



NUTRITIONAL AND PHYSICOCHEMICAL CHARACTERIZATION OF FISH PROTEIN CONCENTRATE FROM CULTURED STRIPED CATFISH (*Pangasianodon hypophthalmus*)

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Abstract

High-quality protein is essential for human nutrition, and there is a growing demand for nutrient-dense protein ingredients derived from underutilized aquatic resources. Fish protein concentrate (FPC) represents a promising approach for valorizing fishery products into stable, protein-rich ingredients with favorable nutritional profiles. The striped catfish, *Pangasianodon hypophthalmus*, is a widely cultivated freshwater fish in Indonesia with significant potential as a protein source. This study aimed to produce and characterize a chemical-free FPC from cultured striped catfish based on its proximate, amino acid, and fatty acid compositions. The FPC was produced using a simple thermal-mechanical method involving mincing, pressing, steaming, and drying. The final product was analyzed for its nutritional and physicochemical properties. The resulting FPC exhibited a high crude protein content of 86.61%, with relatively low moisture and lipid contents, indicating good potential for stability. Amino acid analysis revealed a complete profile of essential and non-essential amino acids, with L-leucine and L-glutamic acid identified as the most abundant amino acids. Fatty acid analysis showed that the concentrate retained essential polyunsaturated fatty acids, including docosahexaenoic acid (DHA). Based on these results, the FPC produced from cultured *P. hypophthalmus* has a favorable nutritional profile and represents a potential protein-rich ingredient for further development in food applications. Further studies are needed to evaluate the functional properties, digestibility, sensory characteristics, and performance of these products in food applications.

Keywords: amino acids, docosahexaenoic acid, fatty acid, L-glutamic, L-leucine

Karakterisasi Nutrisi dan Fisikokimia Konsentrat Protein Ikan dari Ikan Patin (*Pangasianodon hypophthalmus*) Hasil Budi Daya

Abstrak

Protein berkualitas tinggi merupakan komponen esensial bagi pemenuhan gizi manusia, dan terdapat peningkatan kebutuhan terhadap bahan pangan padat gizi yang berasal dari sumber daya perairan yang belum memanfaatkan secara optimal. Konsentrat protein ikan (KPI) merupakan salah satu pendekatan yang menjanjikan untuk meningkatkan nilai tambah hasil perikanan menjadi bahan pangan stabil dan kaya akan kandungan asam amino dengan profil gizi yang baik. Ikan patin (*Pangasianodon hypophthalmus*) merupakan spesies air tawar yang banyak dibudidayakan di Indonesia dan memiliki potensi besar sebagai sumber protein. Penelitian ini bertujuan untuk memproduksi dan mengkaji KPI bebas bahan kimia yang diperoleh dari ikan patin hasil budi daya berdasarkan komposisi proksimat, profil asam amino, dan profil asam lemaknya. KPI diproduksi menggunakan metode termal-mekanis sederhana yang meliputi tahap penggilingan, pengepresan, pengukusan, dan pengeringan. Produk akhir kemudian dianalisis untuk mengetahui mutu gizi dan sifat fisikokimianya. KPI yang dihasilkan menunjukkan kadar protein kasar yang tinggi sebesar 86,61% dengan kadar air dan lemak yang relatif rendah sehingga mengindikasikan potensi stabilitas yang baik. Analisis asam amino mengungkap kelengkapan profil asam amino esensial dan non-esensial, dengan L-leusina dan asam L-glutamat sebagai komponen yang paling dominan. Analisis asam lemak memperlihatkan bahwa produk masih mempertahankan asam lemak tak jenuh ganda esensial, termasuk asam dokosaheksaenoat (DHA). Berdasarkan temuan tersebut, KPI yang dihasilkan dari *P. hypophthalmus* hasil budi daya memiliki mutu gizi yang baik dan berpotensi sebagai bahan pangan kaya protein untuk dikembangkan lebih lanjut dalam aplikasi pangan. Kajian lanjutan diperlukan untuk mengevaluasi sifat fungsional, daya cerna, atribut sensoris, dan kinerja produk dalam aplikasi pangan.

Kata kunci: asam amino, asam dokosaheksaenoat, asam lemak, L-glutamat, L-leusina

INTRODUCTION

Protein is an essential macronutrient that is critical for human growth, development, and tissue repair, particularly during the first 1,000 days of life (Ghosh, 2016). The rising global demand for sustainable protein sources has increasingly directed attention towards underutilized aquatic resources as strategic raw materials for protein ingredient development (Kaushik *et al.*, 2024). The striped catfish, *Pangasianodon hypophthalmus*, is one such resource a widely cultivated freshwater species recognized for its relatively high protein content, complete essential amino acid profile, and low cholesterol concentration (Chakma *et al.*, 2022; Madhulika *et al.*, 2024), rendering it a suitable candidate for the development of fish protein concentrates (FPC). Despite its extensive cultivation across Indonesia, the valorisation of *P. hypophthalmus* sourced from specific local aquaculture systems in eastern

Indonesia, particularly in Sulawesi, remains poorly documented in the scientific literature.

In South Sulawesi Province, striped catfish have emerged as a promising freshwater aquaculture commodity. Its cultivation has been actively promoted by local fisheries authorities to meet the steadily increasing domestic demand. According to the BPS (2024), striped catfish production during the 2018–2022 period ranged from 18 to 30 tons. The Jeneberang River Basin in Gowa Regency is a key cultivation site where river-based cage aquaculture (keramba jaring apung) has been practiced by local communities and is recognized for its developmental potential (Melin & Mado, 2025). The hydrological characteristics of the Jeneberang River, including its favorable water quality and flow dynamics, are considered conducive to the growth and flesh quality of cultured fish (Melin & Mado, 2025),



suggesting that fish produced in this system may possess a distinct nutritional profile. Nevertheless, the nutritional composition of *P. hypophthalmus* cultivated in this river-based system has never been characterized, resulting in a significant knowledge gap, given that aquatic environments, feed regimes, and local ecological conditions are known to substantially influence the nutritional profile of farmed fish (Chakma *et al.*, 2022).

Proximate analyses from various studies on raw *P. hypophthalmus* filets report considerable variation, with protein content ranging from 14.36% to 19.49% and lipid content from 3.74% to 12.90% (Table 1). Previous studies have identified oleic acid (40.14%) as the dominant monounsaturated fatty acid and palmitic acid (26.22%) as the main saturated fatty acid in this species, with omega-3 and omega-6 concentrations subject to variation (Ayu *et al.*, 2020; Lubis *et al.*, 2024). Such variability across geographic origins and aquaculture conditions reinforces the importance of characterizing fish from distinct local systems (Toomey *et al.*, 2020) and, crucially, of employing standardized processing methods to produce a consistent, high-quality protein ingredient (Woodgate *et al.*, 2020).

FPC is a refined product designed to maximize protein content while reducing fat, moisture, and volatile odor compounds, and is typically characterized by a protein content of 70–90%, favorable solubility, digestibility, and storage stability (Kaushik *et al.*, 2024). The development of FPC from *P. hypophthalmus* represents a strategic approach to valorize this locally cultivated resource into a stable, protein-rich ingredient. Most existing studies on FPC from this species have employed chemical solvent-based extraction using ethanol or isopropyl alcohol to achieve high protein purity (Fitri *et al.*, 2021; Rieuwpassa *et al.*, 2022). Although effective, these methods raise concerns regarding solvent residue, production cost, and scalability at the community level, particularly in rural aquaculture settings such as those along the Jeneberang River. Nutrient retention in FPC is also known to vary considerably depending on the extraction approach employed (Mohanty

et al., 2014; Nuryanto *et al.*, 2022), making the compositional characterization of each processing route an important prerequisite before further application.

Accordingly, this study aimed to produce and characterize FPC from cultured *P. hypophthalmus* obtained from the Jeneberang River Basin, Gowa Regency, South Sulawesi, using a chemical-free method. Characterization was limited to proximate composition, amino acid profile, and fatty acid profile. To the best of our knowledge, no prior study has reported the nutritional characterization of FPC derived from *P. hypophthalmus* cultivated in this river-based system or employed this chemical-free processing approach in combination with an integrated three-parameter compositional analysis for locally cultivated Indonesian stocks. This study was designed to provide region-specific baseline evidence regarding the feasibility of transforming locally cultured striped catfish into a stable, protein-rich ingredient through a simple processing approach that is potentially adaptable to decentralized and small-scale fish-processing settings. Functional properties, protein digestibility, sensory characteristics, shelf-life performance, and incorporation into food products were beyond the scope of the present study and should be evaluated in future studies.

MATERIALS AND METHODS

Fish Sampling and Experimental Sites

The study was conducted from February to May 2025. Cultured striped catfish were obtained from a river-based aquaculture farm in the Jeneberang River Basin, Gowa Regency, South Sulawesi, Indonesia. Three fish weighing 2.5–3.0 kg were randomly selected as biological samples. Immediately after collection, the fish were placed in a styrofoam container containing flaked ice and transported to the Fishery Product Processing Laboratory, Hasanuddin University, Makassar, Indonesia, to maintain freshness prior to processing. FPC preparation was conducted at the Fishery Product Processing Laboratory, Hasanuddin University, whereas physicochemical analyses

were performed at the Chemistry Laboratory of PT Saraswanti Indo Genetech (SIG), Bogor, Indonesia.

Preparation of Fish Protein Concentrate (FPC)

The FPC was prepared following a modified procedure described in a previous study (Melita, 2023). The catfish were filleted to separate the flesh from their skin and bones. The fillets were washed thoroughly, minced using a meat grinder, and then weighed. The minced fish was then marinated in a 10% (v/w) lime juice solution for 10 min to reduce the fishy odor, followed by thorough washing with deionized water.

The washed mince was pressed to remove excess water and steamed for 15 min. After steaming, the fish was pressed again to further reduce the moisture and lipid content. The resulting fish press cake was dried in an oven at 65°C for 8 h. The dried material was then pulverized into a fine powder using a dry blender and sieved through a 100-mesh screen to obtain the final FPC.

Analytical Methods

The FPC was analyzed for its proximate composition (moisture, protein, lipid, and ash), carbohydrate content (by difference), fatty acid profile (EPA, DHA, omega-3, -6, and-9), and amino acid profile (18 types).

Moisture

Moisture content was determined using the thermogravimetric method described by the AOAC International (AOAC, 1988; Bendary *et al.*, 2013; Latimer, 2023). Pre-dried porcelain crucibles were weighed, and 1-2 g of the FPC sample was added. The crucibles were then dried in an oven at 102-105°C for 6 h. After drying, the crucibles were cooled in a desiccator and weighed again. Moisture content was calculated as follows:

$$\text{Moisture (\%)} = \frac{A - B}{A} \times 100$$

Where:

A = initial sample weight (g)

B = dry sample weight (g)

Protein

Crude protein was determined using the Kjeldahl method (SNI 01-2891-1992), which involves digestion, distillation, and titration. One gram of the sample was digested in a Kjeldahl flask with 10 ml of concentrated H₂SO₄ and a Kjeldahl tablet (selenium catalyst) at 410°C until the solution turned clear green (approximately 1 h). The digest was cooled, diluted to 100 ml with deionized water, and distilled after adding 10 ml of 40% NaOH. The distillate was collected in an Erlenmeyer flask containing 2% boric acid and a mixture of indicators. The solution was titrated with a standardized 0.1 N HCl solution. A blank titration was concurrently performed.

$$\text{Crude protein (\%)} = \frac{(A - B) \times N_{\text{HCl}} \times 14.007 \times 6.25}{C} \times 100$$

Where:

A = mL HCl_{sample}

B = mL HCl_{blank}

C = sample weight (g)

6.25 is the nitrogen-to-protein conversion factor

Ash

The ash content was determined using the dry ashing method described by the AOAC International (AOAC, 1988). The crucibles containing the dried samples from the moisture analysis were placed in a muffle furnace at 600°C for approximately 6 h or until a white or grey ash was obtained. The crucibles were then cooled in a desiccator and weighed again.

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Initial sample weight (g)}} \times 100$$

Lipid

Total lipid content was determined using the Soxhlet extraction method following the AOAC International (AOAC, 1988). A 2-3 g sample was weighed into a filter paper thimble. Extraction was performed using n-hexane as the solvent for 5-6 hours. After extraction, the solvent was evaporated, and the remaining lipid residue was dried in an oven to obtain a constant weight.



$$\text{Lipid (\%)} = \frac{\text{Extracted lipid weight (g)}}{\text{Initial sample weight (g)}} \times 100$$

Carbohydrate

Carbohydrate content was determined by difference, calculated as follows:

$$\text{Carbohydrate (\%)} = 100 - (\% \text{moisture} + \% \text{protein} + \% \text{lipid} + \% \text{ash})$$

Amino Acid Analysis

The amino acid profile was determined using HPLC after derivatization (AOAC, 1988; Latimer, 2023). The samples were hydrolyzed and then derivatized with a solution of methanol, picolyl-isothiocyanate (PITC), and triethylamine (3:3:1 v/v/v). The derivatized sample was injected into an HPLC system (Varian 940-LC) equipped with a P1 Cotag amino-acid column. The analysis was performed with a mobile phase flow rate of 0.5 ml/min and detection at a wavelength of 272 nm.

Fatty Acid Analysis

The fatty acid profile was analyzed using Gas Chromatography (GC) (Latimer, 2023). Lipids were first extracted from the samples using the Soxhlet method. The extracted lipids were saponified and esterified to form fatty acid methyl esters (FAMES). The FAMES were then separated and quantified using a GC system equipped with a suitable capillary column and Flame Ionization Detector (FID).

Data Analysis

All chemical analyses were performed in triplicate, and the results are expressed as the mean $\pm$ standard deviation. Given the descriptive design of this study, no inferential statistical hypothesis testing was performed. Data tabulation and initial processing were performed using Microsoft Excel.

RESULT AND DISCUSSIONS

Proximate Composition

The proximate composition of the FPC produced from cultured *P. hypophthalmus* is presented in Table 1. The FPC had a high crude protein content of $86.61 \pm 0.06\%$. The total lipid, moisture, and ash contents were $6.46 \pm 0.09\%$, $3.41 \pm 0.06\%$, and $2.00 \pm 0.01\%$,

respectively. The carbohydrate content, calculated by difference, was 1.52 ± 0.03 . Based on these macronutrient values, the total energy content of the FPC was calculated to be 410.71 ± 0.71 kcal per 100 g.

The protein level achieved in this study positions FPC as a high-quality protein ingredient. For context, the protein content in raw *P. hypophthalmus* fillets typically ranges from 15-20% (Begum *et al.*, 2019). The chemical-free concentration process employed in this study effectively increased the protein content by more than four-fold, indicating a highly efficient method. This value is comparable to or exceeds those reported for FPCs from various other fish species (Akhade *et al.*, 2016), confirming the suitability of cultured *P. hypophthalmus* as an excellent raw material. Furthermore, its energy density of 410.71 ± 0.71 kcal/100 g is similar to that of commercial whey protein concentrates, making it an effective ingredient for formulating energy-dense and high-protein nutritional products.

Low moisture content ($3.41 \pm 0.06\%$) is a critical factor for ensuring microbial stability and extending the product's shelf life, a vital attribute for any commercial food ingredient (FAO, 2006). The lipid content ($6.46 \pm 0.09\%$) was also sufficiently low to minimize the risk of lipid oxidation and the development of rancidity during storage. The lipid levels in cultured *P. hypophthalmus* can be highly variable and are often influenced by the composition of commercial feeds (Wibowo *et al.*, 2023). The processing method successfully reduced the fat content while retaining the key fatty acids, as discussed later.

Finally, the ash content of the FPC was recorded at $2.00 \pm 0.01\%$, which may be attributed to the deboning and purification procedures applied during processing of the fish. In fish-derived protein products, ash content is generally regarded as a quantitative indicator of inorganic mineral residues, the majority of which originate from skeletal tissues, particularly hydroxyapatite-rich bone ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), the primary mineral constituent of vertebrate calcified structures (Baeverfjord *et al.*, 2018; Antu *et al.*, 2024). The incomplete separation of bone and

Table 1 Proximate composition of *P. hypophthalmus* fish protein concentrate (FPC) compared with raw *P. hypophthalmus* from previous studies

Parameters	Concentration (%)			
	This study	Chakma <i>et al.</i> , 2022	Hoque <i>et al.</i> , 2021	Mostafa <i>et al.</i> , 2023
Crude protein	86.61±0.06	14.36-20.19	19.49±0.71	15.3
Total lipid	6.46±0.09	2.11-3.74	8.84±0.20	12.9
Moisture	3.41±0.06	75.05-79.49	69.75±0.96	69.4
Ash	2.00±0.01	0.52-0.73	1.71±0.38	1.2
Carbohydrate (by difference)	1.52±0.03	1.05-1.23	0.21	1.2
Total energy	410.71±0.71 kcal/100 g	-	-	-
Protein claim (BPOM)*	High in protein	Source of protein	High in protein	High in protein

Note: Protein classification is based on BPOM Regulation No. 13 of 2016 concerning the Supervision of Claims on Processed Food Labels. A "Source of Protein" claim requires 12% ALG (7.2 g/100 g), and a "High in Protein" claim requires 24% ALG (14.4 g/100 g), where the ALG for protein is 60 g.

non-muscle tissues has been associated with elevated calcium and phosphorus concentrations in the final product, thereby contributing to higher overall ash values. This trend has been reported in raw *Pangasius* spp. byproducts and FPC, where ash contents of approximately 5–7% were observed in products derived from whole fish or minimally processed raw materials (Nam *et al.*, 2019). Similarly, Sriket *et al.* (2020) documented ash levels of 35–46% in raw and washed bone fractions obtained from *Pangasianodon* spp. In comparison, the relatively low ash content of the present FPC (2.00±0.01%) may indicate that the combination of mechanical deboning and manual trimming applied during raw material preparation was reasonably effective in reducing skeletal tissue residues.

Amino acid profile

The nutritional value of FPC is fundamentally defined by its amino acid composition (Junianto *et al.*, 2021), which was quantified to reveal a rich and comprehensive profile (Table 2). The analysis confirmed that FPC is a complete protein, as it contains all nine essential amino acids required for human

physiological functions. The total amino acid content underscores the high quality of the protein, which is critical for its application as a functional food.

The profile is dominated by non-essential amino acids, known for their functional and sensory roles. L-Glutamic Acid was the most abundant, with a concentration of 90,752.03±1265.03 mg/kg, followed by L-Aspartic Acid at 45,732.43±638.69 mg/kg. High concentrations of these two amino acids are a hallmark of fish protein and are significant contributors to the desirable umami taste (Hossain *et al.*, 2024), which can enhance the palatability of fortified food products.

A key nutritional strength of this FPC lies in its exceptionally high content of branched-chain amino acids (BCAAs), which are crucial for muscle metabolism. The concentration of L-leucine (56,147.93±584.48 mg/kg) is particularly noteworthy. L-leucine is a potent anabolic signaling molecule that directly activates the mTOR pathway, which is a primary regulator of muscle protein synthesis (Vianna *et al.*, 2012; Xu *et al.*, 2015). Supported by substantial amounts of L-isoleucine (24,693.47±417.10 mg/kg)

Table 2 Amino acid profile of fish protein concentrate (FPC) from *P. hypophthalmus*

Amino Acid (mg/kg)	<i>P. hypophthalmus</i>	<i>O. niloticus</i> *
Essential amino acids		
L-Leucine	56,147.93±584.48	38,800
L-Lysine	48,518.96±573.35	52,100
L-Phenylalanine	26,312.74±424.55	19,100
L-Isoleucine	24,693.47±417.10	27,400
L-Valine	23,422.18±378.97	50,700
L-Threonine	16,586.88±181.99	22,800
L-Methionine	14,465.59±197.59	16,000
L-Histidin	8,971.05±165.24	37,600
L-Tryptophan	7,940.39±121.88	7,500
Total essential amino acids	227,059.19	272,000
Non-Essential amino acids		
L-Glutamic Acid	90,752.03±1,265.03	71,000
L-Aspartic Acid	45,732.43±638.69	55,400
L-Alanine	40,137.00±564.12	29,200
L-Arginine	39,059.55±575.11	34,600
L-Proline	33,991.68±523.52	18,200
L-Cystine	29,578.57±512.90	5,600
L-Serine	21,785.76±334.86	21,800
L-Glycine	13,446.90±328.55	23,300
Taurine	107.56±0.28	Not Reported
Total non-essential amino acids	314,591.48	259,100
TOTAL amino acids	541,650.67	531,100

Values are presented as mean ± standard deviation (n=3).

*Data includes a comparison with *O. niloticus* FPC (Rieuwpassa *et al.*, 2022)

and L-valine (23,422.18±378.97 mg/kg), this BCAA profile makes FPC an ideal ingredient for nutritional products aimed at promoting muscle growth in children, supporting athletic performance, or mitigating sarcopenia in the elderly (Caldo-Silva *et al.*, 2023).

The competitive advantage of this amino acid profile becomes particularly evident when compared with that of FPCs derived from other commonly cultivated freshwater species. As detailed in Table 2, the L-leucine concentration in the *P. hypophthalmus* FPC (56,147.93±584.48 mg/kg) was notably higher than that reported for *Oreochromis niloticus* FPC extracted using isopropyl alcohol

(38,800 mg/kg) (Rieuwpassa *et al.*, 2022). This substantial difference highlights the superior potential of Striped Catfish as a raw material for formulating targeted BCAA-rich functional foods.

Furthermore, FPC is an excellent source of other vital amino acids. Its high concentration of L-lysine (48,518.96±573.35 mg/kg), an essential amino acid often limiting in cereal-based diets, makes it an effective complementary protein to improve the nutritional quality of staples such as rice or wheat. The profile is also rich in conditionally essential amino acids, such as L-arginine (39,059.55±575.11 mg/kg), which is important

for immune function and cardiovascular health. The presence of taurine (107.56 ± 0.28 mg/kg), although present in a relatively low amount, adds further nutritional value to the FPC. However, the functional implications of taurine content require further investigation through bioavailability and in vivo studies before any specific application claims can be made.

Fatty acid profile

The lipid fraction of FPC, although representing a small portion of the total mass ($6.46 \pm 0.09\%$), contains a diverse and nutritionally significant fatty acid profile (Table 3). The composition is characterized by a balanced distribution of saturated, monounsaturated, and polyunsaturated fatty acids (FAs). Among the monounsaturated fatty acids (MUFAs), Oleic Acid (C18:1n9c)

was the most abundant at $2.44 \pm 0.01\%$. This finding is consistent with the existing literature, as the fatty acid profile of cultured *P. hypophthalmus* is often influenced by the inclusion of plant-based ingredients in aquaculture feeds, which are typically rich in oleic acid (Ho & Paul, 2009). The primary saturated fatty acid (SFA) was Palmitic Acid (C16:0) at $1.48 \pm 0.01\%$, followed by Stearic Acid (C18:0) at $0.59 \pm 0.01\%$.

The most functionally significant aspect of the lipid profile is the retention of key polyunsaturated fatty acids (PUFAs). The FPC serves as a valuable source of essential omega-6 fatty acids, including Linoleic Acid (C18:2n6c) at $0.84 \pm 0.00\%$ and the physiologically important Arachidonic Acid (ARA, C20:4n6) at $0.31 \pm 0.00\%$. Critically, the chemical-free processing method successfully preserved long-chain omega-3 fatty acids, which are vital

Table 3 Fatty acid profile of fish protein concentrate (FPC) from *P. hypophthalmus*

Fatty Acid (%)	Shorthand	<i>P. hypophthalmus</i>	<i>O. niloticus</i> *
Saturated Fatty Acid (SFA)			
Palmitic Acid	C16:0	1.48 ± 0.01	0.74
Stearic Acid	C18:0	0.59 ± 0.01	0.32
Myristic Acid	C14:0	0.09 ± 0.00	0.59
Lauric Acid	C12:0	0.01 ± 0.00	0.95
Total SFA		2.17	2.6
Monounsaturated Fatty Acid (MUFA)			
Oleic Acid	C18:1n9c	2.44 ± 0.01	1.5
Palmitoleic Acid	C16:1	0.18 ± 0.00	0.25
Eicosenoic Acid	C20:1	0.05 ± 0.00	0.06
Total MUFA		2.67	1.81
Polyunsaturated Fatty Acid (PUFA)			
Linoleic Acid	C18:2n6c	0.84 ± 0.00	0.37
Arachidonic Acid	C20:4n6	0.31 ± 0.00	0.08
Docosahexaenoic Acid (DHA)	C22:6n3	0.13 ± 0.00	0.07
Eicosatrienoic Acid	C20:3n6	0.12 ± 0.00	0.02
Eicosadienoic Acid	C20:2	0.07 ± 0.00	0.02
Linolenic Acid	C18:3n3	0.05 ± 0.00	0.17
Eicosapentaenoic Acid (EPA)	C20:5n3	0.02 ± 0.00	0.2
Total PUFA		1.54	0.93

Values are presented as mean $\pm$ standard deviation (n=3).

*Data includes a comparison with *O. niloticus* FPC (Rieuwpassa *et al.*, 2022)



for human health. The concentrate contained pre-formed docosahexaenoic acid (DHA, C22:6n3) at $0.13 \pm 0.00\%$ and eicosapentaenoic acid (EPA, C20:5n3) at $0.02 \pm 0.00\%$.

The presence of bioavailable DHA and EPA provides FPC with a major nutritional advantage over plant-derived protein concentrates (Rizzo *et al.*, 2023). DHA is an indispensable structural component of the human brain and retina, making its dietary intake crucial for infant neural development and cognitive function throughout life (Horrocks & Yeo, 1999). Furthermore, the efficacy of the chemical-free extraction method in preserving these sensitive lipids was highlighted when compared to solvent-based extraction. As shown in Table 3, the DHA content in the *P. hypophthalmus* FPC ($0.13 \pm 0.00\%$) was nearly double that of *O. niloticus* FPC processed using isopropyl alcohol (0.07%) (Rieuwpassa *et al.*, 2022). This suggests that avoiding harsh organic solvents not only eliminates the risk of chemical toxicity but also provides superior retention of highly oxidizable, health-promoting polyunsaturated fatty acids. The ability of this FPC to deliver valuable omega-3 fatty acids, along with a high-quality protein matrix, significantly enhances its potential as a functional food ingredient. This finding demonstrates that producing a protein concentrate from cultured pangasius that is not only rich in protein but also retains a health-promoting fatty acid profile is feasible.

Functional Implications

The proximate composition, amino acid profile, and fatty acid profile collectively demonstrate that the Striped Catfish FPC possesses high nutritional quality suitable for the fortification of complementary foods, as summarized in Table 1. Proximate analysis established the product as a true high-protein concentrate. The protein content of 86.61% is notably high, exceeding levels reported for other freshwater fish FPCs, such as 75.31% in *Patin* and 83.10% in catfish (Setyarini *et al.*, 2024). The lipid content of 6.46% obtained in this study indicates that the FPC produced still retains a portion of the original fish lipids, which may contribute beneficial fatty acids

to the final product. Despite this, the high protein concentration confirms that FPC is a nutritionally dense ingredient with strong potential as a concentrated protein source for food fortification. However, the value of this protein is significantly enhanced by its amino acid composition (Table 2). The exceptionally high concentration of L-leucine, a potent activator of muscle protein synthesis, confirms the high biological value of the protein. The prominence of L-leucine and L-glutamic acid is consistent with the findings for other freshwater fish FPCs, such as catfish, where these were also the most abundant amino acids.

This powerful protein profile is further complemented by the valuable lipid fraction retained in FPC (Table 3). The presence of bioavailable omega-3 fatty acids, particularly DHA, provides a synergistic nutritional advantage. While high protein and L-leucine contents directly support physical growth and muscle development, DHA simultaneously supports cognitive and retinal development. This dual benefit is a key differentiator from many single-nutrient ingredients, such as plant-based proteins, which lack pre-formed DHA. This makes FPC highly suitable for improving the nutritional value of food products, such as biscuits and snacks previously fortified with *Patin* FPC (Dewita *et al.*, 2011; Anugrahati *et al.*, 2012). Therefore, Table 1 collectively illustrates that FPC is not merely a source of protein but a multifunctional ingredient whose integrated profile is uniquely suited for applications in infant nutrition, where both rapid physical growth and neurological development are paramount. The chemical-free process ensures that these sensitive nutrients are preserved (Ağagündüz *et al.*, 2025), making FPC a potent and highly suitable candidate for the fortification of complementary foods.

CONCLUSION

The chemical-free extraction method successfully produced a protein-rich FPC from cultured *P. hypophthalmus*. The resulting FPC exhibited a favorable nutritional composition, containing essential amino acids and omega-3 fatty acids, indicating its potential

as a functional protein ingredient for food applications. Further studies on functional properties, digestibility, bioavailability, and sensory acceptance are required to determine the suitability of these ingredients for specific food products.

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