnamasari *et al.*, 2018). The particle size can influence flour solubility. Smaller particles generally provide a greater surface area, which improves water penetration and the interaction between the solid matrix and water (Lee *et al.*, 2021).

Protein content also strongly influences flour functionality, including solubility, flavor binding, emulsification, viscosity, gelation, texture formation, and dough development. Therefore, proteins are key components that determine the functional characteristics of food products (Alfaro-Diaz *et al.*, 2024). Proteins are the main factor determining solubility because they contain polar groups that bind water more effectively than other components (Zhang *et al.*, 2019). In animal-based materials, proteins contribute more significantly to solubility than carbohydrates. Carbohydrates in animal tissues are present in limited amounts and are generally less soluble; thus, their contribution to solubility is relatively small (Liu *et al.*, 2022).

Giant snakehead flour had a swelling power of 1.09±0.46%. Snakehead flour had a swelling power of 0.85±0.20%. The independent *t*-test indicated no significant difference between the two fish flours (Table 2). The swelling power values of both fish flours were low. A low swelling power indicates limited water absorption and expansion capacity. Therefore, food products formulated with these flours may exhibit a firmer or denser texture. The protein content of flour can influence its functional properties, such as water absorption and swelling power. Proteins can influence the swelling power by interacting with starch and affecting the ability of starch granules to absorb water and expand during heating (Setiavani *et al.*, 2024). The ability of flour to swell at low temperatures supports its use as a cold-swelling ingredient and thickening agent. Rapid swelling may also help form an instant matrix that supports protein particles and other ingredients in the formulated foods (Dobson *et al.*, 2022).

Protein

Giant snakehead flour had a protein content of 76.97±0.46%. The protein content of the snakehead flour was 77.96±0.25%. The independent *t*-test indicated a significant difference between the two fish flours (Table 2). Both values met the Indonesian National Standard for fish flour, which requires a minimum protein content of 65% (BSN, 1996). The nutritional composition of fish meal is influenced by several factors, including fish species, freshness of the raw material, body parts used, and processing methods. Different fish species produce fish meals with varying nutritional qualities owing to differences in their proximate composition. Fresh fish generally yield fish meals with higher protein quality than fish that have undergone quality deterioration. In addition, the use of whole fish typically results in fish meal with a higher protein content than fish meal produced from processing by-products such as heads, bones, skin, and viscera (Ahmed *et al*., 2022).

Processing conditions also play a critical role in determining the nutritional quality of fish meals. Excessively high drying temperatures or prolonged drying times may cause protein denaturation and accelerate lipid oxidation, thereby reducing the nutritional value of fish meals (Rasul *et al*., 2022). Previous studies have reported variable protein contents in snakehead fish flour. Permatasari *et al*. (2021) reported that oven-dried snakehead flour contained 79.62% protein after drying at 60 °C for 8 h, while Wirawan *et al*. (2018) reported a protein content of 65.3%. Dewantara *et al*. (2019) reported protein contents of 88.27% and 50.70% in different snakehead fish flour products. Syafii and Fajriana (2022) reported that penja fish flour contained 62.32% protein after drying at 60 °C for 24 h. The high protein content of fish flour reflects the abundance of essential amino acids in fish muscle proteins (Rahmaniar *et al*., 2023).

Moisture

Moisture content affects the texture, appearance, flavor, freshness, and shelf life of food (Mikdarullah *et al*., 2020). Giant snakehead flour had a moisture content of 10.37 ± 0.13%. The snakehead flour had a moisture content of 13.53±0.13%. The independent *t*-test indicated a significant difference between the two fish flours (Table 2). The moisture values obtained in this study exceeded the limits set by the Indonesian National Standard for fish flour. BSN (1996) specifies a maximum moisture content of 10% for grade I fish flour and 12% for grades II and III fish flours. Giant snakehead flour slightly exceeded the grade I limit but met the limits for grades II and III. Snakehead flour exceeded the specified limits for all three grades of fish meal.

Moisture content affects the texture, appearance, flavor, freshness, and shelf life of food (Mikdarullah *et al*., 2020). Moisture variation among fish flours can result from differences in species characteristics and processing conditions of the fish. Pressing, drying temperature, drying duration, and storage conditions strongly influenced the final moisture content. Higher drying temperatures generally promote faster evaporation and produce lower moisture content (Farida *et al*., 2024). Fish flour is hygroscopic, meaning that it easily absorbs moisture from the environment (Valentina *et al*., 2021). Previous studies have reported different moisture contents in snakehead fish flour. (Wirawan *et al*., 2018) reported a moisture content of 10%. Dewantara *et al*. (2019) reported a moisture content of 4.33%. Permatasari *et al*. (2021) reported a moisture content of 11.05%. Orlan *et al*. (2019) reported a moisture content of 18.86% in skipjack fish flour. Ambarwati (2024) reported moisture contents of 7.41%, 5.01%, and 5.21% in catfish, African catfish, and tilapia fish flours, respectively.

Ash

The ash content represents the total mineral residue remaining after complete combustion. Fish contain minerals such as calcium and Mg. Giant snakehead flour had an ash content of 3.36±0.03. The ash content of the snakehead flour was 3.49±0.03%. The independent *t*-test indicated a significant difference between the two fish flours (Table 2). The ash content of fresh giant snakehead fish was 4.68%, whereas processing it into fish flour increased the ash content to 7.51%. This increase can be attributed to the drying process, which removes moisture from the raw material and consequently increases the concentration of solids, including mineral constituents (Fakhriah, 2019).

The mineral content varies by species and tissue composition. Processing methods, especially drying, can also affect ash content because water removal concentrates the mineral components in the final product (Farida *et al*., 2024). The mineral content of *C. striata* is influenced by its habitat. As a benthic species, snakehead fish inhabit the bottom of aquatic environments and consume sediment (mud) as part of their diet. This feeding behavior may contribute to the relatively high mineral content observed in snakehead fish (Asfar, 2018). Previous studies reported ash contents of 2.94% and 3.80% in snakehead fish flour (Wirawan *et al.*, 2018; Dewantara *et al.*, 2019). Ambarwati (2024) reported ash contents of 2.01%, 2.99%, and 2.23% in catfish, African catfish, and tilapia fish flours, respectively.

Fat

Giant snakehead flour had a fat content of 7.12±0.10%. Snakehead flour had a fat content of 1.74±0.16. The independent *t*-test indicated a significant difference between the two fish flours (Table 2). Both values met the Indonesian National Standard for fish flour, which specifies a maximum fat content of 12% (BSN, 1996). Previous studies have reported variable fat contents in snakehead fish flour. Wirawan *et al.* (2018) reported a fat content of 13.81%. Dewantara *et al.* (2019) reported a fat content of 3.48%. Ambarwati (2024) reported fat contents of 4.58%, 8.10%, and 4.31% in catfish, African catfish, and tilapia fish flours, respectively. Fat content strongly affects fish flour quality. High fat content can accelerate lipid oxidation and increase rancidity during storage (Farida *et al.*, 2024; Orlan *et al.*, 2019). In contrast, particle size does not significantly affect fat content in fish flour (Rahmaniar *et al.*, 2023)

Carbohydrate

Giant snakehead flour had a carbohydrate content of 2.15±0.75%. The carbohydrate content of the snakehead flour was 0.27±0.04%. The independent *t*-test indicated a significant difference between the two fish flours (Table 2). Previous studies reported carbohydrate contents of 21.83% and 2.07% in snakehead fish flour (Wirawan *et al.*, 2018; Dewantara *et al.*, 2019). Ambarwati (2024) reported carbohydrate contents of 4.34%, 7.30%, and 7.01% in catfish, African catfish, and tilapia fish flours, respectively. Carbohydrate content was calculated using the by-difference method. This method estimates the carbohydrate content by subtracting the measured protein, moisture, ash, and fat contents from 100%. Therefore, carbohydrate values strongly depend on the levels of other proximate components. Higher carbohydrate values occur when the measured protein, moisture, ash, and fat contents are lower, whereas lower carbohydrate values occur when these components are higher (Matsuo *et al.*, 2019).

Amino acid

Amino acid analysis was conducted to determine the amino acid composition of the fish flour produced from albumin extraction byproducts. Table 3 shows that snakehead flour has a higher total amino acid content than giant snakehead flour. Snakehead flour contained 87.23% total amino acids, whereas giant snakehead flour contained 72.32% total amino acids.

Amino acids contain two main functional groups: carboxyl (-COOH) and amino ($-NH_2$) groups (Yuanita *et al.*, 2025). Amino acids form proteins, serve as precursors of metabolic compounds, and bind to metal compounds during enzymatic processes. Therefore, the amino acid composition determines the nutritional quality and functional value of protein-rich food materials. The protein quality depends on the type and proportion of amino acids in a food product. The nutritional composition of fish varies according to internal and external factors. Internal factors include species, sex, age, and reproductive phases. External factors include habitat, feed availability and water quality (Fitriliyani *et al.*, 2019). The processing conditions can also affect the amino acid composition. Fish flour processing has been reported to influence the amino acid profile of the swamp barb fish (Adawyah *et al.*, 2020). Sumandiarsa *et al.* (2020) reported that steaming preserved essential and non-essential amino acid proportions in cooked skipjack tuna more effectively than pressure cooking and steam pre-cooking did.

The three dominant essential amino acids in both fish flours were lysine, leucine, and valine, respectively. Giant snakehead flour contained 6.61% lysine, 6.78% leucine, and 4.12% valine content. Snakehead flour contains higher levels of these essential amino acids, with 8.66% lysine, 8.40% leucine, and 5.45% valine. Essential amino acids and glutamine regulate muscle and whole-body protein anabolism. These amino acids also support immune function and maintain cellular and

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Table 3 Amino acid composition of fish meal

Parameters (% w/w)	Giant snakehead flour	Snakehead flour
Amino Acid		
Aspartic Acid	7.98	9.47
Threonine	3.17	3.72
Serine	3.01	3.64
Glutamate	14.02	17.05
Glycine	4.62	5.63
Alanine	5.72	7.04
Valine	4.12	5.45
Methionine	2.42	2.41
Ileucine	3.31	4.15
Leucine	6.76	8.40
Tyrosine	2.07	2.65
Phenylalanine	2.97	3.51
Histidine	1.72	1.96
Lysine	6.61	8.66
Arginine	3.82	3.46
Amino Acid Total	**72.32**	**87.23**

physiological homeostasis, particularly under hypercatabolic conditions, such as surgery, cancer, and intensive care (Negro *et al*., 2024). Insufficient intake of essential amino acids can disrupt metabolic processes and impair linear growth in children (Nurbaiti *et al*., 2023). Lysine supports growth and tissue repair, whereas leucine supports growth in infants and children.

The three dominant non-essential amino acids in both fish flours were glutamic, aspartic, and alanine. Giant snakehead fish flour contained 14.02% glutamic acid, 7.98% aspartic acid, and 5.72% alanine. Snakehead flour contains higher levels of these amino acids, with 17.05% glutamic acid, 9.47% aspartic acid, and 7.04% alanine. Glutamate, aspartate, and glycine contribute to the savory taste of food products (Chan *et al*., 2023). Aspartic acid contributes to the aroma and taste of food during processing. Glutamic and aspartic acids contribute to seafood flavor. Their sodium salts, including monosodium glutamate, produce an umami taste (Tamaya *et al*., 2020). Umami is considered a savory taste because it enhances the overall flavor of food, especially protein-rich sources (Wang *et al*., 2020). It also strengthens sweetness and saltiness while reducing bitterness (Schmidt *et al*., 2021).

CONCLUSION

Fish flour produced from albumin-extraction by-products of snakehead fish showed the most favorable overall characteristics. This flour had an L* value of 72.68 and a hue value of 80.89, which placed it in the yellow-red color range. Its chroma value of 23.18 indicates a pale and weakly saturated color, although the flour appeared visually white. Snakehead fish flour also showed 22% solubility and 0.85% swelling power, respectively. Its chemical composition consisted of 77.96% protein, 13.53% moisture, 3.49% ash, 1.74% fat, and 0.27% carbohydrates. In addition, snakehead fish flour contained 87.23% total amino acids. These characteristics indicate that snakehead fish flour has strong potential as a protein-rich intermediate ingredient derived from albumin extraction by-products.

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