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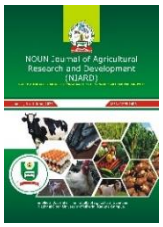

Original Article

Proximate profile of Smoked *Clarias gariepinus* from different vendors in Eke Market, Afikpo, Ebonyi State

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Abstract
This study evaluated the proximate composition of smoked Clarias gariepinus obtained from three independent fish vendors (FT1, FT2 and FT3) at Eke Market Afikpo, Ebonyi State to determine variations in nutritional composition. Five independently sampled fish were collected from each vendor (n = 5) and analysed in technical triplicate using standard AOAC (2016) procedures for moisture, crude protein, crude fat, crude ash, crude fibre and carbohydrate (nitrogen-free extract). Triplicate measurements were averaged for each fish before statistical analysis. Data were subjected to one-way analysis of variance (ANOVA), with significant means separated using Tukey's HSD test at $p < 0.05$. *Significant differences* ($p < 0.05$) *were observed in the proximate composition of fish among vendors. Crude protein ranged from 42.48 ± 0.25% in FT2 to 56.08 ± 0.61% in FT1, while moisture content ranged from 4.72 ± 0.42% in FT3 to 8.81 ± 0.26% in FT2. Ash, crude fibre, crude fat and carbohydrate contents ranged from 3.68–5.90%, 3.67–5.37%, 2.58–3.03% and 26.02–36.11%, respectively. The findings demonstrate that the proximate composition of smoked* C. gariepinus *varies among vendors at Eke Market. Although differences in processing and storage practices may contribute to these variations, they were not investigated in this study. Standardized processing practices are therefore recommended to improve product consistency. Further research involving multiple sampling periods and additional quality parameters is warranted.*

Keywords: *African catfish, smoke fish, market survey, vendor variation, proximate composition*

INTRODUCTION

Fish and fishery products are important sources of animal protein and essential nutrients, contributing about 17–20% of the global intake of animal protein while supplying omega-3 fatty acids, vitamins, and minerals that support human nutrition (FAO, 2020). In Nigeria, fish is one of the most affordable and widely consumed sources of dietary protein, contributing more to protein intake than many other animal products (FAO, 2020).

The African catfish, *Clarias gariepinus*, is one of the most commercially important freshwater fish species in Nigeria because of its rapid growth, efficient feed conversion, adaptability to different production systems, tolerance to environmental stress, and high consumer acceptance (Odeyemi *et al*., 2024). However, fresh fish is highly perishable because of its high moisture content, neutral

pH, and rapid microbial and enzymatic activities, making preservation necessary to reduce post-harvest losses (Eyo, 2010).

Smoking is the most widely used traditional fish preservation method in Nigeria because it reduces moisture content, inhibits microbial growth, improves flavour, extends shelf life, and enhances market value through the formation of antimicrobial compounds such as phenols and organic acids (Oyeniyi *et al*., 2024). The smoking process also produces physicochemical changes that influence the proximate composition of fish, including changes in moisture, protein, lipid, and mineral contents. Proximate composition analysis, which determines moisture, crude protein, crude fat, ash, crude fibre, and carbohydrate contents, is therefore widely used to evaluate the nutritional quality of smoked fish (AOAC, 2016). Previous studies have reported that smoked *C. gariepinus* generally contains lower moisture and higher protein concentrations than fresh fish, although the extent of these changes depends on processing conditions under controlled experimental settings (Odeyemi *et al*., 2024; Oyeniyi *et al*., 2024; Okwuosa *et al*., 2024; Oyekanmi *et al*., 2024).

Despite these findings, limited information is available on the proximate composition of smoked *C. gariepinus* purchased from different vendors within the same retail market. Because the processing history of commercially available smoked fish is generally unknown, differences in proximate composition among vendors cannot be directly attributed to specific smoking methods or storage practices without supporting processing data. Nevertheless, comparing products from different vendors can provide baseline information on the degree of variation in nutritional composition available to consumers.

Eke Market was selected because it is one of the major fish marketing centres in the study area, where smoked *C. gariepinus* from multiple processors is sold through numerous independent vendors. Three vendors located in different sections of the market were selected to provide independent retail samples that represent the variation in smoked catfish available to consumers within Eke Market. The findings are therefore intended to describe the proximate composition of smoked *C. gariepinus* sold in this market rather than to represent all smoked fish markets in Nigeria.

The objective of this study was to compare the dry-basis proximate composition of smoked *C. gariepinus* sampled independently from three selected vendors in Eke Market. It was hypothesized that significant differences would exist in the proximate composition of smoked *C. gariepinus* among the selected vendors.

MATERIALS AND METHODS

Study Area

The primary materials used in this study included smoked *C. gariepinus* samples purchased from three independent vendors located at different sections of Eke Market. The samples were coded as FT1, FT2, and FT3 to represent the respective vendors. The vendors were selected to obtain independent retail samples for comparison of their proximate composition.

Laboratory chemicals and reagents used for the proximate analysis included concentrated sulfuric acid (H_2SO_4) for crude protein determination, petroleum ether for crude fat extraction, and other analytical-grade reagents required for the determination of moisture, ash, crude fibre, and carbohydrate contents following standard analytical procedures.

The laboratory equipment used included a digital analytical balance (±0.001 g accuracy), a hot air oven for moisture determination, a muffle furnace for ash determination, a Soxhlet extraction apparatus for crude fat analysis, a Kjeldahl digestion and distillation unit for crude protein determination, oven-dried crucibles, and desiccators for sample cooling and storage before weighing.

Materials

The primary materials used in this study included: Smoked *Clarias gariepinus* samples was purchased from three different locations within Eke Market (coded as FT1,

FT2, and FT3). Each location represents independent vendors with potentially different smoking techniques. Laboratory chemicals and reagents used for the analysis of nutritional qualities including: Sulfuric acid (H_2SO_4) for protein determination, petroleum ether for fat extraction, oven-dried crucibles for ash determination, reagents for moisture, fiber, and carbohydrate calculations. Laboratory equipment used include digital analytical balance (±0.001 g accuracy), hot air oven for moisture determination, muffle furnace for ash determination, soxhlet apparatus for lipid extraction, Kjeldahl digestion and distillation setup for crude protein analysis and desiccators for sample drying and storage.

Sample Collection

A total of 15 smoked *Clarias gariepinus* samples were purchased once from three independent vendors located in different sections of Eke Market, with five fish obtained from each vendor. The vendors were coded as FT1, FT2, and FT3. Fish of similar market size (250–350 g) were selected to minimize variation in proximate composition associated with size (Odeyemi *et al*., 2024; Okwuosa *et al*., 2024). Following purchase, the samples were transported to the laboratory in clean polyethylene bags placed inside insulated containers and analysed within 24 hours of collection. Until analysis, the samples were stored at controlled setting of 3°C to 4°C of the laboratory storage refrigerator.

Sample Preparation

Only the edible muscle portion of each smoked fish was used for proximate analysis. The muscle tissue was carefully separated from non-edible parts, cut into small pieces, and homogenized using a clean stainless-steel blender to obtain representative samples. The smoked fish were analyzed as purchased and were not washed before sample preparation to avoid changes in moisture content or loss of soluble constituents. Since the samples were obtained as finished retail products, information on the processing history, including whether gutting occurred before or after smoking, was not available.

Laboratory Analysis

Proximate composition analyses were carried out on the homogenized edible muscle of smoked *Clarias gariepinus* following the standard methods of the Association of Official Analytical Chemists (AOAC, 2016). All analytical determinations were performed in triplicate for each independent sample, and the triplicate values were averaged before statistical analysis. Results are expressed on a dry-weight basis (g/100 g dry matter).

Moisture Content

Moisture content was determined according to AOAC Method 925.10. Approximately 5 g of the homogenized sample was weighed into a pre-dried moisture dish and dried in a hot-air oven at 105°C to constant weight. Moisture content was calculated from the loss in weight after drying.

Moisture content (%) was calculated using:

$$\text{Moisture \%} = \frac{\text{Initial weight} - \text{Dry weight}}{\text{Initial weight}} \times 100$$

Crude Protein

Crude protein was determined using the Kjeldahl method (AOAC Method 2001.11). Approximately 1 g of the sample was digested with concentrated sulfuric acid in the presence of a catalyst mixture until a clear digest was obtained. The digest was distilled after neutralization with sodium hydroxide, and the liberated ammonia was collected in boric acid and titrated with standard hydrochloric acid. Nitrogen content was converted to crude protein using a conversion factor of 6.25. Crude Protein % = Nitrogen % x 6.25

Crude Fat

Crude fat was determined by Soxhlet extraction (AOAC Method 920.39). Approximately 2 g of the dried sample was extracted with petroleum ether for 6 hours, after which the solvent was evaporated and the extracted lipid was determined gravimetrically. The extracted fat was weighed, and percentage calculated as:

$$\text{Crude Fat \%} = \frac{\text{Weight of extracted fat}}{\text{Weight of sample}} \times 100$$

Crude Ash

Ash content was determined according to AOAC Method 923.03 by incinerating approximately 2 g of the sample in a muffle furnace at 550°C until a constant weight of light grey ash was obtained. Ash (%) was calculated as:

$$\text{Ash \%} = \frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$$

Crude Fibre

Crude fibre was determined using AOAC Method 978.10. Approximately 2 g of the defatted sample was subjected to sequential acid and alkaline digestion, after which the residue was dried, weighed, ashed, and reweighed to determine crude fibre content. Because fish muscle contains negligible dietary fibre, the values obtained represent crude fibre only and should not be interpreted as dietary fibre. Residual fibre content after sequential acid and alkaline treatment was dried, ashed, and calculated as:

$$\text{Crude Fiber \%} = \frac{\text{Weight before ashing} - \text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Carbohydrate

Carbohydrate was estimated as nitrogen-free extract (carbohydrate by difference) using the equation:

Carbohydrate (%) = 100 − [Moisture (%) + Crude Protein (%) + Crude Fat (%) + Ash (%) + Crude Fibre (%)]

All analyses were performed in triplicate to ensure accuracy and reproducibility.

Statistical Analysis

Statistical analyses were performed using GraphPad Prism version 8.0.2 (GraphPad Software, San Diego, CA, USA). For each independent fish sample, the technical triplicate measurements were averaged to obtain a single value before statistical analysis; therefore, only independent biological samples (n = 15 per vendor) were used for statistical comparisons.

Descriptive statistics were expressed as mean ± standard deviation (SD). Differences in the proximate composition of smoked *Clarias gariepinus* among the three vendors (FT1, FT2, and FT3) were evaluated using one-way analysis of variance (ANOVA). Prior to ANOVA, the assumptions of normality and homogeneity of variance were assessed using the Shapiro–Wilk and Brown–Forsythe tests, respectively. No missing data were recorded, and no outliers were excluded from the analysis.

Where a significant overall effect was detected, Tukey's multiple comparison test was used for pairwise comparisons. Different superscript letters assigned to treatment means indicate statistically significant differences between vendors at $p < 0.05$. The Tukey groupings reported in the results were verified directly from the post hoc analysis.

For each ANOVA, the F-statistic, degrees of freedom, exact p-values, 95% confidence intervals, and effect size (η^2) were reported to facilitate interpretation of the magnitude and significance of differences among vendors. Statistical significance was accepted at $p < 0.05$.

The individual fish constituted the experimental units for all statistical analyses. The complete fish-level dataset, together with the calculation worksheets used to generate the reported results, is available from the corresponding author upon reasonable request.

Ethical Considerations

The study involved only commercially sold smoked fish and did not include live animals or human subjects. Ethical handling included proper disposal of waste material and adherence to laboratory safety protocols.

Results

Table 1. Individual proximate composition (%) of smoked *Clarias gariepinus* obtained from three independent vendors in Eke Market (dry-weight basis)

Parameter (%)	Vendor	Fish 1	Fish 2	Fish 3	Fish 4	Fish 5	Mean	p-value
Crude protein	FT1	55.8	56.9	56.1	55.7	55.9	**56.08^{a}**	0.026
	FT2	42.1	42.6	42.7	42.2	42.8	**42.48^{b}**	
	FT3	53.8	54.0	53.7	54.2	53.8	**53.90^{a}**	
Moisture	FT1	5.59	5.94	5.38	5.67	5.88	**5.69^{b}**	0.001
	FT2	8.69	9.01	8.73	8.86	8.75	**8.81^{a}**	
	FT3	4.55	4.78	4.88	4.67	4.71	**4.72^{b}**	
Ash	FT1	4.08	4.04	4.01	4.05	3.96	**4.03^{b}**	0.001
	FT2	5.94	5.99	5.91	5.75	5.89	**5.90^{a}**	
	FT3	3.69	3.66	3.83	3.58	3.63	**3.68^{c}**	
Crude fibre	FT1	5.43	4.97	5.61	5.58	5.26	**5.37^{a}**	0.001
	FT2	3.57	3.68	3.38	3.93	3.79	**3.67^{c}**	
	FT3	4.72	4.85	4.92	5.01	4.90	**4.88^{b}**	
Crude fat	FT1	2.86	2.85	2.83	2.87	2.69	**2.82^{ab}**	0.012
	FT2	3.01	3.08	3.02	3.04	2.99	**3.03^{a}**	
	FT3	2.52	2.68	2.45	2.79	2.47	**2.58^{b}**	
Carbohydrate (nitrogen-free extract)	FT1	26.12	25.69	26.19	26.08	26.01	**26.02^{c}**	0.009
	FT2	36.13	35.89	36.40	36.17	35.94	**36.11^{a}**	
	FT3	30.86	30.04	30.08	29.98	30.23	**30.24^{b}**	

Values represent individual fish samples (n = 5) collected independently from each vendor. The mean for each vendor is shown for reference. Each fish sample was analysed in technical triplicate, and the triplicate measurements were averaged to obtain one value per fish before statistical analysis. Different superscript letters (a–c) within the same parameter indicate significant differences among vendors according to Tukey's honestly significant difference (HSD) test following one-way ANOVA ($p < 0.05$). Carbohydrate was calculated by difference and is reported as nitrogen-free extract.

Proximate composition of smoked *Clarias gariepinus*

The proximate composition of smoked *Clarias gariepinus* obtained from three independent vendors (FT1, FT2, and FT3) in Eke Market is presented in Table 2. Significant differences were observed among the vendors for all proximate parameters evaluated ($p < 0.05$).

Crude Protein

Crude protein content differed significantly among the three vendors ($p = 0.036$). The highest mean crude protein content was recorded in FT1 (56.08 ± 0.61%), followed closely by FT3 (53.90 ± 0.19%). FT2 had the lowest protein content (42.48 ± 0.25%). Based on Tukey's post hoc test, FT1 and FT3 did not differ significantly from each other but both recorded significantly higher protein contents than FT2.

Moisture Content

Moisture content varied significantly among the vendors ($p < 0.001$). FT2 recorded the highest moisture content (8.81 ± 0.26%), whereas FT3 had the lowest value (4.72 ± 0.42%). FT1 had a moisture content of 5.69 ± 0.33%. Statistical comparison showed that FT2 differed significantly from FT1 and FT3,

while FT1 and FT3 were not significantly different.

Table 2. Proximate composition of smoked *Clarias gariepinus* obtained from three independent vendors in Eke Market (dry-weight basis).

Parameter (%)	FT1 (n = 5)	FT2 (n = 5)	FT3 (n = 5)	*p*-value
Crude protein	56.08 ± 0.61^{a}	42.48 ± 0.25^{b}	53.90 ± 0.19^{a}	0.026
Moisture	5.69 ± 0.33^{b}	8.81 ± 0.26^{a}	4.72 ± 0.42^{b}	0.001
Ash	4.03 ± 0.81^{b}	5.90 ± 0.90^{a}	3.68 ± 0.52^{c}	0.001
Crude fibre	5.37 ± 0.14^{a}	3.67 ± 0.31^{c}	4.88 ± 0.14^{b}	0.001
Crude fat	2.82 ± 0.78^{ab}	3.03 ± 0.53^{a}	2.58 ± 0.62^{b}	0.012
Carbohydrate (nitrogen-free extract)	26.02 ± 0.64^{c}	36.11 ± 0.41^{a}	30.24 ± 0.37^{b}	0.009

Values are presented as mean ± standard deviation (SD) on a dry-weight basis for five independent fish samples obtained from each vendor (n = 5). Each fish sample was analysed in technical triplicate, and the triplicate measurements were averaged to obtain one value per fish before statistical analysis. Means within the same row bearing different superscript letters (a–c) differ significantly according to Tukey's honestly significant difference (HSD) test following one-way ANOVA ($p < 0.05$). Carbohydrate was calculated by difference and is reported as nitrogen-free extract.

Ash Content

Ash content also differed significantly among the sampled vendors ($p < 0.001$). FT2 recorded the highest ash content (5.90 ± 0.90%), followed by FT1 (4.03 ± 0.81%), while FT3 had the lowest value (3.68 ± 0.52%). Each vendor formed a distinct statistical group according to Tukey's multiple comparison test.

Crude Fibre

Significant differences were observed in crude fibre content among the three vendors ($p < 0.001$). FT1 recorded the highest crude fibre content (5.37 ± 0.14%), followed by FT3 (4.88 ± 0.14%), whereas FT2 had the lowest value (3.67 ± 0.31%). All three vendors differed significantly from one another.

Crude Fat

Crude fat content ranged from 2.58% to 3.03% and differed significantly among the vendors ($p = 0.012$). FT2 recorded the highest mean crude fat content (3.03 ± 0.53%), FT1 had an intermediate value (2.82 ± 0.78%), and FT3 recorded the lowest value (2.58 ± 0.62%). According to Tukey's test, FT1 was not significantly different from FT2 but differed from FT3.

Carbohydrate

Carbohydrate, expressed as nitrogen-free extract and calculated by difference, showed significant variation among the vendors ($p = 0.029$). FT2 had the highest carbohydrate content (36.11 ± 0.41%), followed by FT3 (30.24 ± 0.37%), while FT1 recorded the lowest value (26.02 ± 0.64%). The differences among the three vendors were statistically significant.

Discussion

The present study demonstrated significant differences in the proximate composition of smoked *Clarias gariepinus* obtained from three independent vendors in Eke Market, Afikpo, Ebonyi State. Although all samples were collected from the same market, significant variation was observed in crude protein, moisture, ash, crude fibre, crude fat, and carbohydrate contents. These findings indicate that smoked catfish sold within the same retail market may differ in nutritional composition, thereby providing consumers with products of varying nutritional quality. Similar variability in the proximate

composition of smoked *Clarias gariepinus* has been reported in previous Nigerian studies, highlighting the influence of processing and post-processing practices on the nutritional characteristics of smoked fish (Eyo, 2010; Odeyemi *et al*., 2024; Oyekanmi *et al*., 2024).

Crude protein was the predominant nutrient in all samples, ranging from 42.48% in FT2 to 56.08% in FT1 on a dry-weight basis. These values demonstrate that smoked *C. gariepinus* remains an excellent source of high-quality protein even after processing. The protein concentrations observed in the present study are comparable with values reported for dried and smoked African catfish in Nigeria. For example, Odeyemi et al. (2024) reported crude protein values ranging from approximately 43–47% in smoked *C. gariepinus*, while Uahomo (2023) observed increased protein concentrations following drying treatments due to moisture reduction. Likewise, Oyeniyi *et al*. (2024) reported that longer smoking duration resulted in increased protein concentration because of progressive dehydration of the fish muscle. These similarities suggest that the protein contents obtained in the present study are consistent with previous reports on processed African catfish (Odeyemi *et al*., 2024; Oyeniyi *et al*., 2024; Uahomo, 2023).

Moisture content varied significantly among the three vendors, ranging from 4.72% to 8.81%. These values are substantially lower than those reported for fresh *Clarias gariepinus*, reflecting the effectiveness of smoking as a dehydration process. Low moisture content is desirable because it reduces water available for biochemical reactions and improves the keeping quality of smoked fish during storage (Eyo, 2010; FAO, 2020). Comparable moisture levels have been reported for smoked African catfish processed under different smoking regimes in Nigeria (Oyeniyi *et al*., 2024; Uahomo, 2023).

An inverse relationship was observed between moisture and crude protein contents, with samples containing lower moisture generally exhibiting higher protein concentrations. Because the present study evaluated fish purchased from retail vendors, the specific processing history of each sample was unknown. Consequently, this relationship should be interpreted as an association rather than direct evidence of differences in smoking conditions. Nevertheless, previous studies have consistently shown that dehydration during smoking concentrates dry matter, thereby increasing the relative proportion of protein in smoked fish (Odeyemi *et al*., 2024; Oyeniyi *et al*., 2024; Oyekanmi *et al*., 2024).

Ash content ranged from 3.68% to 5.90%, indicating appreciable mineral residue in all samples. Similar ash values have been reported in smoked *Clarias gariepinus* from Nigeria, suggesting that smoking generally preserves the mineral fraction of fish tissue despite reducing moisture content (Oyekanmi *et al*., 2024; Odeyemi *et al*., 2024). Since ash represents total inorganic residue, it provides only an estimate of mineral content and does not identify individual minerals such as calcium, phosphorus, potassium or iron. Determination of individual mineral concentrations would require additional elemental analyses beyond the scope of the present study (AOAC, 2016; Oyekanmi *et al*., 2024).

Crude fat values were relatively low, ranging from 2.58% to 3.03%, confirming that *Clarias gariepinus* remains a relatively lean fish species after smoking. These findings agree with those of Oyekanmi *et al*. (2024) and Olaniyi *et al*. (2024), who reported low lipid contents in smoked African catfish produced using different processing methods. Although fat contributes to the sensory quality and energy value of fish, the relatively low lipid content observed in this study suggests that smoked *C. gariepinus* may be suitable for consumers seeking protein-rich foods with moderate fat content (Oyekanmi *et al*., 2024; Olaniyi *et al*., 2024).

Crude fibre values ranged from 3.67% to 5.37%. Fish muscle is not regarded as a source of dietary fibre; therefore, the crude fibre values obtained using the AOAC procedure should not be interpreted as physiological dietary fibre. Rather, this analytical fraction may include insoluble

residues originating from connective tissues, collagen, skin fragments or other materials that remain after acid and alkali digestion. Consequently, the crude fibre values reported in this study should be interpreted with caution and viewed primarily as analytical residues rather than nutritionally available fibre (AOAC, 2016).

Carbohydrate, estimated as nitrogen-free extract by difference, ranged from 26.02% to 36.11%. Since carbohydrate was calculated rather than measured directly, the values reflect the combined analytical variation associated with moisture, protein, fat, ash and crude fibre determinations. Similar approaches have been adopted in previous proximate studies of smoked fish (AOAC, 2016; Oyekanmi *et al*., 2024). Therefore, carbohydrate values should be interpreted cautiously because they represent calculated rather than experimentally measured quantities.

Overall, the findings demonstrate that smoked *Clarias gariepinus* marketed in Eke Market is nutritionally valuable, particularly because of its high protein content and relatively low moisture content. However, measurable differences in proximate composition were observed among the three vendors, indicating that products sold within the same market are not nutritionally identical. Because the processing histories of the purchased fish were not documented, the present study cannot identify the specific factors responsible for these differences. Nevertheless, the results provide useful baseline information on the nutritional composition of smoked *C. gariepinus* available in a major local market and contribute to the growing body of evidence on the quality of traditionally processed fish in Nigeria. Future studies incorporating documented smoking conditions, storage history and mineral analyses would further improve understanding of the factors influencing the nutritional quality of smoked catfish (FAO, 2020; Eyo, 2010; Odeyemi *et al*., 2024; Oyekanmi *et al*., 2024).

Conclusion

The study revealed significant variations in the proximate composition of smoked *C. gariepinus* obtained from different vendors in Eke Market, Afikpo, Ebonyi State. Despite these differences, the fish samples generally recorded high protein and low moisture contents, confirming smoked *C. gariepinus* as a nutritious and relatively stable source of food. The variations observed may be related to differences in processing, handling, and storage practices among vendors. Overall, the findings highlight the nutritional value of smoked catfish and the need for proper processing and storage practices to maintain its quality and nutritional consistency.

Contribution: All aspect of the work was carried out by the authors. All authors contributed to the benchwork and manuscript writing. OBO designed the work, ACO and EEL participated in all other aspects of the work.

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