Nutritional Assessment of Wild African Catfish (*Clarias Gariepinus* Burchell, 1822): Proximate and Fatty Acid Composition from Calabar River, Nigeria

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Abstract

Fish remains a critical contributor to global nutrition, yet limited data exist on the biochemical composition of wild African catfish (Clarias gariepinus) from Calabar River, Nigeria, despite its high consumption and economic relevance. The lack of such information constrains accurate evaluation of its dietary and commercial value. This study therefore aimed to determine the proximate and fatty acid composition of C. gariepinus obtained from the fish landing site at Calabar River. A total of 60 specimens of varying sizes were collected over a 3-month sampling period, preserved in ice, and transported to the laboratory for analysis. Standard procedures were employed to determine moisture, ash, protein, fat, crude fiber, carbohydrate content, and fatty acid profile. Results showed high moisture levels (93.30–93.50%) consistent with freshwater fish species. Ash content reached 4.27% in larger specimens, suggesting rich mineral composition. Protein content (43.28–43.32%) confirmed C. gariepinus as a high-protein food source, while fat content (7.80%) placed it in the medium-fat category. Essential fatty acids, including omega-3 and omega-6, were detected, though total fatty acids were relatively low (0.14–0.16%). Crude fiber remained minimal (0.40–0.42%), while carbohydrate values (44.10–44.63%) appeared elevated, likely due to methodological factors. C. gariepinus provides significant protein and lipid nutrition with associated health benefits. It is recommended that future studies examine seasonal and environmental influences on its biochemical composition to support aquaculture development and nutritional policy in Nigeria.

Keywords: *Clarias gariepinus*, proximate composition, fatty acid profile, nutritional value, Calabar River.

Introduction

Fish plays a crucial role in global nutrition, serving as a highly reliable source of essential nutrients, particularly proteins and fatty acids. These bioactive compounds not only provide fundamental nourishment but also contribute significantly to physiological and therapeutic processes, aiding in the management of various health conditions (Effiong & Fakunle, 2013). Fresh fish retains its natural texture, flavor, and biochemical properties; however, different processing methods can alter these characteristics, influencing both sensory and nutritional qualities (Edun, 2012).

Fish is an indispensable component of the global food system, contributing to environmental stability and serving as a major source of livelihood worldwide. Unlike other animal proteins such as pork, beef, and mutton, fish is free from cultural or religious dietary restrictions, making it widely accepted across diverse populations (National Institute for Freshwater Fisheries Research, NIFFR, 1999). In many developing nations, fish serves as the primary source of animal protein, supplying over 30% of

daily protein intake for approximately 60% of the population. Conversely, in developed nations, fish consumption is lower, with about 80% of people obtaining less than 20% of their animal protein from fish sources (Osibona *et al*., 2009). However, increased awareness of the health benefits of fish consumption, coupled with rising market demand, is progressively shifting these consumption patterns.

In low-income countries, staple foods such as rice, maize, and cassava constitute the bulk of daily energy intake. However, these carbohydrate-rich foods lack essential amino acids and micronutrients necessary for optimal human health. Fish serves as a vital nutritional supplement, providing high-quality proteins, polyunsaturated fatty acids (PUFAs), vitamins, and essential minerals, thereby enhancing the overall dietary balance of populations dependent on carbohydrate-based diets (Eyo, 2001).

Fish and fish-derived products are renowned for their superior nutritional profile, particularly due to their high content of omega-3 long-chain polyunsaturated fatty acids (LC n-3 PUFAs), such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Ali & Kumars, 2010; Neil, 1997). These bioactive lipids have been extensively documented for their protective role against cardiovascular diseases, notably reducing the risk of coronary heart disease (CHD) (Minis *et al*., 2006). The incorporation of omega-3 fatty acids into human diets has also been linked to immune modulation, skin disease prevention, and accelerated wound healing through the regulation of prostaglandin synthesis (Osibona *et al*., 2009).

Furthermore, fish oils contain a high proportion of unsaturated fatty acids, making them chemically more reactive compared to lipids derived from terrestrial animals and plants (Clucas & Ward, 1996). This reactivity enhances their biological functions, including anti-inflammatory properties and neurodevelopmental benefits. Since LC n-3 PUFAs cannot be endogenously synthesized by humans, their dietary intake from fish sources remains indispensable for maintaining physiological homeostasis (Osibona *et al*., 2009).

The African catfish, *Clarias gariepinus*, is one of the most economically significant freshwater fish species, widely valued for its adaptability, rapid growth rate, and high market demand (Onyia, 2012). This species exhibits resilience in harsh environmental conditions, demonstrating remarkable tolerance to low oxygen levels, disease resistance, and an omnivorous feeding habit that allows it to thrive on cost-effective diets (Ime-Ibanga & Fukunle, 2007).

Morphologically, *C. gariepinus* belongs to the family Clariidae and is characterized by a large head, with body size approximately 3.1 to 3.88 times its head length, and possessing 52–62 dorsal fin rays (Olor *et al*., 2011). It is widely distributed across Africa, ranging from the Nile Basin to West Africa and extending as far south as Algeria and South Africa (Osibona *et al*., 2006). Due to its high commercial value, *C. gariepinus* is extensively cultured, particularly in Nigeria, where it plays a critical role in the local aquaculture industry.

Numerous studies have explored the comparative proximate composition and fatty acid profiles of wild and cultured *C. gariepinus* in various geographic regions (Edward, 2006). However, limited research has focused on the proximate and fatty acid composition of *C. gariepinus* sourced from the landing site of Calabar River, Cross River State, Nigeria. Given the significance of this species in both nutrition and commerce, this study aims to provide a comprehensive analysis of the proximate and fatty acid composition of wild *C. gariepinus* captured in the Calabar River and marketed at the landing site (Beach market), thereby contributing valuable insights into its nutritional and economic value.

Methodology

This study was carried out along the Calabar River in Cross River State, South-South Nigeria. The Calabar River is an important water body that flows through the city of Calabar, providing fishery resources, transportation, and livelihoods for the surrounding communities. The fish samples analyzed in this study were purchased directly from artisanal fishermen at the Fish Landing Site (Beach Market) located on the riverbank, which serves as the major landing point and distribution center for freshly caught fish in the area. Geographically, Calabar lies between latitude 4°51′N and 5°41′N of the equator and longitude 8°18′E and 8°21′E of the Greenwich meridian (Figure 1). The region falls within the tropical rainforest zone, with a climate characterized by dense vegetation cover, average annual temperatures ranging from 25°C to 28°C, and rainfall below 3000 mm (Effiong & Fakunle, 2013; Joseph et al., 2020). The Calabar River and its adjoining landing sites support artisanal fishing, which remains a key economic activity for local inhabitants (Jimmy et al., 2022).

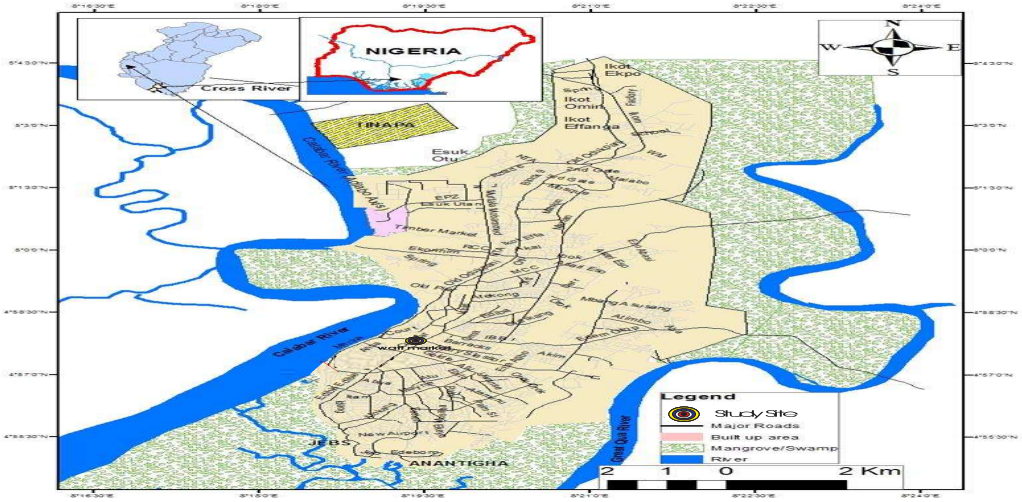

Figure 1. Map of the study area

Sample collection

Freshly harvested samples of *Clarias gariepinus* were purchased from fish sellers at the landing site in Calabar River on each of the sampling occasions.

Preservation and transportation of samples to the laboratory

A total of 60 *Clarias gariepinus* of different sizes were purchased and stored in cooler containing ice blocks and transported to the laboratory throughout the 3 months sampling period. The samples were taken to the Biochemistry laboratory at the Department of Biochemistry, University of Calabar, Nigeria.

Laboratory Studies

Measurement of fish length and weight

In the laboratory, the standard length (L) and weight (W) of the specimens were measured using measuring board calibrated in cm and triple beam balance respectively.

Preparation of fish samples for analysis

Fish samples were gutted, washed, filleted, finely minced and homogenized for chemical analysis. Triplicate determinations were carried out on each chemical analysis. This included proximate composition (moisture content determination, ash content determination, determination of protein content, fat and crude fibre content) and free fatty acid and saponification value determination.

Determination of Proximate Composition

Determination of moisture content (AOAC, 2006)

The apparatus for used for the determination of moisture content includes; Porcelain crucible with covers, air-tight desiccator containing fused calcium chloride as dry agents, vacuum oven Analytical balance (MeterH_20; ($H5_1$ AR) Gallenkamp.

Procedure: 2.0gram of the ground sample was accurately weighed in covered crucible dishes previously dried at 98- 100°C cooled in a desiccator and weighed soon after attaining room temperature. The crucible and samples were heated at 100°C for 5 hours to obtain loss in weight 9 or to constant weight. The dishes and their contents were cooled in a desiccator containing fused calcium chloride as drying agent and then weighed.

The loss in the weight was expressed on in percentage.

$$\% \text{ Moisture} = \frac{\text{Loss in weight on dry (g)}}{\text{Initial sample weight (g)}} \times 100$$

Determination of ash content (AOAC, 2006)

The apparatus used for determination of ash content include: Porcelain crucible with a slip-in cover, Muffle furnace, and Air-tight dessicator with fused calcium chloride drying agent

Procedure: 2.0g of the well-mixed sampled were weighed accurately into shallow relatively broad porcelain crucibles which had been ignited, cooled in dessicator and weight soon after reaching temperature. The porcelain and their crucible content were covered and ignited in a muffled furnace at 550°C (dull red) until light gray ash resulted, or to constant weight.

The crucible and their content were cooled in desiccator and weighed soon after reaching room temperature.

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

Determination of Protein content (AOAC, 2006)

The apparatus used for determination of protein content include: Digestion rack with electric heaters, Kjeldehl digestion flask (300ml capacity), Kjeldehl digestion apparatus, Kjeldehl digestion catalyst (sodium sulphate/ copper sulphur) 400g of sodium was thoroughly mixed with 16g copper sulphate 8g of this mixture was then weighed out for each digestion, Micro-Kjedahl distillation apparatus, Burette (25ml capacity), Erlmeyer (conical) flask (50ml capacity), Pipette 95ml, 10ml capacity, Funnel and measuring cylinder, Analytical balance (Meter H_20, Gallenkamp).

Reagents: Concentrated sulphuric acid, 40% sodium hydroxide, 0.1N HCl, 4% Boric acid solution and double indicator system 9methyl red+methylene blue.

Procedure: 2g of each sample were accurately weight and put into a 300ml standard Kjeldahl digestion flask containing 8g of sodium sulphate/copper sulphate catalyst, some anti-bumping chips and 300ml of concentrated sulphuric acid. The digestion flask was placed into the digestion rack and heated gently to prevent vigorous charring and frothing. The flask and its content were then subjected to rigorous heating for about 2 hours until a clear digest was obtained, after digestion, the solution was cooled, then transferred quantitatively into a 100ml standard flask and made up to the mark with distilled water and 10ml portion of this digest was pipette into a semi-micro Kjeldahl-markham distilled apparatus, 10ml distilled water and treated with 30ml 40%NaOH solution. The ammonia evolved was steam distilled as described by Markham (1942) into a 50ml conical flask

containing 10ml solution of 4% boric acid into which 2 drops of the double indicator had been added. The tip of the condenser was immersed into boric acid double indicator solution and the distillation continued until about 3 times the original volume was obtained and there was a change in color of the original content of the conical flask.

The tip of the condenser was rinsed with a few milliliters of distilled water and what remained of the 10ml digest was discarded and the flask rinsed 3 times with distilled water before the next determination. The distillate was then titrated with the standard 0. In hydrochloric acid solution until an end-point was reached. Distilled was carried out in triplicates for each digest and the percentage nitrogen content obtained by appropriate calculations. The crude protein was obtained by multiplying the percentage N content by the factor 6.25 i.e.

% Crude protein =% N x 6.25.

Determination of crude fat content (AOAC, 2006)

The apparatus used for determination of crude fat include:

Soxhlet extractor, heating mantle, fat extraction thimbles, 500ml round bottom flasks, oven, anti-bumping granules, and analytical balance.

Reagent: Petroleum ether (B.P. 40^0C - 60^0C)

Procedure: 2.0g ground materials were weighed accurately into a fat extractor thimble. 250ml of petroleum ether were poured into a previously weighed 500ml flask containing anti-bumping chips. The soxhlet extractor (Bolawa, *et al*., 2011) into which the thimble with its content had been introduced was then filtered into the round bottom flask and the extractor apparatus sitting on the heating mantle. The content of the flask were heated. As the ether evaporated, it condensed and dropped into the thimble where it extracted the ether soluble concentration into the round bottom flask. The extraction process lasted 8 hours and the thimble was then removed and dried in an oven at50^0C. The petroleum ether contained in the round bottom flask was distilled off using the soxhlet. The small amount of the ether left in the flask was evaporated off using a water bath at 50^0C. The round bottom flask and the lipid extract were finally dried in an oven at 100^0C, cooled in a desiccator and weighed. The amount of lipid extract was obtained from the different between the weighed of the flask before and after extraction.

$$\text{Petroleum ether extract (\%)} = \frac{\text{weight of extract (g)}}{\text{Weight of dry sample (g)}} \times 100$$

Determination of crude fibre content (AOAC, 2006)

The apparatus used for determination of crude fibre content include: A rubber-tipped glass rod, 400ml beakers, Buchner funnel (ground mesh 200), muffle furnace.

Reagents: 1.25% (w/v) NaOH, 1.25 (w/v) H_2SO_4, and 95% methanol.

Procedure: Acid digestion: The fat-free material (8-10g) was weighed and quantitatively transferred into a 40ml beaker which had been previously marked at the 200ml level. 500ml of 1.25% sulphuric acid were added and the mixture was made up to 200ml mark with distilled water. The content of the beaker were heated to boiling point for 30 minutes.

Filtration: The content of the beaker were filtered through a Buchner funnel with the aid of a suction pump. The residue was washed with hot water until it was acid free.

Based digestion: The residue left after acid digestion was quantitatively transferred into the 500ml beaker. 50ml of 1.25% (w/v) NaOH was added and made up to the 200ml mark with distilled water. The mixture was then heated again for 30 minutes with constant stirring and the content of the beaker was filled through the Buchner funnel and washed several times with hot water until it was free from sodium hydroxide. Finally, the residue was washed twice with 95% methanol quantitatively transferred into a porcelain crucible and dried at 100^0C.

Ignition: The weight of the oven-dried residue was noted and was later ignited in a furnace at 550^0C. The weight of the left after ignition was also noted.

Calculation: The crude fibre content was determined from the loss in weight of crucible and its content after ignition i.e.

Weight of sample = a
Weight of crucible + oven dried sample = b
Weight of crucible + ash = c
Fibre = b-c

$$\% \text{ crude fibre} = \frac{b-c}{a} \times 100$$

Determination of Carbohydrate content (NFE)

Carbohydrate content of the samples was determined by adding the values obtained for crude protein, fat, total ash and fibre and subtracting from 100g.

Fatty Acid Analysis

Determination of free fatty acids (Paquotv, 1979)

Reagent: 95% ethanol, 1% phenolphthalein, indicator 0.1M KOH solution (5.6g KOH was dissolved in distilled water and made up to 1000ml).

Procedure: 1g of the oil was weighed into one 250ml Erlenmeyer flask in a second flask 50ml of 05% ethanol was put and brought to boil. While the ethanol was still over 70^0C, it was neutralized with 0.1MKOH) solution with 3 drops of phenolphthalein as the indicator. The neutralized ethanol was poured into the flask containing the oil. This was thoroughly mixed by swirling the flask. The flask containing the mixture was brought to boil and the titrated hot with 0.1M KOH.

Calculation: Mass (in g) of oil weighed = W
Volume (in ml) of KOH = V
Molecular mass of KOH (in g/mol) =56.1
Mean molecular weight of fatty acid = M=282

Titre of KOH solution= T= 0.1mol/l

$$\text{Therefore, free fatty acid content (\%)} = \frac{\text{MVT}}{10\text{W}} = \frac{2.82\text{V}}{\text{W}}$$

Determination of Saponification value (AOAC, 2006)

Reagents: 0.1M HCl, alcohol potassium hydroxide 1% phenolphthalein indicator

Procedure: 1g of the oil accurately weighed and put in a 250ml Erlenmeyer flask, 10ml of alc. KOH solution was pipetted into the flask. Time of draining pipette was noted. The flask was connected with completely saponified (30minutes). To ensure complete saponification, the flask was swirled at frequent intervals. The flask was cooled and the content titrated with 0.5M HCl using phenolphthalein as indicator. The same procedure was carried out under the same conditions for the blank determination except that oil was not added.

Calculation: Mass (in g) of oil weighed = W
Volume of 0.5M HCl in test = V_1
Volume of 0.5M HCl used in blank = V_2
Titre of HCl, C (HCl) Ca =0.5mol/l = T

$$\text{Saponification value} = 56.1\text{T}\frac{\text{V1}-\text{V2}}{\text{W}} = \frac{28.05\ (V2-V1)}{\text{W}}$$

Statistical Analysis

Apart from routine calculations of means and standard deviations, other methods such as student t-test were used to assess if there was any significant different between the proximate and fatty acid composition in the different fish size and also on different sampling occasions.

Result

Proximate Composition

The result of the present investigation showed that the proximate composition of *C. gariepinus* varied with respect to nutrients and fish size. The summary of the results of different nutrients and fish sizes group is shown in Table 1.

Moisture Content

The major content of the fish species was moisture. The moisture content of the fish species ranged from 93.30% - 93.50%. The highest value of moisture was observed in the fish species with mean standard length 24.5cm and mean weight of 230g whereas the lowest value was in fish species with mean standard length of 36.8cm and mean weight of 474g (Table 1, Fig. 2).

TABLE 1: Proximate Composition of *C. gariepinus* captured from the wild (g/100gdry matter)

Mean Length (cm) (SL)	Mean Weight(g)	Mean Moisture (%)	Mean Ash (%)	Mean Protein (%)	Mean Fat (%)	Mean Fibre (%)	Mean Carbohydrate (%)
36.8±1.15	475±13.37	93.30±5.08	4.27±0.72	43.32±3.07	7.80±0.85	0.42±0.04	44.10±1.80
32.3±1.34	291±4.55	93.45±1.68	4.25±0.29	43.30±0.75	7.70±0.48	0.40±0.02	44.42±0.72
24.5±1.24	230±11.22	93.50±3.27	4.24±0.35	43.28±4.68	7.60±0.64	0.41±0.05	44.63±1.23

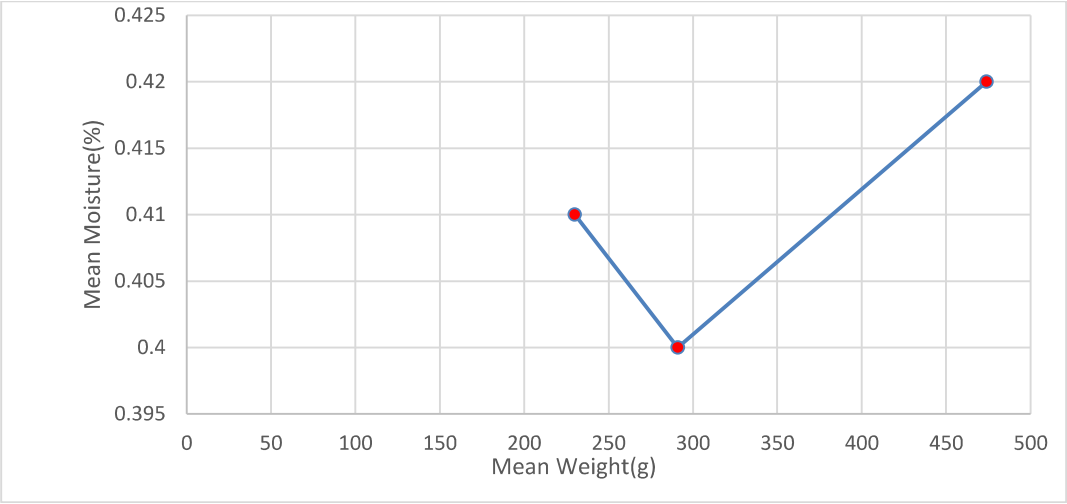

Figure 2: Relationship between the weight and the moisture content of *Clarias gariepinus* obtained from the wild

Ash Content

The lowest ash content of was recorded in the fish species with mean standard length of 24.5cm and mean weight of 230g whereas the highest ash content was observed in fish species with mean standard length of 36.8cm and mean weight of 474g. The ash content of the fish species ranged from 4.25% - 4.27% (Table 1, Fig. 3)

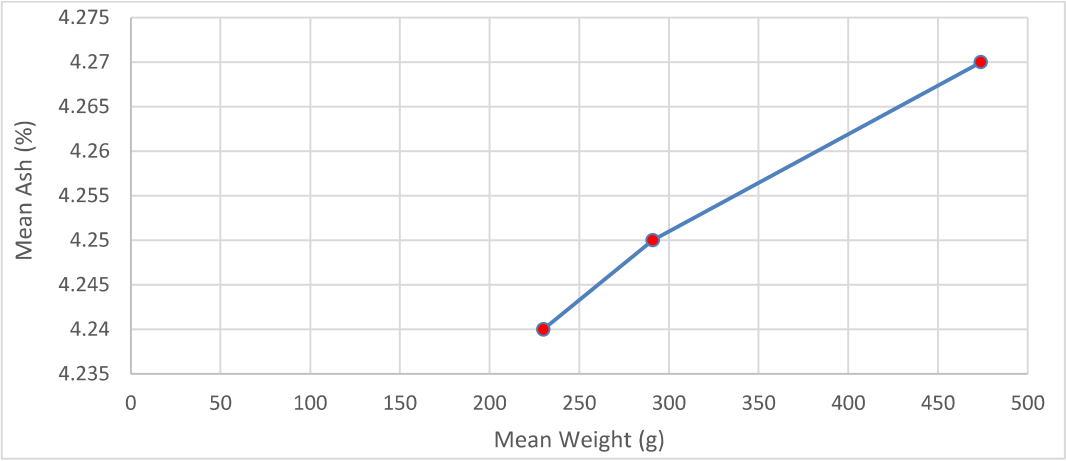

Figure 3. Relationship between the weight and the Ash content of *C. gariepinus* obtained from the wild

Protein Content

The protein content of the fish species ranged from 43.28% - 43.32%. The highest mean value of protein was observed in the fish species with mean standard length of 36.8cm and mean weight of 474g whereas the lowest value was in fish species with mean standard length of 24.5cm and mean weight of 230g. There was no significant different in protein content among the different fish sizes studies (P>0.05) (Table 1, Fig. 4)

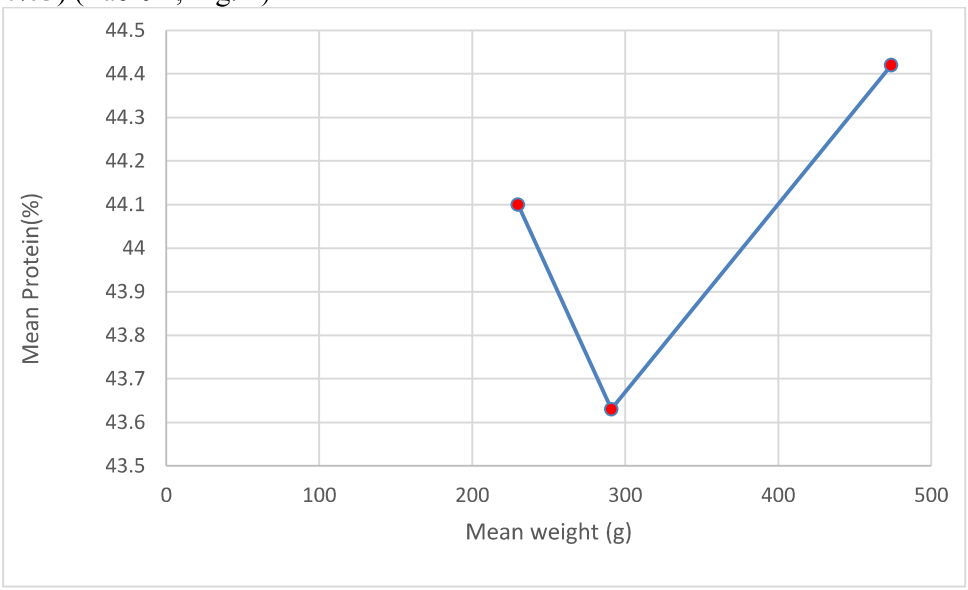

Figure 4. Relationship between the weight and the Protein content of *Clarias gariepinus* obtained from the wild

Fat Content

The highest fat content of 7.80% recorded in the studied *C. gariepinus* species was observed in the fish species with mean standard length of 36.8cm and mean weight of 474g, followed by 7.70% in fish species with mean standard length of 32.3cm and mean weight of 291g and the lowest value of 7.60% was found in fish species with standard length of 24.5cm and weight of 230g. There was no significant difference in ash content amongst the different fish sizes (P>0.05) (Table 1, Fig. 5).

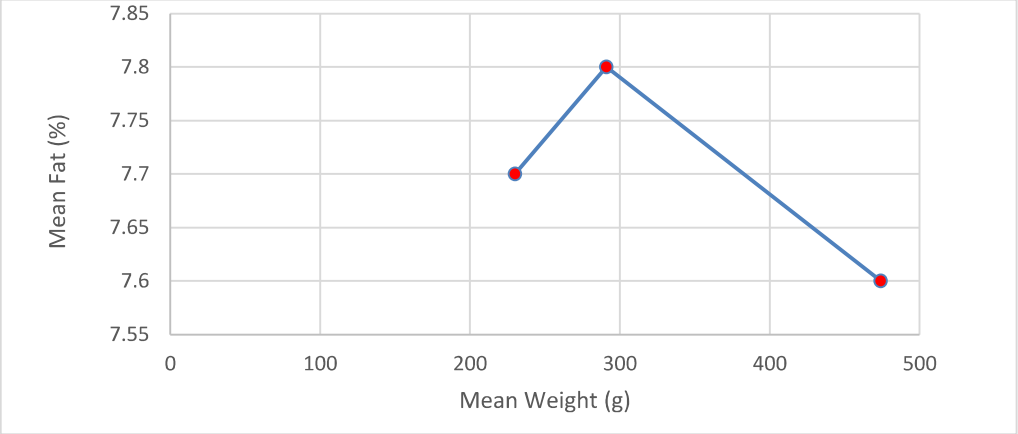

Figure 5. Relationship between the weight and the Fat content of *Clarias gariepinus* obtained from the wild

Crude Fibre Content

The crude fibre content of the fish species ranged from 0.41% - 0.42%. The highest value of crude fibre of 0.42% was observed in the fish species with mean standard length of 36.8cm and mean weight of 474g whereas the lowest value of 0.40% was in fish species with mean standard length of 24.5cm and mean weight of 230g. There was no significant different in Crude fibre content among the different fish sizes studied. (P>0.05) (Table 1, Fig. 6)

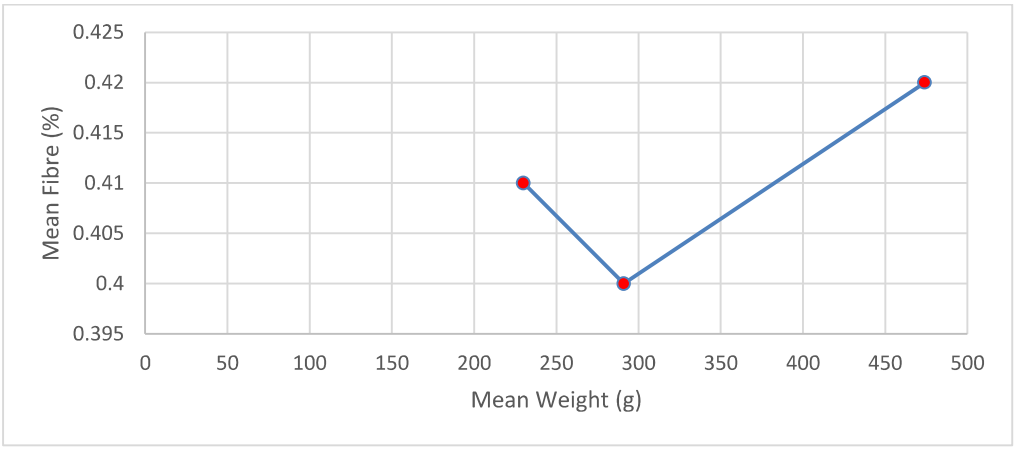

Figure 6. Relationship between the weight and the Fibre content of *Clarias gariepinus* obtained from the wild

Carbohydrate Content

The highest carbohydrate content of 44.63% recorded in the experimental *C. gariepinus* species was observed in the fish with mean standard length of 24.5cm and mean weight of 230g, this was followed by 44.42% in fish species with mean standard length of 32.3cm and mean weight of 291g and the lowest value of 44.10% was found in fish species with mean standard length of 36.8cm and mean weight of 474g. There was no significant different in Carbohydrate content among the different sizes of fish studied. (P>0.05) (Table 1, Fig. 7)

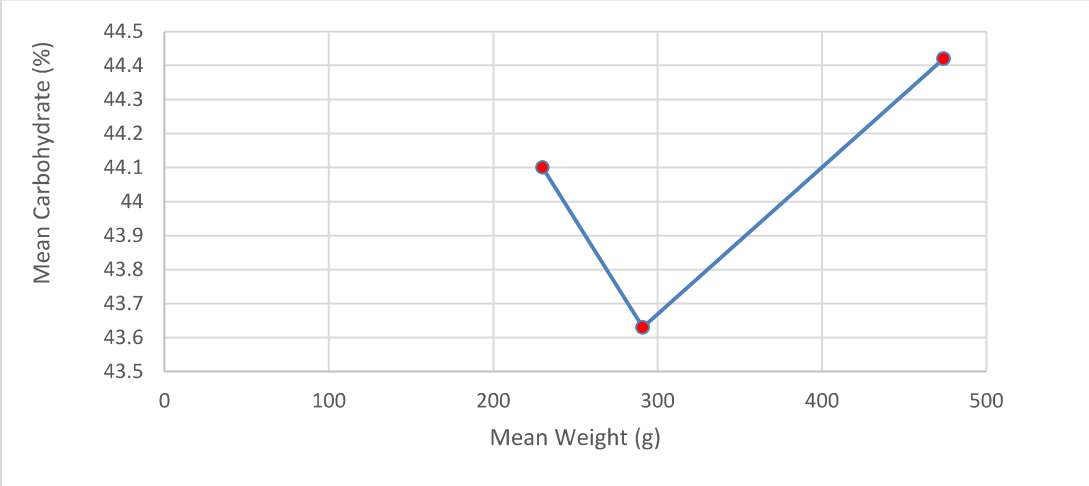

Figure 7: Relationship between the weight and the Carbohydrate content of *Clarias gariepinus* obtained from the wild

Fatty Acid Content and Saponification Value

Fatty acid Content

The fatty acid content of the fish species ranged from 0.14% - 0.16%. The highest value of fatty acid of 0.16% was observed in the fish species with mean standard length of 32.3cm and mean weight of 291g whereas the lowest value of 0.14% was in fish species with mean standard length of 24.5cm and mean weight of 230g. There was no significant different in fatty acid content among the different fish sizes studied. (P>0.05) (Table 2)

Saponification value

The saponification value of the fish species ranged from 197.75g-197.78g. The highest saponification value of 197.78g was observed in the fish species with mean standard length of 32.3cm and mean weight of 291g whereas the lowest value of 197.75KOH/g was in fish species with mean standard length of 36.8cm and mean weight of 474g. There was no significant different in saponification value among the different fish sizes studied. (P>0.05) (Table 2)

TABLE 2: Free fatty acid content and saponification value of *C. gariepinus*

Length (cm)	Mean Weight (g)	Mean Free fatty acid content (%)	Saponification value (mg KOH/g)
36.8	474	0.15	197.75
32.3	291	0.16	197.78
24.5	230	0.14	197.76

Discussion

Biochemical Composition and Fatty Acid Characterization of Wild African Catfish

Moisture Content in Fish Specimens

Moisture is the predominant component in fish muscle tissue, significantly influencing its biochemical properties, texture, and shelf life (Huss, 1995). In the present study, the moisture content of the fish specimens ranged from 93.30% to 93.50%, with the highest value observed in samples measuring 24.5 cm in length and weighing 230 g. This high moisture content is consistent

with findings from previous studies, which have reported similar values in various fish species, particularly those with high water retention capacity (Gallager *et al*., 1991; Love, 1970).

Fish species generally exhibit moisture levels between 65% and 85%, with variations depending on species, habitat, and physiological factors such as growth stage and diet (Aberoumand & Ziaei-Nejad, 2021). However, certain freshwater and marine species, especially those adapted to specific environmental conditions, may exceed these values. For instance, Gallager *et al*. (1991) reported moisture contents exceeding 90% in juvenile fish, which aligns with the present findings. The relatively high moisture content observed in this study may be attributed to the physiological state of the fish, including factors such as age, metabolic rate, and feeding behavior (Love, 1970).

From a nutritional and processing perspective, moisture content plays a crucial role in determining fish quality, post-harvest handling, and susceptibility to microbial spoilage (Huss, 1995). The high water content observed in the analyzed specimens suggests a need for careful preservation strategies to maintain freshness and minimize quality deterioration during storage and transportation (Ghaly *et al*., 2010).

Ash content in Fish Specimens

Ash content represents the total inorganic residue remaining after the complete combustion of organic matter in a food sample. It serves as an indicator of the mineral composition of fish, which is essential for human nutrition (Osibona et al., 2006). In this study, the highest ash content of 4.27% was recorded in *Clarias gariepinus* specimens with a standard length of 36.8 cm and a weight of 474 g. The observed range of ash content suggests that *C. gariepinus* is a reliable source of essential minerals, though variations may occur due to environmental and dietary factors (Adeyeye, 2009).

The ash content values obtained in this study align with previous research on *C. gariepinus*. Osibona et al. (2006) reported similar ash content in African catfish, confirming its potential as a mineral-rich food source. Similarly, Adeyeye (2009) found that freshwater fish species generally exhibit ash content between 3.5% and 5.0%, depending on factors such as diet and habitat conditions.

When compared with other fish species, *C. gariepinus* exhibits moderate ash content. For instance, studies on *Heterobranchus bidorsalis* and *Tilapia zillii* revealed ash contents of 3.8% and 4.5%, respectively, indicating that *C. gariepinus* falls within the expected range for freshwater fish (Jimoh & Fagbenro, 2019). This consistency across studies highlights the reliability of *C. gariepinus* as a mineral-rich species suitable for human consumption.

The variations in ash content observed among different fish sizes may be attributed to factors such as habitat, diet, and age. Fish that inhabit mineral-rich waters tend to have higher ash content due to bioaccumulation of essential elements from their surroundings (Fawole et al., 2007). Additionally, dietary intake plays a significant role in determining mineral levels in fish tissues. Wild *C. gariepinus*, which consume a diverse range of natural prey, may exhibit slightly different ash content compared to farmed catfish, whose diet is often supplemented with formulated feeds (Edward, 2006).

The observed ash content in *C. gariepinus* indicates that it is a valuable source of essential minerals, making it an important component of human nutrition. The findings are consistent with previous studies, reinforcing the significance of *C. gariepinus* as a reliable dietary source of minerals. Further studies could explore the effects of environmental and dietary factors on ash content to provide a more comprehensive understanding of its nutritional potential.

Protein content in Fish Specimens

Protein is an essential macronutrient required for growth, tissue repair, and metabolic functions in both humans and animals. Fish, particularly *Clarias gariepinus*, is widely recognized as a high-protein food source, making it an important dietary component in many regions (Osibona *et al*., 2006).

The protein content of *C. gariepinus* in this study ranged from 43.28% to 43.32%, with the highest value recorded in specimens measuring 36.8 cm in length and 474 g in weight, while the lowest value was found in specimens with a standard length of 24.5 cm and a weight of 230 g (Table 1). This slight variation in protein levels may be influenced by factors such as age, diet, and

environmental conditions (Adebayo-Tayo *et al*., 2012). The relatively high protein content observed is indicative of the species' suitability as a rich protein source, which aligns with previous findings on *C. gariepinus* and other freshwater species (Ime-Ibanga & Fakunle, 2007).

The protein content of *C. gariepinus* observed in this study is consistent with findings in other freshwater fish species. For instance, *Oreochromis niloticus* (Nile tilapia) has been reported to contain protein levels ranging from 40% to 45%, depending on diet and environmental conditions (Adeparusi, 2006). Similarly, *Heterobranchus bidorsalis*, another catfish species, has been documented to have a protein content between 41% and 44%, making it comparable to *C. gariepinus* (Fagbenro et al., 2013).

Several factors contribute to variations in protein levels in fish, including diet, habitat, and metabolic activity. The relatively high protein content in *C. gariepinus* can be attributed to its omnivorous diet, which includes fish items, crustaceans, mollusks, algae, and diatoms. Previous studies have demonstrated that fish with a diet rich in high-protein feed sources tend to exhibit elevated protein levels (Hossain et al., 2018). Furthermore, the protein content of fish may also be influenced by seasonal changes, with fish harvested during peak feeding periods generally exhibiting higher protein concentrations (Olaleye, 2005).

The high protein content of *C. gariepinus* underscores its importance as a valuable food source. Proteins play a crucial role in human health by providing essential amino acids required for muscle development, enzymatic functions, and immune response (WHO, 2020). Additionally, *C. gariepinus* is an excellent alternative to traditional animal protein sources such as beef and poultry, particularly in regions where fish is more accessible and affordable (Adewumi & Olaleye, 2011).

Fat and Fatty Acid Content in *Clarias gariepinus*

In this study, the highest fat content observed in *Clarias gariepinus* was 7.80%, which aligns with previous research indicating that fat deposition in fish is influenced by multiple factors, including species, geographical location, age, diet, and seasonal variations (Piggot & Tucker, 1990; Osman et al., 2001). Variability in lipid content across fish populations is often linked to differences in feeding habits and habitat conditions. Fat accumulation in fish serves critical biological functions, such as energy storage, membrane integrity, and reproductive processes (Tocher, 2015). Moreover, fish are categorized based on their lipid content, with *C. gariepinus* falling into the high-protein, medium-fat category (Onyia et al., 2012), in contrast to *Tilapia zillii*, which is classified as a high-protein, low-fat species (Kleimenov, 1971).

In terms of fatty acid composition, the highest fatty acid content recorded in *C. gariepinus* samples in this study was 0.16%, found in fish with a mean standard length of 32.3 cm and a mean weight of 291 g. Conversely, the lowest fatty acid value (0.14%) was detected in samples with a mean standard length of 24.5 cm and a mean weight of 230 g. This suggests a slight variation in fatty acid accumulation based on fish size, although statistical analysis revealed no significant differences among the different size groups studied. The variability in fatty acid content may be attributed to individual metabolic differences, dietary intake, and growth rates, as fish assimilate and store fatty acids based on their energy demands and physiological needs (Sargent et al., 2002).

The saponification value, which indicates the average molecular weight of fatty acids in the lipid fraction, followed a similar pattern. The highest saponification value (197.78 KOH/g) was recorded in specimens measuring 32.3 cm in length and 291 g in weight, while the lowest value (197.75 KOH/g) was observed in larger fish specimens (36.8 cm, 474 g). These values are in agreement with previous studies on the lipid properties of *C. gariepinus* and other freshwater fish species (Chioma *et al*., 2012; Osibona *et al*., 2006). Saponification values provide insights into lipid stability and quality, influencing the suitability of fish oil for industrial applications such as biodiesel production and food processing (Borlongan, 1992).

Fish lipid content and composition are essential for both ecological and nutritional reasons. Polyunsaturated fatty acids (PUFAs), particularly omega-3 and omega-6 fatty acids, play a significant role in human health, reducing cardiovascular risks and improving cognitive functions

(Calder, 2017). The lipid profile of *C. gariepinus* suggests its potential as a valuable dietary source of essential fatty acids, making it an important species for aquaculture and food security.

Crude fiber in Fish Specimens

In fish, crude fiber is not a major component of muscle tissue. Instead, it is primarily associated with plant-based feed ingredients consumed by the fish. The presence of crude fiber in fish muscle is minimal, as fish do not have a significant capacity to digest and assimilate fibrous plant materials. Therefore, the crude fiber content in fish muscle is generally low and often considered negligible.

The reported crude fiber content in *Clarias gariepinus* across different size groups ranges from 0.40% to 0.42%, with the highest value observed in fish measuring 36.8 cm in standard length and weighing 474 g, and the lowest in fish measuring 24.5 cm and weighing 230 g. The lack of significant differences ($P>0.05$) among the various sizes suggests that fish size does not substantially influence crude fiber content.

The observed crude fiber content in this study aligns with findings from other research. For instance, a study on *Clarias gariepinus* reported crude fiber contents of 1.50% to 3.50% in different commercial feeds, reflecting the fiber content of the diets rather than the fish muscle itself (Oluwatosin *et al*., 2023). Another study examining the proximate composition of *Clarias gariepinus* from cultured and wild sources found that crude fiber content in the muscle tissue was negligible, emphasizing that fiber is not a significant component of fish muscle (Obaroh, *et al*., 2015).

The minimal variation in crude fiber content among different sizes of *Clarias gariepinus* may be attributed to uniform feeding practices and the species' limited ability to metabolize fiber. Fish primarily utilize proteins and lipids for energy, and their digestive systems are not well-adapted to process high-fiber diets. Consequently, the crude fiber content in fish muscle remains consistently low, regardless of the fish's size or growth stage. The study's findings of crude fiber content ranging from 0.40% to 0.42% in *Clarias gariepinus* are consistent with the understanding that fish muscle tissue contains minimal fiber. The lack of significant variation across different fish sizes further supports the notion that crude fiber is not a major constituent of fish muscle and is largely influenced by dietary intake rather than intrinsic factors.

Carbohydrate content in Fish Specimens

The reported carbohydrate content in *Clarias gariepinus* across different size groups, ranging from 44.10% to 44.63%, is notably high compared to typical values observed in fish muscle tissues. Fish generally store minimal carbohydrates, primarily in the form of glycogen, with muscle carbohydrate content usually constituting less than 1% of their composition. For instance, the Food and Agriculture Organization (FAO) notes that dietary carbohydrate content for *C. gariepinus* larvae and early juveniles can be as high as 21%, but this refers to their diet, not muscle composition (FAO 2013)

The minimal variation in carbohydrate content among the different size groups, coupled with the lack of statistical significance ($P>0.05$), suggests that fish size does not substantially influence carbohydrate accumulation in *C. gariepinus*. This aligns with general fish physiology, where proteins and lipids serve as the primary energy reserves, and carbohydrates play a limited role.

The unusually high carbohydrate values reported in this study may result from methodological factors, such as the calculation method used. In some studies, carbohydrate content is determined by difference, subtracting the sum of moisture, protein, lipid, and ash content from 100% (Mohammed *et al*., 2023). If there are inaccuracies in measuring these components, it could lead to an overestimation of carbohydrate content.

Environmental and dietary factors can also influence the biochemical composition of fish (Arati *et al*., 2021). Fish exposed to certain environmental conditions or diets may exhibit variations in muscle composition, including carbohydrate levels. For example, studies have shown that dietary carbohydrate levels can affect growth performance and body composition in fish (Han *et al.,* 2025). However, such high carbohydrate levels in muscle tissue as reported in this study are uncommon and warrant further investigation. The high carbohydrate content observed in *C. gariepinus* in this study

is atypical for fish muscle tissue as reported by Job *et al*., (2015). This anomaly underscores the need for further research to verify these findings and explore the underlying causes, considering factors such as methodological approaches, environmental conditions, and dietary influences.

Nutritional Profile and Health Benefits

The study's findings on the proximate composition and fatty acid profile of *Clarias gariepinus* have significant implications for human nutrition, particularly in regions where this species is a dietary staple.

Recent studies have explored the health benefits associated with consuming *C. gariepinus*. For instance, supplementation with catfish oil enriched with omega-3 fatty acids has been shown to improve oxidative stress markers and cognitive function in the elderly (Atmadja *et al*., 2020). This suggests that regular consumption of *C. gariepinus* could confer similar benefits, potentially aiding in the prevention of cognitive decline and related disorders.

The high protein content observed in *C. gariepinus* (ranging from 43.28% to 43.32%) underscores its value as a substantial protein source, essential for muscle development, immune function, and overall health. This aligns with previous studies highlighting the species' high protein and moderate fat content, categorizing it as high-protein, medium-fat fish (Abdel- Mobdy, *et al.,* 2021).

The lipid profile of *C. gariepinus* is particularly noteworthy due to its composition of essential fatty acids. Notably, oleic acid, a monounsaturated fat linked to cardiovascular health benefits, constitutes a significant portion of its fatty acid content (Abdel- Mobdy, *et al.,* 2021). Additionally, the presence of omega-3 and omega-6 fatty acids, such as linoleic and alpha-linolenic acids, contributes to anti-inflammatory properties and supports cognitive function (Mustapha et al., 2014).

Furthermore, the mineral content of *C. gariepinus*, including calcium, phosphorus, and iron, enhances its nutritional value, contributing to bone health, oxygen transport, and enzymatic processes (Abdel- Mobdy, *et al.,* 2021). The ash content observed in the study indicates a rich mineral profile, reinforcing the fish's role as a valuable dietary component.

Conclusion

The consumption of *Clarias gariepinus* offers substantial nutritional benefits, including high-quality protein, essential fatty acids, and vital minerals, making it a valuable component of a balanced diet. As a species widely cultivated in tropical freshwater ecosystems, *C. gariepinus* plays a significant role in tropical ecology by contributing to food security, local livelihoods, and sustainable aquaculture practices. Its adaptability to diverse environmental conditions and efficient feed conversion make it an ecologically viable species within tropical aquaculture systems. Incorporating *C. gariepinus* into the diet offers multiple health benefits, supporting cardiovascular health, cognitive function, and overall nutritional well-being. Comprehensive nutritional assessments continue to highlight its value in addressing micronutrient deficiencies prevalent in tropical regions.

Recommendations

Ongoing research into its nutrient composition, bioavailability, and health effects will further elucidate its role in improving dietary quality and public health outcomes, particularly in ecologically sensitive and nutritionally vulnerable tropical areas.

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