



Research Article

Comparative Effects of Neem Wood and Charcoal Smoking on the nutrient Composition of farmed African Catfish (*Clarias gariepinus*)

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ABSTRACT

Smoking has been practiced for centuries as a preservation technique, combining dehydration with the antimicrobial and antioxidant properties of smoke compounds. This study evaluated the effects of neem wood (*Azadirachta indica*) and charcoal as smoking fuels on the proximate composition of African catfish (*Clarias gariepinus*). A Completely Randomized Design (CRD) comprising three treatments fresh fish (control), neem wood-smoked fish, and charcoal-smoked fish was employed with three replicates each. A total of 45 pieces (15kg) of healthy catfish (300–400 g) were processed and smoked for 6 hours using traditional smoking kilns. Proximate composition analyses, including moisture, crude protein, lipid, ash, and nitrogen-free extract (NFE), were conducted using standard procedures. Results showed significant differences ($P < 0.05$) among treatments. Fresh fish had the highest moisture (20.40%), ash (4.80%), lipid (7.51%), and NFE (35.59%) contents, while smoked samples exhibited markedly higher crude protein levels. Neem-smoked fish recorded significantly higher crude protein (53.01%) and ash (4.33%) contents than charcoal-smoked fish (51.33% and 3.70%, respectively). Charcoal-smoked fish showed the lowest moisture content (7.62%), indicating greater dehydration efficiency. Lipid contents did not differ significantly between the smoking treatments. The findings demonstrate that smoking substantially improves the protein concentration of catfish through moisture reduction, with neem wood producing nutritionally superior smoked fish compared to charcoal. Therefore, neem wood is recommended as a sustainable and effective smoking fuel for enhancing the nutritional quality of smoked *Clarias gariepinus*.

Keywords: Charcoal; *Clarias gariepinus*; Fish Smoking; Neem Wood; Proximate Composition

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INTRODUCTION

African catfish remains a vital component of the human diet, offering high-quality protein, essential fatty acids, vitamins, and minerals (Balami *et al.*, 2019). Fish provides a major source of high-quality protein and essential nutrients for human populations worldwide. However, its highly perishable nature necessitates preservation methods capable of extending shelf life while maintaining nutritional value (FAO, 2022). To mitigate post-harvest losses and preserve nutritional integrity, effective preservation techniques are essential. Smoking is a traditional and widely accepted

preservation method that enhances flavor, improves texture, reduces microbial load, and extends the shelf life of fish products (Adeyeye and Oyewole, 2016). Despite these advantages, hot smoking exposes lipids to high temperatures, which can accelerate lipid oxidation, resulting in the deterioration of sensory quality and nutrient loss, particularly in PUFA-rich species (Puke and Galoburda, 2020). The nutritional profile of catfish makes it particularly valuable for addressing protein-energy malnutrition. Fresh catfish contains approximately 16-18% protein, essential amino acids, polyunsaturated fatty acids including

omega-3 and omega-6, and micronutrients such as iron, zinc, and selenium (Adeyemi *et al.*, 2021).

Smoking remains one of the most widely adopted traditional preservation techniques in West Africa due to its affordability and effectiveness. The type of fuel used during smoking influences heat generation, smoke composition, and ultimately the nutritional characteristics of the finished product (Doe, 2021).

Neem wood and charcoal are among the most common smoking fuels used by fish processors in northern Nigeria. Despite their widespread use, limited information exists regarding their comparative effects on the proximate composition of African catfish (Ibrahim and Mohammed, 2023). This study aimed to compare the effects of neem wood and charcoal smoking on moisture, crude protein, lipid, ash, and nitrogen-free extract contents of *Clarias gariepinus*.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Fish Farm Complex of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Bayero University, Kano. The farm is located at latitude 11.977616°N and longitude 8.424571°E in Kano State, Nigeria. (NPC, 2006).

Experimental Design

The study employed a Completely Randomized Design (CRD) with two treatment groups and control, replicated three times. A total of 15 kg of African catfish (*Clarias gariepinus*) were used for the study. The experimental treatments were:

T1 (Control): Fresh catfish samples (unsmoked)

T2: Catfish smoked with neem wood (*Azadirachta indica*)

T3: Catfish smoked with charcoal

Sample Collection and Preparation

The catfish samples were purchased from Idris Uba Muhammad's fish farm located in Guringawa Quarters, Kumbotso Local Government Area, Kano State, Nigeria. A total of 45 pieces (15kg) of healthy African catfish (*Clarias gariepinus*) with average weight of 300-400 grams was acquired for the study to minimize biological variation. The fish were transported live using 50 litres Jericans to the Department of Fisheries and Aquaculture Fish Farm Complex at Bayero University, Kano. Upon arrival, the fish were held in a well-aerated concrete tank and acclimated for 24 hours prior to processing. The fish were healthy, free from visible abnormalities, injuries, or diseases before the commencement of the study.

Preparation of Smoking Materials

Neem wood:

Neem wood (*Azadirachta indica*) was sourced from matured neem trees within Kano metropolis. The wood was sun-dried to achieve moisture content below 20%, which ensures efficient combustion and reduced formation of undesirable compounds. The seasoned neem wood was cut into uniform sizes (approximately 15-20 cm in length and 5-8 cm in diameter) to facilitate consistent burning characteristics during the smoking process.

Charcoal:

Hardwood charcoal was purchased from the local market within Kano metropolitan. The charcoal was sourced from mixed hardwood species commonly available in northern Nigeria. Only high-quality charcoal with consistent size, minimal ash content, and uniform black color were selected for the study. The charcoal was stored in a dry location to prevent moisture absorption prior to use.

Fish Processing and Smoking Procedure

Pre-smoking Preparation:

The fish were stunned with a sharp blow to the head. They were then transferred to a clean processing table where they were gutted by making a ventral incision from the anus to the gills and removing all internal organs. The gutted fish were thoroughly washed with clean water to remove blood, slime, and any remaining visceral materials. Each fish was split longitudinally along the backbone (butterfly cut) to facilitate uniform smoking and drying. The prepared fish were briefly rinsed again and allowed to drain on a clean wire mesh for 60 minutes before smoking (Oli *et al.*, 2024).

Control Samples: For the control treatment (T1), samples of fresh fish were taken immediately after processing and preparation. These samples were analyzed for proximate composition to establish baseline nutritional values before smoking.

Smoking Process

The smoking of both treatments was carried out at 70-90°C for 6 hours, the smoking of process described by Adeyeye, (2019) was adopted as follows;

Neem Wood Smoking (T2)

The traditional smoking kiln was prepared by loading seasoned neem wood into the combustion chamber. The wood was ignited and allowed to establish a steady combustion with moderate smoke generation. Fish samples were arranged on wire mesh trays placed approximately 60-80 cm above the heat source (Adeyeye, 2019).

Charcoal Smoking (T3)

For charcoal smoking, the kiln was prepared by loading high-quality hardwood charcoal into the combustion chamber. The charcoal was ignited and allowed to reach optimal burning temperature. Fish samples were arranged on wire mesh trays at the same distance (60-80 cm) from the heat source as the neem wood treatment to ensure comparability (Adeyeye, 2019).

For both smoking treatments, fish were turned at regular intervals during the smoking process to ensure even drying, uniform smoke penetration, and consistent color development on all surfaces. The smoking process was continued for 6 hours until the fish achieve the desired level of dryness, characterized by firm texture, reduced moisture content, and characteristic smoked appearance.

After smoking, the fish were removed from the kiln and allowed to cool on clean wire mesh trays in a well-ventilated indoor area with ambient temperature of 28°C for approximately 48 hours before packaging and analysis.

Sample Collection for Analysis

Samples for proximate analysis were collected from each treatment group following the completion of smoking process. Control samples (T1) were collected immediately after fish preparation, before smoking. Smoked samples (T2 and T3) were collected after the smoking process and cooling period.

For each treatment, three replicate samples were collected, with each sample consisting of approximately 200-300 grams of fish flesh. The

samples were properly labeled, packaged in clean polyethylene bags, and stored under appropriate conditions until analysis. All proximate analyses were conducted within 24-48 hours of sample collection to ensure accuracy of results.

Proximate Analysis

Proximate analysis of fresh and smoked catfish samples was carried out at the Centre for Dryland Agriculture Laboratory, Bayero University, Kano. The following parameters were analyzed using standard methods of the Association of Official Analytical Chemists (AOAC, 2016): moisture content, crude protein, crude fat, ash content, and carbohydrate (nitrogen-free extract).

Data Analysis

Data collected were subjected to one-way ANOVA using SPSS version 20. Turkey's test was used to separate the means at 5% significant level ($P < 0.05$).

RESULTS

The results of the proximate analyses of fresh and processed experimental fish are presented in Table 1. Fresh fish sample recorded significantly ($P < 0.05$) higher (20.40±0.02) moisture content, (4.80±0.30) ash, (7.51±0.05) lipid and (35.59±0.02) nitrogen free extract contents than smoked fish samples. Both smoked samples recorded significantly ($P < 0.05$) higher (53.01±0.29), (51.33±0.24) protein contents, although it was highest (53.01±0.29) with neem smoked samples.

Table 1.0: Proximate Composition of Fresh, Neem-Smoked, and Charcoal-Smoked *Clarias gariepinus*

Treatments	%Moisture	%Ash	%CP	%Lipid	%NFE
Neem Smoked	8.52±0.07	4.33±0.15	53.01±0.29	5.52±0.11	28.62±0.55
Charcoal Smoked	7.62±0.06	3.70±0.20	51.33±0.24	5.39±0.12	31.96±0.42
Fresh (Unprocessed)	20.40±0.02	4.80±0.30	31.70±0.20	7.51±0.05	35.59±0.02

Values represent the mean of triplicate samples (n = 3)

DISCUSSION

The results obtained in the present study revealed significant variations between the control and two smoking treatments employed. These findings are consistent with previous studies reporting the influence of smoking fuel on the nutritional profile of smoked fish (Abolagba and Melle, 2020).

The moisture content of Neem-smoked fish (8.52±0.07) was significantly higher than that of charcoal-smoked fish (7.62±0.06), yet both values represent a dramatic reduction from fresh fish moisture (20.40±0.02), confirming the dehydrating efficacy of smoking. These findings align with Abolagba and Melle, (2020), who reported moisture

contents of 5.70–8.40% for smoked *Clarias gariepinus* processed using different fuel types, and with Bezbaruah and Deka, (2021), who recorded values of 7.2–8.9% in smoked catfish from South-western Nigeria. The lower moisture in charcoal-smoked fish corroborates Bomfeh *et al.* (2019), who found that charcoal generates more sustained heat, resulting in greater dehydration compared to firewood alternatives.

The significantly higher crude protein in Neem-smoked fish (53.01±0.29) compared to charcoal-smoked fish (51.33±0.24) is consistent with Abolagba and Melle, (2020), who recorded protein values of 46.74–55.28% for smoked catfish, and with Ledesma

et al. (2022), who reported 44.2–58.9% for traditionally smoked catfish in the Niger Basin. The elevation in crude protein from 31.70±0.20 in fresh fish to over 51% in both treatments is a well-established concentration effect resulting from moisture removal during smoking (Ledesma *et al.*, 2022). Okonkwo *et al.* (2019) similarly found that wood-smoked fish generally recorded higher crude protein than charcoal-smoked alternatives, which is consistent with the present findings.

The absence of a significant difference in lipid content between the two treatments is consistent with Ledesma *et al.* (2022), who reported non-significant lipid differences between fuel-type smoked catfish, suggesting that lipid changes are primarily driven by smoking duration and temperature rather than fuel type. The decline in lipid from 7.51±0.05 (fresh) to approximately 5.44% in both treatments aligns with Bezbaruah and Deka, (2021), who documented lipid reductions of 25–35% following smoking of freshwater fish in Nigeria, and attributed to lipid oxidation and dripping of melted fat during thermal processing.

The significantly higher ash in Neem-smoked fish (4.33±0.15) compared to charcoal-smoked fish (3.70±0.20) may reflect the mineral-rich profile of Neem wood. Abolagba and Ighile, (2019) reported ash values of 3.60–4.80% for traditionally smoked catfish using various fuel types in Nigeria, a range within which the present values fall. The slight decline in ash relative to fresh fish (4.80±0.30) in both treatments may reflect the volatilization of some mineral fractions during high-temperature processing. The higher NFE in charcoal-smoked fish (31.96±0.42) compared to Neem-smoked fish (28.62±0.55) is consistent with Usman *et al.* (2016), who found elevated NFE in charcoal-smoked fish. This can be attributed to greater deposition of smoke-borne organic compounds from charcoal combustion.

CONCLUSION

Neem wood smoking significantly improved crude protein and ash content compared to charcoal smoking. Although charcoal achieved greater moisture reduction, neem wood produced nutritionally superior smoked catfish. The study supports the use of neem wood as a sustainable alternative smoking fuel capable of enhancing the nutritional quality of smoked fish.

Conflict of interest

Authors declare that there is no conflict of interest, and therefore, given consent for the publication of the article.

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