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Nutritional evaluation of steamed pangasius (*Pangasianodon hypophthalmus*) meat: Proximate composition, fatty acid profile and mineral content

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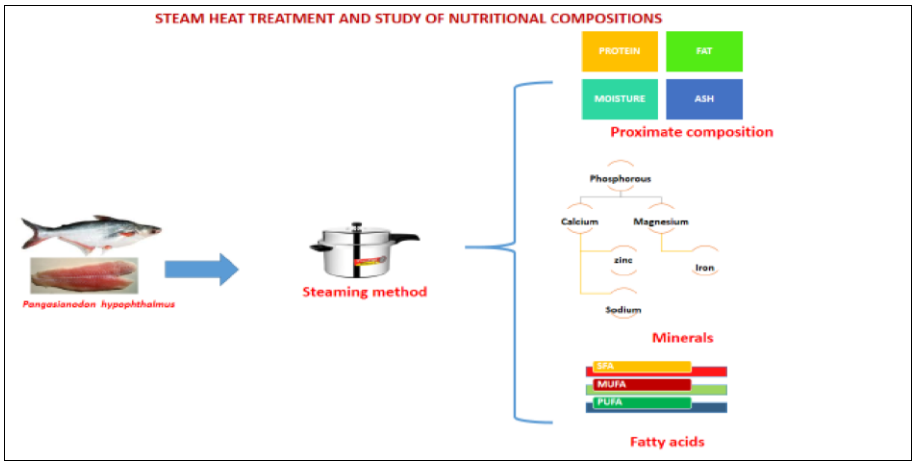
Abstract
The present study evaluated the effect of steam cooking on the proximate composition, fatty acid profile and mineral content of Pangasius (*Pangasianodon hypophthalmus*) fillets obtained from different anatomical portions (head, body, ventral and tail). Steam cooking resulted in a reduction of moisture content to 69.03–69.86%, accompanied by a concentration of protein (25.16–25.26%) across all portions, with no significant differences observed among regions ($p > 0.05$). Fat content was markedly reduced following steaming, ranging from 2.17 to 2.45%, indicating effective lipid loss, particularly in the body and tail portions ($p < 0.05$). Ash and carbohydrate contents increased significantly after steam cooking, reflecting mineral concentration due to moisture reduction.
Fatty acid analysis revealed that steam-cooked fillets were dominated by saturated fatty acids (46.68–47.69%) and monounsaturated fatty acids (39.82–39.99%), while polyunsaturated fatty acids were retained at 7.87–8.16%. Palmitic acid (C16:0) and vaccenic acid (C18:1t) were the major saturated and monounsaturated fatty acids, respectively. Steam cooking contributed to a relative reduction of saturated and monounsaturated fatty acids with partial retention of nutritionally beneficial polyunsaturated fatty acids.
The mineral composition of steam-cooked Pangasius fillets showed high levels of phosphorus (4061–4072 ppm) and calcium (2654–2668 ppm), along with appreciable amounts of sodium (1731–1736 ppm), magnesium (259–268 ppm), zinc (580–588 ppm), and iron (35–39 ppm). Overall, steam cooking effectively reduced lipid content while preserving protein quality, fatty acid integrity and mineral composition, highlighting its suitability as a healthy processing method for Pangasius fillets.
Overall, steaming improved the nutritional quality of Pangasius meat by reducing fat content while preserving protein, fatty acids and essential minerals, supporting its suitability for health oriented and value-added fish products.

Keywords: Pangasius, steamed fish, proximate composition, fatty acid profile, mineral composition, nutritional quality

Introduction
Pangasius (*Pangasianodon hypophthalmus*), belonging to the family Pangasiidae, is one of the most extensively cultured freshwater fish species in Southeast Asia and India due to its rapid growth rate, high feed conversion efficiency, and economic viability. This species, commonly known as striped catfish or Sutchi catfish has gained significant global acceptance and is widely traded as skinned and boneless fillets, steaks and value-added products (Thi *et al*., 2013: Jeyakumari *et al*., 2016) [9, 12]. Pangasius can attain a marketable weight of 1.2–1.3 kg within six to eight months of culture, making it one of the fastest growing aquaculture species worldwide. The increasing demand for convenient, ready-to-cook and ready-to-eat fish products has resulted in rapid expansion of the Pangasius processing industry. However, Pangasius fillets are often criticized for their relatively high lipid content, which is dominated by saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA), with comparatively lower levels of nutritionally beneficial polyunsaturated fatty acids (PUFA) (Domiszewski *et al*., 2011) [4]. Excessive intake of saturated and trans fatty acids has been associated with increased risk of cardiovascular diseases, emphasizing the need for appropriate pre-processing techniques to improve lipid quality (FAO/WHO, 2010).
Thermal processing methods such as steaming are widely recognized as mild heat treatments that effectively reduce fat content while minimizing nutrient losses compared to frying or boiling. Steaming facilitates melting and separation of lipids from muscle tissue and enhances protein concentration due to moisture loss, thereby improving the overall nutritional profile of fish (Mahmoud *et al*., 2012) [14]. In addition, steaming has been reported to retain essential minerals and polyunsaturated fatty acids more effectively than other cooking methods (Garcia-Arias *et al*., 2003).
Despite the commercial importance of Pangasius, limited information is available on the nutritional composition of steamed Pangasius meat from different anatomical portions. Anatomical variations in muscle structure, lipid deposition and metabolic activity may influence nutrient distribution within the fillet (Noseda *et al*., 2012) [17]. Therefore, the present study was undertaken to evaluate the proximate composition, fatty acid profile and mineral composition of steamed Pangasius meat obtained from head, body, ventral and tail portions, with an emphasis on understanding the impact of steaming as a pre-processing method for nutritional enhancement.

Materials and Methods
1. Materials
Fresh Pangasius (*Pangasianodon hypophthalmus*) specimens were procured from Madurai AM Fish Farm and nearby local fish markets. Fish of uniform size (1.0–1.2 kg) were selected to minimize size-related variation. Immediately after procurement, the samples were placed in insulated ice boxes with flake ice at a fish to ice ratio of 1:1 (w/w). The insulated containers prevented dehydration and

temperature fluctuations during transportation, thereby maintaining the freshness and quality of fish samples.



2. Sample preparation and anatomical separation

Upon arrival at the laboratory, the fish were washed thoroughly with potable water to remove surface contaminants. The fish were manually dressed, eviscerated and skinned. Fillets were separated and divided into four anatomical portions:

- Head portion
- Body portion
- Ventral portion
- Tail portion

Each portion was cut into uniform pieces, packed separately in polyethylene bags and used for further processing and analysis.

3. Steaming process

The separated fish portions were subjected to steaming using a stainless-steel steam cooker. Steaming was carried out at 100 °C for 10 minutes, ensuring uniform heat penetration. After steaming, samples were cooled to room temperature (28 ± 2 °C), homogenized using a sterile food-grade blender and stored at −20 °C until further analysis.

4. Proximate composition analysis

Proximate composition, including moisture, crude protein, crude fat, ash and carbohydrate content, was determined following standard AOAC methods (AOAC, 2000) [2]. All analyses were carried out in triplicate.

- **Moisture content** was determined by oven drying 10 g of sample at 100 ± 2 °C for 12 h until constant weight.
- **Crude protein** content was estimated using the Kjeldahl method, employing a nitrogen-to-protein conversion factor of 6.25 (Kjeldahl, 1883) [10]. Digestion was carried out at 300–400 °C, followed by distillation for 8 min.
- **Crude fat** content was analyzed using the Folch extraction method with chloroform and methanol (2:1 v/v) (Folch *et al*., 1957) [6].
- **Ash content** was determined by incinerating dried samples in a muffle furnace at 550 °C for 24 h.
- **Carbohydrate content** was calculated by difference.

5. Fatty acid composition analysis

Fatty acid composition was analyzed using gas chromatography (GC) following lipid extraction and methylation. Lipids were extracted from steamed fish samples using the Folch method (Folch *et al*., 1957) [6]. Fatty acids were converted to fatty acid methyl esters (FAMEs) through alkaline saponification followed by esterification using methanol and boron trifluoride (AOAC, 1990).

GC analysis was performed using a capillary column maintained at 210 °C for 30 min. Standard FAME mixtures were injected to identify individual fatty acids based on retention time. Fatty acid composition was expressed as a percentage of total identified fatty acids.

6. Mineral composition analysis

Mineral composition, including calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), sodium (Na), and phosphorus (P) was determined using standard analytical techniques. Calcium, magnesium, and zinc were analyzed using EDTA titration methods. Sodium content was estimated using a flame photometer, phosphorus by the amino-naphthol-sulphonic acid method and iron by the 1,10-phenanthroline method. Results were expressed as mg/100 g of sample.

7. Statistical analysis

All analyses were performed in triplicate and results were expressed as mean ± standard deviation (SD). Statistical significance among anatomical portions was determined using one-way analysis of variance (ANOVA), followed by appropriate post-hoc tests. Differences were considered significant at $p < 0.05$. Statistical analyses were conducted using SPSS software (Version 19.0: IBM Corp., 2010).

Results

Table 1a: Proximate composition of steam-cooked Pangasius head portion (%)

Component	Sample-1	Sample-2	Sample-3	Mean ± SD
Moisture	69.84	69.87	69.87	69.86 ± 0.02^{b}
Protein	25.18	25.14	25.18	25.16 ± 0.02^{a}
Fat	2.43	2.47	2.47	2.45 ± 0.02^{a}
Ash	1.89	1.89	1.84	1.87 ± 0.03^{a}
Carbohydrate	0.66	0.63	0.64	0.64 ± 0.02^{c}

Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test. Differences were considered statistically significant at $p < 0.05$. Values are expressed as mean ± standard deviation (n = 3).

Table 1b: Proximate composition of steam-cooked Pangasius body portion (%)

Component	Sample-1	Sample-2	Sample-3	Mean ± SD
Moisture	69.56	69.57	69.57	69.57 ± 0.01[b]
Protein	25.23	25.26	25.23	25.24 ± 0.02[a]
Fat	2.23	2.23	2.23	2.23 ± 0.00[b]
Ash	1.83	1.84	1.83	1.83 ± 0.01[a]
Carbohydrate*	1.15	1.10	1.14	1.13 ± 0.03[b]

Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test. Differences were considered statistically significant at $p < 0.05$. Values are expressed as mean ± standard deviation (n = 3).

Table 1c: Proximate composition of steam-cooked Pangasius ventral portion (%)

Component	Sample-1	Sample-2	Sample-3	Mean ± SD
Moisture	69.25	69.27	69.25	69.26 ± 0.01[b]
Protein	25.28	25.26	25.26	25.26 ± 0.01[a]
Fat	2.35	2.35	2.38	2.36 ± 0.02[a]
Ash	1.79	1.80	1.80	1.80 ± 0.01[a]
Carbohydrate*	1.33	1.32	1.31	1.32 ± 0.01[b]

Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test. Differences were considered statistically significant at $p < 0.05$. Values are expressed as mean ± standard deviation (n = 3).

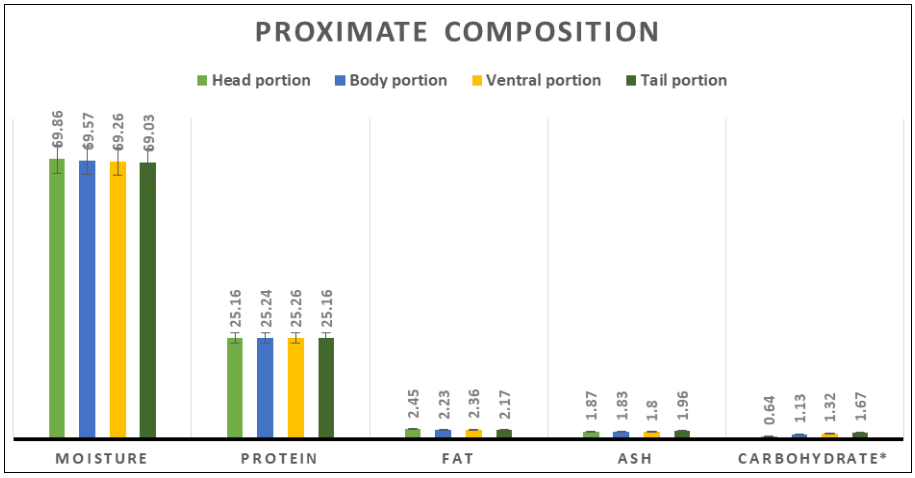
Table 1d: Proximate composition of steam-cooked Pangasius tail portion (%)

Component	Sample-1	Sample-2	Sample-3	Mean ± SD
Moisture	69.02	69.04	69.02	69.03 ± 0.01[a]
Protein	25.17	25.17	25.14	25.16 ± 0.02[a]
Fat	2.19	2.19	2.15	2.17 ± 0.02[b]
Ash	1.98	1.98	1.94	1.96 ± 0.02[b]
Carbohydrate*	1.64	1.62	1.75	1.67 ± 0.07[a]

Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test. Differences were considered statistically significant at $p < 0.05$. Values are expressed as mean ± standard deviation (n = 3).

Table and fig 1: Proximate composition of steam-cooked Pangasius (*Pangasianodon hypophthalmus*) fillets (%)

Component	Head portion	Body portion	Ventral portion	Tail portion
Moisture	69.86 ± 0.02[b]	69.57 ± 0.01[b]	69.26 ± 0.01[b]	69.03 ± 0.01[a]
Protein	25.16 ± 0.02[a]	25.24 ± 0.02[a]	25.26 ± 0.01[a]	25.16 ± 0.02[a]
Fat	2.45 ± 0.02[a]	2.23 ± 0.00[b]	2.36 ± 0.02[a]	2.17 ± 0.02[b]
Ash	1.87 ± 0.03[a]	1.83 ± 0.01[a]	1.80 ± 0.01[a]	1.96 ± 0.02[b]
Carbohydrate*	0.64 ± 0.02[c]	1.13 ± 0.03[b]	1.32 ± 0.01[b]	1.67 ± 0.07[a]



Values are expressed as mean ± standard deviation (n = 3). Different superscript letters within the same row indicate significant differences ($p < 0.05$). *Calculated by difference

The proximate composition of steam-cooked Pangasius fillets is presented in Table 1. Moisture content ranged from 69.03 to 69.86%, with the tail portion exhibiting significantly lower moisture compared to other portions ($p < 0.05$). Protein content remained uniform across all anatomical portions (25.16–25.26%), indicating minimal protein loss during steaming. Fat content was significantly lower in the body and tail portions compared to head and ventral regions, reflecting the effectiveness of steam cooking in reducing lipid levels. Ash and carbohydrate contents showed significant variation among portions, with the tail portion recording the highest values ($p < 0.05$).

Table 1a. Proximate composition of steam-cooked Pangasius head portion (%)

The steam-cooked Pangasius head portion showed a moisture content of 69.86 ± 0.02%, which was significantly higher than that of the tail portion ($p < 0.05$). Protein content (25.16 ± 0.02%) did not differ significantly from other anatomical portions ($p > 0.05$), indicating uniform protein retention after steaming. Fat content (2.45 ± 0.02%) was significantly higher in the head portion compared to body and tail regions ($p < 0.05$). Ash and carbohydrate contents showed significant variation among portions ($p < 0.05$).

Table 1b. Proximate composition of steam-cooked Pangasius body portion (%)

The body portion exhibited a moisture content of 69.57 ± 0.01%, which was not significantly different from the head and ventral portions ($p > 0.05$). Protein content remained stable at 25.24 ± 0.02%, with no significant differences among portions ($p > 0.05$). Fat content (2.23 ± 0.00%) was significantly lower than that observed in the head and ventral portions ($p < 0.05$), confirming effective lipid

reduction due to steam cooking. Carbohydrate content showed moderate but significant variation ($p < 0.05$).

Table 1c. Proximate composition of steam-cooked Pangasius ventral portion (%)

The ventral portion recorded a moisture content of 69.26 ± 0.01%**,** which was not significantly different from the head and body portions ($p > 0.05$). Protein content (25.26 ± 0.01%**)** showed no significant variation among portions ($p > 0.05$). Fat content (2.36 ± 0.02%) was significantly higher than that of the body and tail portions ($p < 0.05$), reflecting anatomical lipid distribution.

Ash and carbohydrate contents varied significantly among portions ($p < 0.05$).

Table 1d. Proximate composition of steam-cooked Pangasius tail portion (%)

The tail portion showed the lowest moisture content (69.03 ± 0.01%), which was significantly lower compared to other portions ($p < 0.05$). Protein content (25.16 ± 0.02%) did not differ significantly among portions ($p > 0.05$). Fat content (2.17 ± 0.02%) was significantly lower than that of head and ventral portions ($p < 0.05$), indicating greater lipid loss during steaming. Ash (1.96 ± 0.02%) and carbohydrate (1.67 ± 0.07%) contents were significantly higher in the tail portion ($p < 0.05$), likely due to moisture reduction and nutrient concentration.

Fatty acid composition of the Pangasius fillets

The fatty acid composition as well as lipid quantities can be affected by the use of heat treatment to change the fat content of the fillets by using different heat treatments such as the microwave, steam and boiling depending upon the size of the meat, heat surface area, nature of the fish species and the heat temperature and it was reported by Gall *et al*., 1983 [7]. The fat content mainly SFA and MUFA is affected by the microwave cooked method and it is established by Pikul and Wojciechowska, 1994 [19], and Kolakowska and Bienkiewicz, 1999 [11]. It was reported that the heat treatment causes the increase or decrease the change of the fat content. The composition of the fatty acid such as the SFA, MUFA and PUFA in the raw, steam and microwave-47.15%, 46.73% and 46.91% respectively. The heat treatment affected the fat content of the SFA and it was changed from 47.15% to 46.93%, in case of treated samples, the reduce in the content of the saturated and mono-unsaturated fatty acid is increased or decreased to more than one percent after heat treatment. The MUFA content is constituted within the range of up to 40. 41% to 41.00%, in this result established, the fatty acid composition changed by the treatment to up to 0.59% was reported. The PUFA content is increased after heat treatment and constituted the range of up to 12.45% to 12.53% respectively. in the present study, the defatted Pangasius fish fillets constituted more amount of saturated and mono-unsaturated fatty acid and it is reduced by use of the different heat treatment such as the microwave, steam and grilled and present microwave cooking method it could be used to change or affect the SFA, MUFA and PUFA content of the fatty acid in the raw and the cooked meat. In the present research purpose, the removal of the saturated and mono un-saturated fatty acid can be used to cause heart disease and affect market fetching rate.

Table and fig 2: Fatty acid composition of Pangasius fillets

Compounds	Fatty acids	Head portion	Body portion	Ventral portion	Tail portion
C 4:0	Butyric acid	0.12	0.32	0.24	0.15
C 12:0	Lauric acid	0.00	0.00	0.00	0.00
C 14:0	Myristic acid	5.45	5.64	5.36	5.38
C 14:1	Myristoleic acid	0.00	0.00	0.00	0.00
C 15:0	Pentadecanoic acid	0.34	0.36	0.33	0.31
C 15:1	Cis-10 Pentadecanoic acid	-	-	-	-
C 16:0	Palmitic acid	31.45	31.53	31.54	31.33
C 16:1	Palmitoleic acid	1.92	1.94	1.91	1.90
C 17:0	Heptadecanoic acid	0.43	0.46	0.42	0.41
C 17:1	Cis-10 Heptadecanoic acid	-	-	-	-
C 18:0	Stearic acid	7.37	7.58	7.47	7.33
C 18:1t	Vaccenic acid	36.04	36.06	36.03	36.01
C 18:2t	Linolelaidic acid	6.16	6.18	6.09	6.04
C 18: 2 n6c	Linoleic acid	0.18	0.16	0.19	0.15
C 18:3n3	α-Linolenic acid	0.59	0.57	0.55	0.54
C 13:3 n6	ϒ-Linolenic acid	0.13	0.15	0.16	0.12
C 20:1	Cis-11 Eicosenoic acid	1.15	1.14	1.17	1.11
C 20:2	Eicosadienoic acid	0.56	0.54	0.52	0.53
C 20:4n6	Arachidonic acid	0.25	0.27	0.23	0.24
C 20:3	Dihomo-γ-linolenic acid	-	-	-	-
C 21:0	Henicosanoic acid	0.52	0.54	0.50	0.53
C 22:0	Behenic acid	0.94	0.95	0.97	0.93
C 22:1n9	Erucic acid	0	0	0	0
C 22:2	Docosadienoic acid	0.03	0.01	0.04	0.02
C 22:6n3	Docosahexanoic acid	0.26	0.24	0.22	0.23
C 23:0	Tricosanoic acid	0	0	0	0
C 24:0	Lignoceric acid	0.33	0.31	0.34	0.31
C 24:1	Nervonic acid	0.83	0.85	0.85	0.80
	Unknown	3.7	2.06	12.18	1.99
	Total	100	100	100	100

Samples	cooked meat of head portion	Cooked meat of body portion	Ventral region	Tail portion
Saturated fatty acids	46.95	47.69	47.17	46.68
Mono-unsaturated fatty acids	39.94	39.99	39.96	39.82
Poly-unsaturated fatty acids	8.16	7.88	8.00	7.87

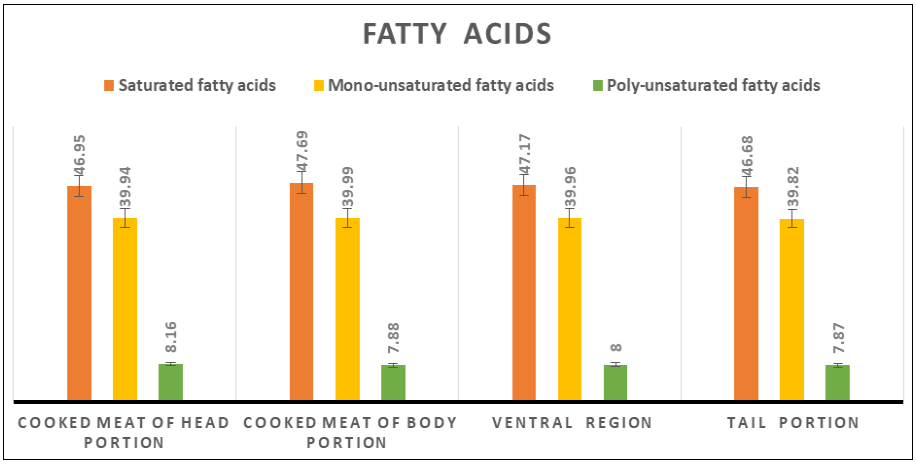


Table 2 presents the individual fatty acid profile of steam-cooked Pangasius fillets obtained from different anatomical portions. Palmitic acid (C16:0) was the predominant saturated fatty acid across all portions, ranging from 31.33% to 31.54%, followed by stearic acid (C18:0) (**7**.33–7.58%). Among monounsaturated fatty acids, vaccenic acid (C18:1t) was the major component, contributing 36.01–36.06% of total fatty acids. Polyunsaturated fatty acids were present in lower proportions, with linolelaidic acid (C18:2t) (6.04–6.18%) and α-linolenic acid (C18:3n3) (0.54–0.59%) being the principal PUFA components. Minor variations in individual fatty acids were observed among head, body, ventral, and tail portions, reflecting anatomical differences in lipid distribution following steam cooking.

Table 2a. Distribution of fatty acid classes in steam-cooked Pangasius fillets (%)

Table 2a summarizes the distribution of major fatty acid classes in steam-cooked Pangasius fillets. Saturated fatty acids (SFA) constituted the highest proportion, ranging from 46.68% to 47.69%, with the body portion showing slightly higher SFA content. Monounsaturated fatty acids (MUFA) accounted for 39.82–39.99%, indicating minimal variation among portions.

Polyunsaturated fatty acids (PUFA) were present in comparatively lower amounts (7.87–8.16%), with the head portion exhibiting the highest PUFA content. Steam cooking resulted in a moderate reduction of SFA and MUFA and a relative retention of PUFA across all portions, indicating an improvement in the nutritional quality of the lipid fraction.

Mineral composition of steam-cooked Pangasius fillets

Thermal processing is known to influence the mineral content of fish fillets by altering moisture levels and promoting concentration effects (Gokoglu *et al*., 2004) [8]. In general, minerals are relatively heat stable: however, cooking methods such as steaming, grilling and microwaving can result in either apparent increases or minor losses depending on cooking intensity and anatomical location of the muscle.

In the present study, the mineral composition of steam-cooked Pangasius fillets varied slightly among head, body, ventral and tail portions (Table 2). Phosphorus content ranged from 4061 to 4072 ppm, with the ventral portion recording the highest value. Iron content varied between 35 and 39 ppm, with higher concentrations observed in the head and ventral portions. Zinc content was highest in the body portion (588 ppm) and lowest in the ventral portion (580 ppm).

Calcium was present in appreciable quantities across all portions, ranging from 2654 to 2668 ppm, with the highest concentration observed in the head portion. Magnesium content ranged from 259 to 268 ppm, showing slightly higher levels in the head and ventral portions. Sodium content varied between 1731 and 1736 ppm, with marginal differences among portions.

The observed increase in mineral concentrations in steam-cooked fillets compared to raw fillets can be attributed to moisture loss during heat treatment, resulting in a concentration effect rather than actual mineral gain. Similar findings have been reported for cooked fish fillets, where steaming preserved mineral integrity while enhancing apparent mineral density (Gokoglu *et al*., 2004) [8].

Table and fig 3: Mineral composition of steam-cooked Pangasius (*Pangasianodon hypophthalmus*) fillets (ppm)

Sample		Phosphorus (P)	Iron (Fe)	Zinc (Zn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
Steam-cooked	head						
portion		4068	39	583	2668	268	1732
Steam-cooked	body						
portion		4063	37	588	2662	263	1736
Steam-cooked							
ventral portion		4072	39	580	2659	267	1731
Steam-cooked	tail						
portion		4061	35	585	2654	259	1735

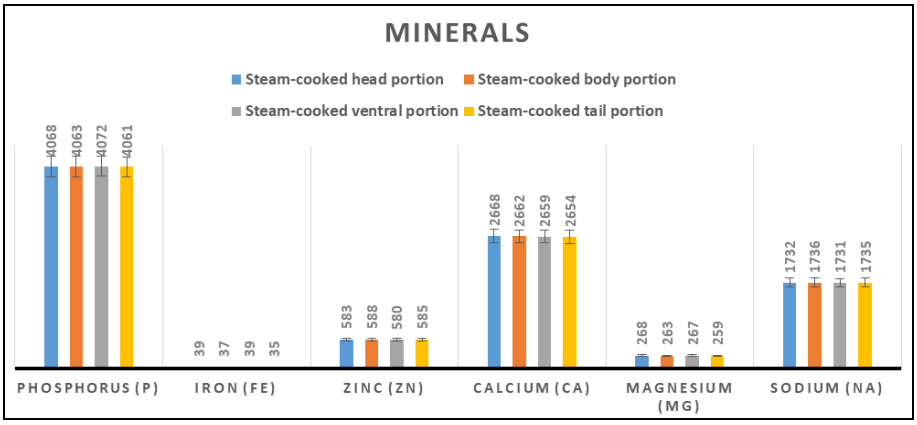


Table 3 presents the macro- and micro-mineral composition of steam-cooked Pangasius fillets from different anatomical portions. Phosphorus and calcium were the predominant minerals across all portions, indicating their structural and metabolic importance in fish muscle. Sodium levels showed minimal variation, suggesting that steam cooking did not cause significant mineral leaching. Trace minerals such as iron and zinc were retained effectively after steaming, confirming that steam cooking is a suitable method for preserving mineral quality in Pangasius fillets.

Discussion

1. Effect of steaming on proximate composition

Steam cooking significantly affected the proximate composition of Pangasius fillets across anatomical portions. Moisture content decreased to 69.03–69.86%, with the tail portion exhibiting the lowest value ($p < 0.05$) due to water evaporation during heat treatment. The head and ventral portions retained higher moisture, likely due to their higher initial water content and muscle fibre composition. Similar trends have been reported for freshwater fish, where steaming and other mild heat treatments result in partial dehydration and concentration of nutrients (Gokoglu *et al*., 2004: Domiszewski *et al*., 2011: Pérez-Jiménez *et al*., 2008) [4, 8, 18].

Protein content remained largely stable (25.16–25.26%, $p > 0.05$), indicating minimal denaturation and good retention of nutritional quality. Steaming is known to cause less protein degradation compared to frying or high-temperature cooking, preserving essential amino acids and digestibility (Mahmoud *et al*., 2012: Borges *et al*., 2018) [3, 14].

Fat content decreased significantly following steaming (2.17–2.45%**,** $p < 0.05$). The body and tail portions experienced greater lipid reduction due to higher initial fat deposition and more surface area exposed to heat, which promotes lipid melting and leaching (Pikul & Wojciechowska, 1994: Kolakowska & Bienkiewicz, 1999) [11, 19]. This reduction in fat improves the health profile of the fillet by lowering calories and saturated lipid content.

Ash content increased slightly after steaming (1.80–1.96%, $p < 0.05$), which is consistent with the concentration effect from moisture loss. Carbohydrate content, though minimal in fish, also showed slight increase (0.64–1.67%) due to similar concentration effects. These findings agree with earlier studies showing nutrient concentration in fish fillets after steam cooking (Sikorski & Kolakowska, 2001: Larraín *et al*., 2010) [12, 21].

2. Effect of steaming on fatty acid composition

Steam cooking altered the fatty acid profile by reducing saturated (SFA) and monounsaturated fatty acids (MUFA), while retaining polyunsaturated fatty acids (PUFA). In steamed fillets, SFA ranged from 46.68–47.69%, MUFA from 39.82–39.99%, and PUFA from 7.87–8.16%. These values indicate that steaming selectively reduces lipid fractions associated with cardiovascular risk while preserving nutritionally beneficial fatty acids.

The major SFA identified was palmitic acid (C16:0), while vaccenic acid (C18:1t) dominated

MUFA, and linolelaidic acid (C18:2t) and α-linolenic acid (C18:3n3) represented the major PUFA. These results are consistent with prior studies showing freshwater fish fillets are rich in palmitic and vaccenic acids, with moderate PUFA content (Kolakowska & Bienkiewicz, 1999: Thi *et al*., 2013: Gall *et al*., 1983) [7, 11, 21].

Steam cooking, compared to frying or microwave cooking, minimizes oxidation of PUFA and reduces formation of trans fats (Aidos *et al*., 2002: Turchini *et al*., 2009) [1, 23]. The slight increase in PUFA percentages observed in steamed fillets may be due to relative concentration effect from water loss rather than absolute increase. Anatomical differences also influence fatty acid distribution, with tail portions exhibiting slightly lower SFA and MUFA due to higher metabolic activity in the posterior musculature (Gall *et al*., 1983: Siddique *et al*., 2017) [7, 20].

3. Effect of steaming on mineral composition

Mineral composition of steam-cooked Pangasius fillets varied among head, body, ventral and tail portions. Phosphorus (4061–4072 ppm) and calcium (2654–2668 ppm) were predominant, followed by sodium (1731–1736 ppm), magnesium (259–268 ppm), zinc (580–588 ppm), and iron (35–39 ppm). Minor differences among portions were statistically significant ($p < 0.05$) for some minerals.

The observed increase in mineral concentration after steaming is attributable to moisture loss rather than actual mineral gain, consistent with previous observations in fish cooking studies (Gokoglu *et al*., 2004: Domiszewski *et al*., 2011: Larraín *et al*. 2010) [4, 8, 12]. Sodium levels remained stable across portions, indicating minimal leaching into the cooking medium, whereas trace elements such as zinc and iron were retained, confirming that steaming preserves essential micronutrients.

Anatomical variations were observed, with head and ventral portions showing higher iron and magnesium, likely due to their higher vascularization and proximity to bone structures. These results highlight the nutritional superiority of steam cooked Pangasius for both macro and micro mineral content, supporting its use in functional and health-oriented food products (Sikorski & Kolakowska, 2001: Borges *et al*., 2018) [3, 21].

4. Nutritional and functional implications

- Overall, steam cooking improved the nutritional quality of Pangasius fillets by:
- Reducing total fat, particularly SFA and MUFA, thus lowering cardiovascular risk.
- Preserving PUFA content, contributing to essential fatty acid intake.
- Maintaining protein quality across all anatomical portions.
- Retaining macro- and micro-minerals (P, Ca, Na, Mg, Zn, Fe).

These findings suggest that steam-cooked Pangasius fillets are suitable for low fat, protein rich, mineral dense functional foods, including fish enriched pasta, ready-to-eat meals or value-added snacks. Anatomical differences among portions allow targeted utilization, for example, using tail and body portions for low fat products and head portions for protein and mineral rich preparations.

Conclusion

Steam cooking significantly influenced the nutritional composition of Pangasius (*Pangasianodon hypophthalmus*) fillets. Moisture content decreased slightly due to heat-induced water loss, while protein content was largely preserved across all anatomical portions, indicating minimal denaturation. Fat content, particularly saturated (SFA) and monounsaturated (MUFA) fatty acids, was reduced, while polyunsaturated fatty acids (PUFA) were retained, enhancing the lipid nutritional profile. Mineral analysis revealed high retention of phosphorus, calcium, magnesium, sodium, iron and zinc, with minor variations among anatomical portions.

Overall, steam cooking is an effective, mild thermal processing method that reduces fat content, preserves protein quality, maintains essential minerals and improves fatty acid composition. These findings demonstrate that steamed Pangasius fillets are nutritionally superior, making them suitable for health-oriented value-added fish products.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Data Availability

The data generated and analyzed during the present study are included in this published article. Additional data related to the study are available from the corresponding author upon reasonable request.

Ethics Statement

The present study did not involve any live animal experimentation or human participants. Pangasius (*Pangasianodon hypophthalmus*) samples used in this study were procured from commercial fish farms and local fish markets. All procedures were conducted in accordance with institutional guidelines and standard laboratory practices for food and fish product analysis.

Therefore, ethical approval was not required for this study.

Highlights

- Steam cooking reduced fat content while preserving protein and minerals in Pangasius fillets.
- Saturated and monounsaturated fatty acids decreased, while polyunsaturated fatty acids were retained.
- Tail portions showed lower fat and moisture content, while head portions retained higher mineral and PUFA concentrations.
- Steam cooked Pangasius fillets are suitable for low fat, protein rich and mineral dense functional foods.
- Mild heat treatment (steam cooking) enhances the nutritional and market value of Pangasius fillets.

Recommendations

1. **Food Industry Application:** Steam-cooked Pangasius fillets can be used in health-oriented products such as fish-enriched pasta, ready-to-eat meals and functional snacks.
2. **Anatomical Portion Utilization:** Tail and body portions can be prioritized for low fat formulations, while head portions can be utilized for protein and mineral rich products.
3. **Further Research:** Future studies should investigate long term storage effects on proximate composition, fatty acids and mineral retention in steam cooked fillets.
4. **Consumer Health:** Incorporation of steam cooked Pangasius in diets may help reduce cardiovascular risk due to lower SFA and MUFA intake while providing essential nutrients.
5. **Processing Optimization:** Optimization of steam time and temperature could further enhance PUFA retention and overall nutrient quality.

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