



ASSESSMENT OF BIOCHEMICAL COMPOSITION AND SAFETY INDEX OF THE BAGRID CATFISH (*CHRYSICHTHYS NIGRODIGITATUS*) ACROSS BODY PARTS

Mogbonjubola Mutiat OGUNBAMBO¹, Binta Isyaku USMAN², Oluwafolakemi Anthonia AFOLAYAN

¹Department of Marine Sciences, University of Lagos, Akoka, Lagos, Nigeria

²Department of Fisheries and Aquaculture, Bayero University, Kano, Kano-Nigeria

³Department of Fisheries Technology, Federal College of Fisheries and Marine Technology, Lagos State, Nigeria

*Corresponding Author: mutiat.ogunbambo@gmail.com

Received 22th July, Accepted 21th September 2025

Abstract: The economic value of the bagrid catfish lies in its desirable taste and rich nutritional profile. This study examined the proximate composition, energy distribution, mineral content, and mineral safety index (MSI) of different anatomical parts (head, body, and tail) of the bagrid catfish (*Chrysichthys nigrodigitatus*). Proximate analysis revealed significant variations across parts, with protein content progressively increasing from head (46.99%) to tail (70.22%), while crude fat was highest in the body (19.38%) and lowest in the tail (7.37%). The nitrogen-free extract (NFE) was highest in the head (13.70%) and lowest in the tail (4.74%). The energy contribution varies by body part, averaging 1708.77 kJ/100 g. Protein was the main energy source (1004.27 kJ/100 g), highest in the tail (1193.80 kJ/100 g). Fat contributed 561.50 kJ/100 g on average, while carbohydrates were minimal (143.03 kJ/100 g). Tail protein energy utilization peaked at 47.00 kJ. Mineral analysis showed spatial variation, with Ca and Mg highest in the body and head, respectively, and Na and K most concentrated in the head. Mineral ratios indicated acceptable Ca/Mg, Na/K, and Na/Mg balances, though Ca/P and K/(Ca+Mg) ratios fell below ideal levels. MSI evaluation revealed potential excesses of Ca, Mg, and Na in certain parts, particularly the head, which exceeded safety thresholds for Na. These findings underscore the nutritional value and potential safety considerations in the consumption of different parts of *C. nigrodigitatus*, with implications for dietary recommendations.

Keywords: catfish, food safety, mineral content, mineral ratio, nutritional

1. Introduction

Fish is a highly nutritious food valued by consumers for its rich content of protein, omega-3 fatty acids, vitamins, and minerals, with its nutritional value-comprising moisture, dry matter, protein, lipids, vitamins, minerals, and caloric content [1]. The nutritional value of fish varies across different body parts such that the fillet is rich in protein and omega-3 fatty acids, the liver contains high levels of vitamins A and D, the head and roe are good sources of protein and minerals, and the

bones provide calcium, while minerals also play essential roles in enzymatic functions, metabolism, and the growth of the fish itself [2]. *Chrysichthys nigrodigitatus*, commonly known as the bagrid catfish, is a commercially important species of catfish native to West and Central Africa. Its economic value stems from its palatability, nutritional composition, and adaptability to diverse aquatic environments [3]. Like many other catfish species, *C. nigrodigitatus* serves as a vital protein source, especially in riverine and coastal

communities where fish consumption constitutes a significant component of dietary intake [4]. However, the nutritional content of fish may vary considerably across different body parts due to metabolic differences and tissue specialization, necessitating a part-specific evaluation to inform consumption and processing practices [5]. Biochemical profiling such as the determination of proximate composition, fatty acids, and essential micronutrients is pivotal in understanding the nutritional quality of fish. In addition, safety indices, including mineral and microbiological load, are crucial for public health assurance, especially in regions susceptible to pollution from industrial or domestic effluents [6]. Previous studies have shown that contaminants often accumulate in specific body tissues [7-9]. Therefore, assessing the biochemical and safety status of different anatomical parts of *C. nigrodigitatus* offers critical insights into its overall edibility and nutritional value. Despite growing research on fish nutrition and safety, part-specific investigations on *C. nigrodigitatus* remain sparse. Most studies adopt a whole-body analysis approach, which may mask localized biochemical variations or toxicant concentrations. Given the increasing health consciousness among consumers and the need for evidence-based dietary recommendations, it becomes imperative to evaluate the nutrient profile and potential risks associated with consuming different body parts of this catfish species [10]. This study, therefore, aims to fill this knowledge gap by providing a detailed assessment of the biochemical and safety indices in relation to various anatomical sections of *C. nigrodigitatus*. Although *C. nigrodigitatus* is a widely consumed fish species in Nigeria, there is a lack of empirical data on how its nutritional and safety parameters vary across different body parts. Consumers often utilize the head, fillet, skin, and

internal organs without clear understanding of their respective health benefits or potential risks [11]. This knowledge gap poses a challenge to food safety regulation and informed consumer choices, especially in areas affected by aquatic pollution. The absence of such information may lead to the ingestion of contaminated or nutritionally inferior parts, with long-term implications for public health.

This study aims to assess the biochemical composition and safety indices of different body parts of *C. nigrodigitatus* with a view to determining their nutritional quality and potential health risks. The findings will inform better utilization strategies for fish processing and consumption, while also guiding public health interventions and environmental monitoring programs. Furthermore, the research will contribute to the growing body of knowledge on fish-based food safety and provide evidence-based recommendations for stakeholders in fisheries, food industries, and regulatory bodies.

2. Materials and methods

2.1 Sample collection and preparation

Samples of *C. nigrodigitatus* were obtained from Makoko Jetty of the Lagos Lagoon. The lagoon lies between latitudes 6°26' and 6°39'N and longitudes 3°29' and 3°50'E. Lagos Lagoon is a part of a continuous system of lagoons and creeks' lying along the coast of Nigeria and it is an open tidal estuary situated within the low-lying coastal zone of Nigeria [12]. Eighty (80) fresh samples were collected over four months (March – June 2025). The samples were rinsed with ultrapure water to remove foreign particles and patted dry with paper towels. The samples were transported in a 10 L bucket to the laboratory and processed within 4 hours of the collection. The fresh samples were identified using Identification Guides [13]. Routine body measurement was determined using a 30 cm plastic ruler.

Each fish was separated into exoskeleton and flesh, dried under 60 °C, grounded into powder and homogenized.

2.2 Laboratory analysis

Fresh fish samples were first cleaned thoroughly with deionized water to remove surface contaminants, then oven-dried at 105 °C until a constant weight was achieved. The dried samples were ground into a fine powder using a mortar and pestle and stored in airtight containers. Methods of the Association of Official Analytical Chemists [14] were adopted for moisture, crude fibre, protein, fat, ash and carbohydrate analyses. By means of the already confirmed amount of proteins and fat, the energy content of the edible part of the organism was calculated. The energy values ($\text{Kj } 100\text{g}^{-1}$) of the specimen were estimated, multiplying the amount of proteins (%) by factor 17.16 and multiplying the amount of fat (%) by factor 38.96 and then calculating the number of the two already determined values [15].

For mineral analysis, approximately 2 g of each powdered sample was digested using a mixture of concentrated nitric acid (HNO_3) and perchloric acid (HClO_4) in a ratio of 3:1. The digestion was performed in a fume hood on a hot plate at 150 °C until a clear solution was obtained, indicating complete digestion. After cooling, the digested samples were filtered using Whatman No. 42 filter paper and diluted to a final volume of 50 mL with deionized water. The concentrations of macro minerals (e.g., sodium, potassium, calcium, and magnesium) were determined using a flame photometer (Model 405, Corning, U.K.). Each analysis was performed in triplicate to ensure precision, and calibration curves were prepared using standard solutions at five concentration levels (e.g., 5, 10, 15, 20, and 25 ppm) [16]. Mineral Ratios and Mineral Safety Indices were calculated according to the formulae described by Santoso [17] and Hatcock [18],

respectively.

2.3 Statistical data analysis

Data were analyzed by descriptive analysis and Duncan multiple range test. Statistical software package (SPSS version 17, Chicago, USA) was employed in the analysis. Differences were considered significant at an alpha level of 0.05.

3. Results

3.1 Proximate composition and Energy contribution

The proximate composition of different parts of bagrid catfish *C. nigrodigitatus* (Figure 1) reveals significant variations across most parameters. Protein content increased progressively from head (46.99%) to body (60.01%) and was highest in the tail (70.22%), showing significant differences among all parts. Crude fat content was similar in the head (18.78%) and body (19.38%) but significantly lower in the tail (7.37%). Total ash content showed no significant differences among the parts. Nitrogen-Free Extract (NFE), which represents carbohydrate content, was highest in the head (13.70%) and significantly lower in the body (6.80%) and tail (4.74%). Overall, the tail had the highest protein but the lowest fat and carbohydrate content, while the head showed a higher moisture and NFE concentration.

The energy contribution of nutrients in *C. nigrodigitatus* varies across different body parts, with the body section exhibiting the highest total energy value (1853.01 kJ/100 g), followed by the head (1726.35 kJ/100 g), and the tail (1546.94 kJ/100 g). On average, the fish provides 1708.77 kJ/100 g. Protein emerged as the major contributor to the total energy across all parts, particularly in the tail (1193.80 kJ/100 g), with an overall average of 1004.27 kJ/100 g, indicating the species' high protein energy density. Fat contribution was highest in the body (717.18 kJ/100 g) but significantly lower in

the tail (272.57 kJ/100 g), yielding an average of 561.50 kJ/100 g. Carbohydrate contribution was relatively minimal, with an average of 143.03 kJ/100 g. The utilization of energy due to protein was highest in the tail (47.00 kJ) and lowest in

the head (32.01 kJ), averaging 39.73 kJ, suggesting the tail section offers the most efficient protein-derived energy, reinforcing its potential nutritional advantage.

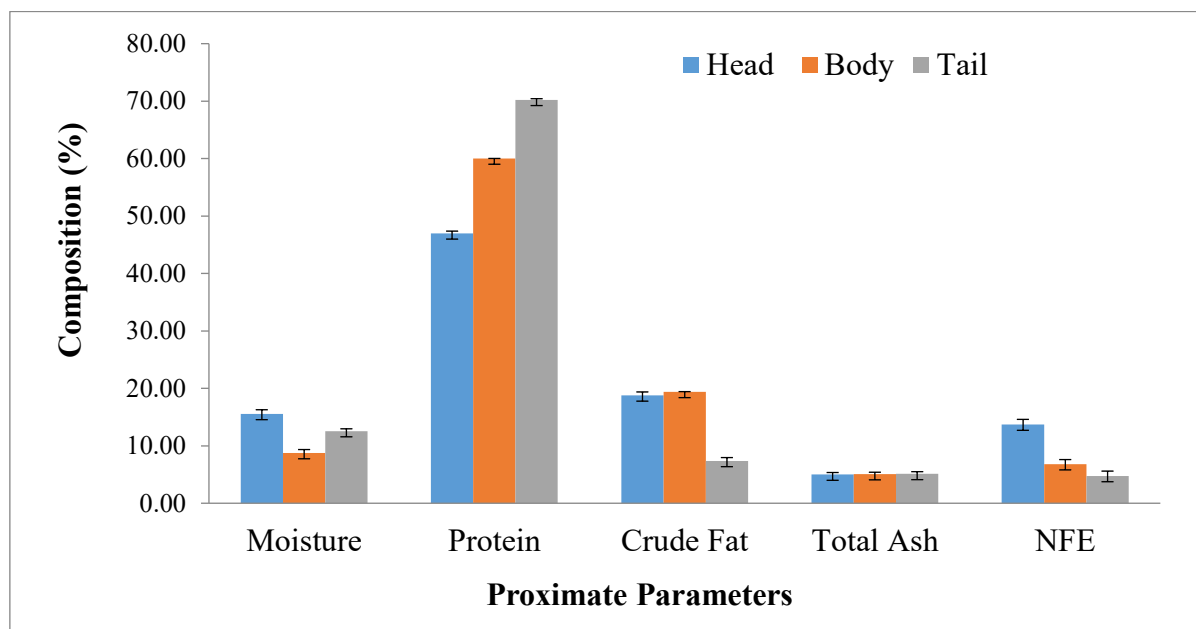


Fig. 1. Proximate composition of bagrid catfish *Chrysichthys nigrodigitatus* based on dry matter

Table 1
Energy value contributed by nutrients in bagrid catfish *Chrysichthys nigrodigitatus*

Parameter (Unit)	Head	Body	Tail	Average (per 100 g)
Total energy (kj 100g ⁻¹)	1726.35	1853.01	1546.94	1708.77
Proportion of total energy due to fat (kj 100 g ⁻¹)	694.74	717.18	272.57	561.50
Proportion of total energy due to carbohydrate (kj 100 g ⁻¹)	232.84	115.60	80.64	143.03
Proportion of total energy due to protein (kj 100 g ⁻¹)	798.77	1020.23	1193.80	1004.27
Utilization of energy value due to protein (kj)	32.01	40.17	47.00	39.73

3.2 Mineral compositional differentiation

Figure 2 shows the mineral composition of the fish parts, revealing significant variations across the head, body, and tail. Calcium was highest in the body (1755.61 mg 100g⁻¹) and lowest in the tail (1154.97 mg 100g⁻¹), with the head showing intermediate values. Sodium and potassium followed a similar trend, being

most concentrated in the head (1404.70 mg 100g⁻¹ and 821.67 mg 100g⁻¹, respectively), and least in the body and tail. Magnesium was significantly higher in the head (453.51 mg 100g⁻¹), while no statistical difference was observed between the body and tail. Phosphorus levels were highest in the head (1124.70 mg 100g⁻¹), followed by the tail, and least in the body.

Mogbonjubola Mutiat OGUNBAMBO, Binta Isyaku USMAN, Oluwafolakemi Anthonia AFOLAYAN, Assessment of biochemical composition and safety index of the bagrid catfish (*Chrysichthys nigrodigitatus*) across body parts, Food and Environment Safety, Volume XXIV, Issue 3 – 2025, pag. 193-201

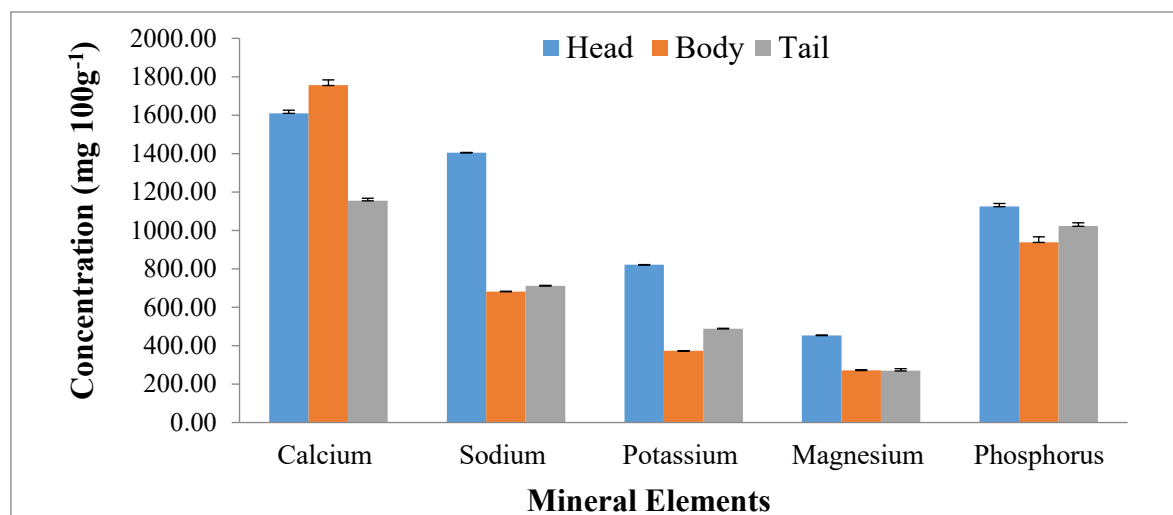


Fig. 2 Mineral compositional differentiation in bagrid catfish *Chrysichthys nigrodigitatus*

The mineral ratio analysis of *C. nigrodigitatus* (Table 2) reveals varied nutritional balance across the head, body, and tail regions when compared with ideal and acceptable ranges. The Ca/Mg ratio in the head (3.55), body (6.47), and tail (4.29) all fall within the acceptable range (3–11), indicating a balanced calcium-to-magnesium relationship. The Ca/K ratio is optimal in the body (4.71) but falls below the ideal in the head (1.96) and tail (2.36), though still within acceptable limits. For Ca/P, all parts fall below the ideal (2.6), particularly the tail (1.13), suggesting potential phosphorus dominance or calcium

deficiency. The Na/K ratio is within the acceptable range across all parts, indicating good sodium-potassium balance. The Na/Mg ratio is also within range, though slightly lower in the body (2.51). However, the $[K/(Ca + Mg)]$ ratio is significantly below the expected ideal of 2.2 in all regions, implying a lower proportion of potassium relative to calcium and magnesium combined. Overall, the body part of the fish demonstrates the most balanced mineral profile, while the head and tail show relative deficiencies in certain ratios.

Table 2

Mineral ratios in the bagrid catfish <i>Chrysichthys nigrodigitatus</i>					
Parameter	Reference Balance (Watt [19])	Acceptable ideal range	Head	Body	Tail
Ca/Mg	7.0	3 to 11	3.55	6.47	4.29
Ca/K	4.2	2.2 to 6.2	1.96	4.71	2.36
Ca/P	2.6	1.5 to 3.6	1.43	1.87	1.13
Na/K	2.4	1.4 to 3.4	1.71	1.83	1.46
Na/Mg	4.0	2 to 6	3.10	2.51	2.64
$[K/(Ca + Mg)]$	2.2	-	0.66	0.45	0.61

The mineral safety index (MSI) assessment of the Bagrid Catfish (Table 3) shows varying levels across the head, body, and tail portions of the fish. For calcium (Ca), the MSI values exceeded the threshold

($MSI_{tv} = 10$) in the head (13.42) and body (14.63), indicating potential excess with percent deviations (%D) of -34.20 and -46.30 respectively, while the tail (9.62) was within the safe range. Magnesium (Mg)

Mogbonjubola Mutiat OGUNBAMBO, Binta Isyaku USMAN, Oluwafolakemi Anthonia AFOLAYAN, Assessment of biochemical composition and safety index of the bagrid catfish (*Chrysichthys nigrodigitatus*) across body parts, Food and Environment Safety, Volume XXIV, Issue 3 – 2025, pag. 193-1

levels surpassed the safe limit only in the head (17.01; %D = -13.38), whereas both body and tail parts had safe MSI values but still showed positive deviations, implying better safety margins. Phosphorus (P) levels remained within acceptable limits across all parts, with the highest safety in the head

(%D = 6.27). However, sodium (Na) levels were consistently above the safe MSI threshold in all parts, particularly the head (MSI_{cv} = 13.49; %D = -180.94), suggesting a potential health risk due to excessive sodium content.

Table 3

Mineral safety index of the bagrid catfish <i>Chrysichthys nigrodigitatus</i>								
Mineral	RAI (mg)	MSI _{tv}	Head		Body		Tail	
			MSI _{cv}	%D	MSI _{cv}	%D	MSI _{cv}	%D
Calcium	1200	10	13.42	-34.20	14.63	-46.30	9.62	3.75
Magnesium	400	15	17.01	-13.38	10.18	32.11	10.10	32.64
Phosphorus	1200	10	9.37	6.27	7.82	21.78	8.52	14.78
Sodium	500	4.8	13.49	-180.94	6.55	-36.39	6.83	-42.36

4. Discussion

The observed variations in the proximate composition of *C. nigrodigitatus* align with previous studies on fish body part differentiation. The progressive increase in protein content from head to tail corroborates findings by Nemova et al. [20], who reported higher protein accumulation in the muscular regions of fish, particularly the tail, due to its active involvement in locomotion. Similarly, the lower fat content observed in the tail agrees with the report of Rudy et al. [20], which noted that fat tends to accumulate more in the head and body where metabolic storage is concentrated. The relatively uniform ash content across parts mirrors earlier observations by Kiczorowska et al. [22], indicating consistent mineral distribution throughout the fish body. Although overall carbohydrate (NFE) levels were low, the relatively higher proportion in the head may be linked to glycogen reserves in organ-dense tissues, as suggested by Vornanen et al. [23]. These findings reaffirm the influence of anatomical location on the nutritional profile of fish, with implications for targeted utilization of specific parts based on nutritional needs. The energy distribution across different parts of *C. nigrodigitatus* in this study corroborates

reports by Nemova et al. [20], who observed higher protein energy content in the tail muscles of marine species due to dense myofibrillar tissue. Similarly, Rudy et al. [21] reported that fish body parts differ significantly in energy composition, with body and head regions often containing higher lipid content, supporting our observation of higher fat contribution in these parts. The low carbohydrate contribution across all parts reflects typical trends in fish composition, as noted by Pigott and Tucker [23], who stated that carbohydrates are generally negligible in fish tissue. Additionally, the higher proportion of protein-derived energy in the tail reflects its dense muscular tissue, consistent with its role in locomotion, consistent with the work of Abowei and Nemova et al. [20], who highlighted the tail region as nutritionally superior due to concentrated protein reserves. These findings collectively emphasize the tail portion of *C. nigrodigitatus* as a valuable protein source with efficient energy utilization. The relatively high calcium content observed in the body may partly reflect inclusion of bone or connective tissues alongside muscle samples, corroborating Kiczorowska et al. [22]. The elevated sodium and potassium levels in the

head agree with Iyiola et al. [24], who reported that the fish head often retains more electrolytes due to proximity to nervous tissues and gills. The significant magnesium concentration in the head mirrors results by Yoshimura et al. [25], suggesting that bones and brain tissues are mineral-rich reservoirs. Phosphorus dominance in the head, as also documented by Anita et al. [26], may reflect the abundance of phosphate-bound proteins and skeletal structures. These patterns emphasize the nutritional variability across fish parts and underline the head's contribution to overall mineral intake.

The mineral ratio profile of *C. nigrodigitatus* across different body parts reflects a generally acceptable but uneven nutritional balance, aligning with trends reported in similar studies. The Ca/Mg ratios observed (3.55–6.47) fall within the acceptable range of 3–11, consistent with findings by Zafar and Khan [27], who reported balanced Ca/Mg ratios in freshwater fish species, suggesting adequate skeletal and enzymatic support. The Ca/K ratio, although optimal in the body, was suboptimal in the head and tail, a pattern also observed by Abimbola et al. [28], in *Pseudotolithus spp.*, where muscle tissue had superior calcium-potassium balance compared to other parts. The low Ca/P ratios (<2.6) in all portions reflect possible phosphorus dominance or calcium inadequacy, supporting earlier observations by Moruf et al. [29], who emphasized the importance of maintaining a higher Ca/P ratio for bone health and metabolic stability. Sodium-related ratios (Na/K and Na/Mg) remained within acceptable limits, indicating favorable electrolyte balance, as corroborated by the work of Iyiola et al. [24], who found similar trends in estuarine fish species. However, the consistently low $[K / (Ca + Mg)]$ ratios across all regions echo the concerns of Abimbola et al. [28], who noted that inadequate potassium relative to divalent cations may limit

cardiovascular benefits. In summary, while the body portion of *C. nigrodigitatus* appears nutritionally superior in mineral balance, the head and tail present mild deficiencies, especially in calcium-related ratios. The observed variations in the Mineral Safety Index (MSI) of *C. nigrodigitatus* align with previous findings that fish mineral composition often differs by anatomical part and may exceed recommended intake levels. Similar to the present study, Zafar and Khan [27], reported elevated calcium and magnesium levels in the head regions of commonly consumed fish species, attributing this to bone concentration. Elevated sodium levels in the head, while still within natural biological ranges, may contribute to dietary sodium load, as noted by Iyiola et al. [24]. The relatively safe phosphorus levels across all parts support findings by Moruf et al. [29], who noted that phosphorus in fish generally falls within safe nutritional limits due to its essential role in metabolic functions.

5. Conclusion

The present study highlights the significant nutritional variability among different anatomical parts of the bagrid catfish, *Chrysichthys nigrodigitatus*, offering valuable insights for informed dietary choices and fish processing practices. The tail portion emerged as the most protein-rich part, with minimal fat and carbohydrate levels, making it ideal for high-protein, low-fat diets. Conversely, the head exhibited higher moisture and carbohydrate contents, while the body demonstrated a balanced nutritional profile with the highest energy yield. Mineral distribution revealed that essential macro-minerals such as calcium, magnesium, and phosphorus were unevenly distributed, with some exceeding recommended safety limits, especially in the head. Although most mineral ratios fell within acceptable nutritional standards, deviations in Ca/P and $K/(Ca+Mg)$ ratios

suggest potential nutritional imbalances that warrant caution. The MSI further underscored these concerns, particularly the high sodium levels in the head, which may pose health risks if consumed excessively. Overall, the body portion exhibited the most nutritionally balanced profile, while the tail offered the highest protein energy efficiency. These findings provide a scientific basis for optimizing fish utilization, especially in resource-limited settings where nutritional security is paramount. Consumers and processors should consider these variations to maximize the nutritional benefits while minimizing potential health risks associated with excessive mineral intake.

6. Acknowledgments

The technical input of Dr R.O. Moruf of Fisheries and Aquaculture Department, Bayero University, Kano (Nigeria) is acknowledged.

7. References

- [1]. MORUF, R. O., AKINYEMI, K. A., AMINU, M. U., LAWAL-ARE, A. O. Nutritional safety assessment of giant tiger shrimp (*Penaeus monodon*): Impact of smoking. *Agriculture, Food, and Natural Resources Journal*, 4(1): 79-85, (2025).
- [2] OPEYEMI I. E. Proximate Analysis and Mineral Composition of Some Fish Species in Ero Reservoir Ikun Ekiti, Nigeria. *Global Advanced Research Journal of Agricultural Science*, 9(1): 1-9, (2020).
- [3] TOSSOU, A. R., KPOGUE, G. N. S. D., DJISSOU, A. S., LIADY, N. D. M., SOHOU, Z., FIOGBÉ, E. D. Bibliography on the biology, ecology, and breeding of the *Chrysichthys nigrodigitatus* (Lacépède, 1803). *International Journal of Fisheries and Aquatic Studies*, 11(6): 50-56, (2023).
- [4]. OURO-SAMA, K., AFIADEMANYO, K. M., SOLITOKE, H. D., TANOUAYI, G., BADASSAN, T. E. E., AHOUDI, H., GNANDI, K. Diet and food consumption of the African catfish, *Chrysichthys nigrodigitatus* Lacépède (1803) (Siluriformes: Claroteidae), from the hydrosystem Lake Togo-Lagoon of Aného (South of Togo). *Journal of Environmental Protection*, 11(11): 954-976, (2020).
- [5]. MORAES, G., DE ALMEIDA, L. C. Nutrition and functional aspects of digestion in fish. In *Biology and physiology of freshwater neotropical fish* (pp. 251-271). Academic Press, (2020).
- [6]. MEKURIA, D. M., KASSEGNE, A. B., ASFAW, S. L. Assessing pollution profiles along Little Akaki River receiving municipal and industrial wastewaters, Central Ethiopia: Implications for environmental and public health safety. *Heliyon*, 7(7): 23-34, (2021).
- [7]. PYZ-ŁUKASIK, R., CHAŁABIS-MAZUREK, A., GONDEK, M. Basic and functional nutrients in the muscles of fish: a review. *International Journal of Food Properties*, 23(1): 1941-1950 (2020).
- [8]. LALL, S. P., KAUSHIK, S. J. Nutrition and metabolism of minerals in fish. *Animals*, 11(09): 2711-2723, (2021).
- [9]. MORUF, R. O., AKINWUNMI, M. F. Compositional energy values, macro and trace elements in the caridean species, *Macrobrachium macrobrachion* (Herklots, 1851). *Food and Environment Safety Journal*, 21(1): 39 - 46, (2022).
- [10]. OGUNBAMBO, M. M., SANNNI, O. A. Nutritional Variation in Bagrid Catfish *Chrysichthys nigrodigitatus* (Lacépède, 1803) with Processing Methods. *Journal of Material and Environmental Science*, 14(5): 592-601, (2023).
- [11]. ABERA, B. D., ADIMAS, M. A. Health benefits and health risks of contaminated fish consumption: Current research outputs, research approaches, and perspectives. *Heliyon*, 10(13): 23-34, (2024).
- [12]. MORUF R. O., LAWAL-ARE A. O. Size composition, growth pattern and condition factor of two Portunid crabs, *Callinectes amnicola* (De Rochebrune) and *Portunus validus* (Herklots) off Lagos coast, Nigeria. *Nigerian Journal of Fisheries and Aquaculture*, 5, 1: 15-21, (2017).
- [13]. POWELL C.B. Fresh and brackish water shrimps of economic importance in Niger Delta. Proceedings of 2nd Annual Conference of Fisheries Society of Nigeria (FISON), Calabar: 254-284, (1983).
- [14]. AOAC. Official Methods of analysis, 18th ed., Association of Official Analytical Chemists, Washington, DC, USA, (2006).
- [15]. SAVESKI A., KALEVSKA T., STAMATOVSKA V., DAMJANOVSKI D. Chemical composition and energy value in the meat of the Macedonian and Ohrid trout. *Food and Environmental Safety*, 16(1):40–46, (2017).
- [16]. GOKOGLU N., YERLIKAYA P. Determination of proximate composition and mineral contents of blue crab (*Callinectes sapidus*) and swim crab (*Portunus pelagicus*) caught off the Gulf of Antalya. *Food Chemistry*, 80(4):495–498, (2003).
- [17]. SANTOSO J., YOSHIE-STARK Y., SUZUKI T. Comparative content of minerals and dietary fibers in several tropical seaweeds. *Bulletin of*

Mogbonjubola Mutiat OGUNBAMBO, Binta Isyaku USMAN, Oluwafolakemi Anthonia AFOLAYAN, *Assessment of biochemical composition and safety index of the bagrid catfish (Chrysichthys nigrodigitatus) across body parts*, Food and Environment Safety, Volume XXIV, Issue 3 – 2025, pag. 193-201

- Aquatic Product Technology*, 9 (1): 1–11, (2006).
- [18]. HATCOCK J.N. Quantitative evaluation of vitamin safety. *Pharmacy Times*, 104-135, (1985).
- [19]. WATTS D.L. HTMA Mineral Ratios. A brief discussion of their clinical importance. *Trace Elem Newsletter* 21: 1-3, (2010).
- [20]. NEMOVA, N. N., KANTSEROVA, N. P., LYSENKO, L. A. The traits of protein metabolism in the skeletal muscle of teleost fish. *Journal of Evolutionary Biochemistry and Physiology*, 57(3): 626-645, (2021).
- [21]. RUDY, M. D., KAINZ, M. J., GRAEVE, M., COLOMBO, S. M., ARTS, M. T. Handling and storage procedures have variable effects on fatty acid content in fishes with different lipid quantities. *PLoS One*, 11(8): e0160497. (2016).
- [22]. KICZOROWSKA, B., SAMOLIŃSKA, W., GRELA, E. R., BIK-MAŁODZIŃSKA, M. Nutrient and mineral profile of chosen fresh and smoked fish. *Nutrients*, 11(7): 1448, (2019).
- [23]. VORNANEN, M., ASIKAINEN, J., HAVERINEN, J. Body mass dependence of glycogen stores in the anoxia-tolerant crucian carp (*Carassius carassius* L.). *Naturwissenschaften*, 98(3): 225-232, (2011).
- [24] IYIOLA, A. O., KOLAWOLE, A. S., SETUFE, S. B., BILIKONI, J., OFORI, E., OGWU, M. C. Fish as a sustainable biomonitoring tool in aquatic environments. *In* Biomonitoring of pollutants in the global south (pp. 421-450). Singapore: Springer Nature Singapore, (2024).
- [25] YOSHIMURA, T., ISHIKAWA, N. F., OGAWA, N. O., KUSAKA, S., WAKAKI, S., ISHIKAWA, T., OHKOCHI, N. Magnesium isotopic variation in marine fish organs. *Progress in Earth and Planetary Science*, 12(1): 1-12, (2025).
- [26] ANITA, S., HARYONO, H., WAHYUDEWANTORO, G. Nutritional component of *Barbonymus balleroides*: A wild fresh water fish from Indonesia. *Biodiversitas Journal of Biological Diversity*, 20(2), 581-588, (2019).
- [27] ZAFAR, N., KHAN, M. A. Effects of dietary magnesium supplementation on growth, feed utilization, nucleic acid ratio and antioxidant status of fingerling *Heteropneustes fossilis*. *Animal Feed Science and Technology*, 273: 114819, (2021).
- [28] ABIMBOLA, A. O. Proximate and mineral composition of *Pseudolithus senegalensis* and *Pseudolithus typus* from Lagos Lagoon, Nigeria. *Food and Applied Bioscience Journal*, 4(1): 35-40, (2016).
- [29]. MORUF R.O., AFOLAYAN O.A., TAIWO M.A., OGUNBAMBO M.M. Estimation of nutritional energy values, mineral ratio and mineral safety index in the Royal Spiny Lobster, *Panulirus regius* (De Brito Capello, 1864). *Croatian Journal of Food Science and Technology*, 13 (1): 105-110, (2021).