Nutritional Variation in Five Indigenous Fish Species Processed with Traditional, Improved, and Institutional Kiln Technologies in Northern Nigeria

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Abstract
Fish constitutes a vital source of animal protein and essential nutrients for many households in Northern Nigeria, where traditional smoking remains a dominant preservation method despite its limitations in retaining nutritional quality. This study investigated the effects of three smoking kiln technologies—traditional market kiln, modified drum kiln, and institutional FUTY kiln—on the proximate composition of five native freshwater fish species: Bagrus bayad, Clarias gariepinus, Heterotis niloticus, Mormyrus rume, and Oreochromis niloticus. A total of 150 fish samples (30 per species) were smoked and analyzed for crude protein, lipid, ash, moisture, fibre, and dry matter contents using standard AOAC procedures. Results showed that the modified drum kiln consistently preserved the highest protein values, with Heterotis niloticus reaching 61.72%, compared to 50.12% and 57.00% in market and FUTY smoked samples respectively. Moisture content was lowest in samples smoked using the modified kiln (as low as 3.33%) and highest in FUTY samples (up to 27.41%). Lipid content peaked in Heterotis niloticus smoked with the FUTY kiln (11.20%), while ash content varied slightly across all treatments. The study concludes that the modified drum kiln offers superior drying efficiency and nutrient preservation, particularly for protein and moisture, while the FUTY kiln retained more lipids in some species. The findings underscore the importance of kiln type in post-harvest fish processing and recommend the widespread adoption of improved smoking technologies to enhance nutritional quality and shelf life.

Key words;
Fish smoking, proximate composition, modified drum kiln, FUTY kiln, nutritional quality.

Introduction

Fish is a major contributor to dietary protein in Nigeria, supplying approximately 35–40% of the nation's total animal protein intake (FAO, 2020). Its role is particularly significant among rural and low-income populations, where it serves as an affordable source of high-quality protein, essential fatty acids, vitamins, and minerals (Adewumi & Olaleye, 2011). In some rural areas, fish contributes over 40% of total protein intake, making it a cornerstone of household food and nutrition security (Béné et al., 2015). However, due to the highly perishable nature of fish and the lack of reliable cold chain infrastructure, post-harvest losses remain a significant problem in the region.

Smoked fish are usually exposed to smoke particles that contain potential carcinogens such as polycyclic aromatic hydrocarbons (PAHs) (Olaoye et al., 2015). Guillen et al. (1997) reported that fish smoked by traditional techniques usually contain high concentrations of PAHs resulting from the source of fuel used in their preparation.

To mitigate spoilage and extend the shelf life of fish, traditional smoking remains the most widely used preservation technique in many parts of Nigeria and sub-Saharan Africa. However, this method often exposes fish to uncontrolled heat and smoke, which can lead to inconsistent product quality, loss of heat-sensitive nutrients, and the formation of polycyclic aromatic hydrocarbons (PAHs)—a

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group of compounds known for their carcinogenic and mutagenic properties (FAO, 2016)

Furthermore, a study stated the extent of fish damage depends on the processing techniques, the type of fish being processed, (Eyo, 1993 & Ayeloja et al., 2013). Similarly, Fawole et al. (2016) reported that improved smoking methods significantly reduced microbial load and PAH contamination in smoked fish.

Despite these promising findings, there is still limited comprehensive data on how different smoking technologies influence the nutritional composition across a variety of native fish species in Northern Nigeria. Fish such as Heterotis niloticus, Clarias gariepinus, Bagrus bayad, Tilapia zillii, and Synodontis nigrita are widely consumed in the region, yet their nutritional response to different smoking systems remains under-explored.

This study therefore aims to assess the nutritional variation in five native freshwater fish species smoked using traditional, improved, and institutional kiln technologies in Northern Nigeria. The central research question is: To what extent does the type of smoking kiln influence the proximate and micronutrient composition of smoked fish? It is hypothesized that fish smoked using improved and institutional kilns will retain higher levels of essential nutrients than those smoked traditionally.

Materials and Method

Study Location and Design

This study was carried out at Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria, which lies between latitudes 9°20′00″ and 9°21′30″ N and longitudes 12°29′00″ E and 12°30′30″ E (GIS, 2015). Modibbo Adama University of Technology, Yola is located within Girei Local Government Area of Adamawa State and falls within the Sudan savannah vegetation zone. The Local Government Area has a population of 129,855 people (NPC, 2006) and a total land mass of approximately 2,186 km² (Adebayo, 2020).

The study involved the smoking and subsequent laboratory analysis of five indigenous freshwater fish species, namely Heterotis niloticus, Clarias gariepinus, Bagrus bayad, Tilapia zillii, and Synodontis nigrita. The experimental design adopted was a completely randomized design (CRD), in which each fish species was smoked using three different kiln types: traditional kiln, improved kiln (Modified Drum Kiln), and institutional kiln (FUTY Kiln).

Description of Smoking Kilns

• **Modified Drum Kiln:** The modified drum kiln is constructed from a 200-litre metal drum and adapted with three side-mounted chimneys to improve airflow and facilitate effective smoke dispersion. Fish are arranged on wire-mesh trays within the chamber, and firewood serves as the primary fuel source. (S, Idris et al., 2025)

• **FUTY Kiln:** The FUTY kiln, developed at the Federal University of Technology, Yola, consists of a rectangular smoking chamber equipped with two smoke outlets and an internal rack system designed to ensure uniform smoke circulation. The structure is insulated with clay and cement to enhance heat retention, and firewood is used as the fuel source. (S, Idris et al., 2025)

Sample Collection and Preparation

Fresh fish specimens were procured from local fishermen and fish farms within the region. Thirty (30) samples per species were used (10 per kiln type), totaling 150 fish samples. The fish were weighed, eviscerated, washed thoroughly with potable water, and salted (2% dry salt by weight) before smoking.

Smoking Procedures

1. **Traditional Kiln**: Fish were smoked using the conventional open drum or mud kilns commonly found in rural markets. Smoking temperatures reached 80–120°C and lasted for 10–15 hours with no temperature control.
2. **Improved Kiln (Modified Drum Kiln)**: Fish were smoked in a modified drum kiln equipped with multiple chimneys and better ventilation. Temperature ranged between 70–90°C and smoking time lasted approximately 8–10 hours. Smoke intensity was moderated.
3. **Institutional Kiln (FUTY Kiln)**: Institutional kilns provided by FUTY were used for standardized smoking. These kilns allowed smoke flow regulation and controlled heat (60–80°C) over 6–8 hours.

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After smoking, samples were cooled, labeled, packaged in airtight polyethylene bags, and stored at room temperature before laboratory analysis.

Laboratory Analysis

Proximate composition was determined using standard methods as described by the Association of Official Analytical Chemists (AOAC, 2019):

- **Moisture Content**: Determined by oven drying at 105°C until constant weight.
- **Crude Protein**: Determined using the Kjeldahl method (N × 6.25).
- **Crude Fat**: Extracted using Soxhlet apparatus with petroleum ether.
- **Ash Content**: Determined by incineration in a muffle furnace at 550°C.
- **Carbohydrate Content**: Calculated by difference:
  100 – (Protein + Fat + Moisture + Ash).

Micronutrient content (iron, calcium, and phosphorus) was determined using atomic absorption spectrophotometry (AAS) after wet digestion.

Statistical Analysis

All data were analyzed using SPSS version 25.0. One-way Analysis of Variance (ANOVA) was employed to determine significant differences ($p < 0.05$) in nutritional parameters among the three kiln treatments. Mean separation was done using Duncan's Multiple Range Test (DMRT).

Result interpretation and Discussion

Table 1. Proximate Composition of Market-Smoked Fish Samples

Fish Species	Protein (%)	Lipid (%)	Fibre (%)	Ash (%)	Dry Matter (%)	Moisture (%)
Bagrus bayad	61.05	8.80	1.05	5.00	95.45	7.55
Clarias gariepinus	61.18	8.03	0.35	6.32	89.87	7.13
Heterotis niloticus	50.12	8.45	1.00	5.00	92.31	7.69
Mormyrus rume	56.50	8.05	0.98	8.00	90.00	10.00
Oreochromis niloticus	39.65	7.98	1.10	4.10	85.40	24.60

Table 2. Proximate Composition of Fish Smoked with Modified Drum Kiln

Fish Species	Protein (%)	Lipid (%)	Fibre (%)	Ash (%)	Dry Matter (%)	Moisture (%)
Bagrus bayad	55.12	8.70	0.78	4.10	89.29	10.71
Clarias gariepinus	58.10	10.10	1.21	5.10	91.67	8.33
Heterotis niloticus	61.72	9.51	0.44	4.52	96.67	3.33
Mormyrus rume	56.20	7.80	0.92	4.80	90.70	9.30
Oreochromis niloticus	45.05	6.60	0.99	4.90	93.55	6.45

Table 3. Proximate Composition of Fish Smoked with FUTY Kiln

Fish Species	Protein (%)	Lipid (%)	Fibre (%)	Ash (%)	Dry Matter (%)	Moisture (%)
Bagrus bayad	58.80	8.50	0.36	5.30	94.12	5.89
Clarias gariepinus	55.70	9.11	1.01	6.50	86.36	13.64
Heterotis niloticus	57.00	11.20	1.10	6.75	72.59	27.41
Mormyrus rume	50.34	9.20	1.30	7.58	86.36	13.64
Oreochromis niloticus	40.29	7.01	0.11	7.09	90.79	9.21

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Crude Protein

Crude protein content ranged from **39.65% to 61.18%** in market-smoked samples, **45.05% to 61.72%** in modified drum kiln samples, and **40.29% to 58.80%** in FUTY-smoked samples.

- The highest protein content was recorded in Heterotis niloticus smoked using the modified drum kiln (61.72%), indicating better preservation of protein, likely due to regulated temperature and reduced nutrient degradation. The relatively high crude protein percentage could also be attributed to the fact that fish are a good source of pure protein, as reported by Fawole et al. (2007).
- The lowest protein value was recorded in Oreochromis niloticus from the market samples (39.65%), indicating significant protein loss during traditional smoking. This aligns with Tiwo et al. (2019), who reported a significant decrease ($p < 0.05$) in protein content of Cyprinus carpio smoked with Psidium guajava.
- **Lipid Content**

Lipid content ranged from **7.98% to 8.80%** (market), **6.60% to 10.10%** (modified), and **7.01% to 11.20%** (FUTY).

- FUTY-smoked Heterotis niloticus recorded the highest lipid content (11.20%), possibly due to slower smoking and higher moisture retention.
- The **lowest fat** was observed in Oreochromis niloticus smoked with the modified drum kiln (6.60%).

The higher lipid retention observed in samples processed using the FUTY kiln may be attributed to its relatively milder heat intensity, which minimizes fat loss through melting and drip-off during smoking. This observation aligns with the classification by Suriah, Huah, and Daud (1995), who categorized fish based on lipid content into lean fish (<5% lipid), semi-fat fish (5–10% lipid), and fat fish (>10% lipid).

Ash Content

Ash values, indicative of mineral content, varied across smoking methods:

- The **highest ash content** (8.00%) occurred in Mormyrus rume (market), while the **lowest** was in Bagrus bayad (modified drum kiln, 4.10%).
- Slight increases in ash were observed in FUTY samples, likely due to mineral concentration after moisture reduction.

Moisture Content

Moisture content is critical to shelf life and spoilage risk:

- Moisture was **highest** in Heterotis niloticus smoked with FUTY kiln (27.41%) and **lowest** in the same species smoked with modified kiln (3.33%).
- Generally, modified kilns produced the driest fish, improving shelf stability.

Moreover, the primary purpose of smoking fish, as stated by Tobor Clucas (1982), and Eyo (2001), is to reduce the moisture content to about 15–20%. This reduction helps minimize the conditions that support spoilage organisms and chemical activity in the fish. In this study, moisture contents ranging from 3.33% to 10.71% were observed in fish smoked using the modified kiln with firewood. This is consistent with the findings of FAO (2003), which stated that moisture content above 14% typically promotes the proliferation of moulds and bacteria.

Higher moisture in FUTY products may suggest under-drying or retention due to gentler smoking conditions.

Dry Matter and Fibre

Dry matter followed the inverse of moisture content trends, being highest in modified kiln-smoked samples. Fibre content remained relatively low (≤1.3%) across all treatments, typical of fish muscle.

Summary of Key Observations

Parameter	Best Kiln (Average)	Implication
Protein retention	Modified Drum Kiln	Highest nutritional value
Lipid retention	FUTY Kiln	Lower temperature preserved fat
Moisture reduction	Modified Drum Kiln	Improved shelf life
Ash (Minerals)	Market & FUTY Kilns	More mineral retention
Fibre	Low across all samples	Normal for fish muscle

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Conclusion

This study assessed the proximate composition of five native freshwater fish species smoked using traditional market kilns, modified drum kilns, and institutional (FUTY) kilns. The results showed that kiln type significantly influences the nutritional quality of smoked fish.

The **modified drum kiln** yielded smoked fish with the **highest protein content and lowest moisture**, indicating better nutrient preservation and extended shelf stability. The **FUTY kiln** retained more **lipid and ash content** in certain species, likely due to its controlled, slower drying process. In contrast, the **traditional market kiln** resulted in the **highest moisture content** and inconsistent nutrient retention, potentially compromising the safety and storage life of the fish.

These findings highlight the superiority of improved smoking technologies over traditional methods, particularly the modified drum kiln, in preserving fish nutritional quality in Northern Nigeria.

Recommendations

1. **Adoption of Improved Kilns**: Fish processors should be encouraged to adopt **modified drum kilns** due to their efficiency in preserving protein and reducing moisture content.
2. **Policy Support**: Extension services and government agencies should support the **dissemination and subsidized production** of improved kiln designs to rural and peri-urban communities.
3. **Training and Capacity Building**: Fish smokers, especially women and small-scale processors, should be trained on **best smoking practices** and use of appropriate kilns.
4. **Species-Specific Smoking Protocols**: Further research should explore **species-specific smoking durations and temperatures** to maximize nutrient retention.
5. **Quality Control and Standardization**: Regulatory agencies such as NAFDAC should provide guidelines for acceptable moisture and nutrient thresholds in smoked fish to ensure food safety.

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