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# Comparative Sensory Evaluation of Wild African Catfish (*Clarias gariepinus*) Smoked with Neem Wood (*Azadirachta indica*) and Hard Wood Charcoal

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*Abstract*

Fish constitutes an important source of high-quality protein and essential nutrients; however, its highly perishable nature necessitates effective preservation methods. Smoking remains one of the most widely adopted traditional preservation techniques in Nigeria, although the choice of smoking fuel may influence the sensory quality and consumer acceptability of the final product. This study evaluated the sensory characteristics and consumer acceptability of wild African catfish smoked using neem wood and hard wood charcoal to identify the most suitable fuel source for commercial processing. A Completely Randomized Design with two treatments, neem wood-smoked fish, and hard wood charcoal-smoked fish was employed, in triplicate. Forty-five samples weighing between 300 and 400 g were collected from Tiga Dam, Kano State, Nigeria, processed under standardized smoking conditions, and subjected to sensory evaluation by twenty semi-trained panelists. Appearance, flavour, texture, and taste were assessed using a 4-point sensory quality rating scale, while the data were analyzed using descriptive statistics and Anova at 5% level of significance. The results revealed that hard wood charcoal-smoked fish received significantly ($P < 0.05$) higher ratings for all sensory attributes than fish smoked with neem wood. Hard wood charcoal-smoked samples attained 65% combined Excellent and Very Good ratings for appearance, 80% Good-or-better ratings for flavour, 45% top-two ratings for texture, and 85% Good-or-better ratings for taste. Conversely, neem wood-smoked fish received predominantly Fair ratings, particularly for flavour (55%) and taste (60%), indicating poor consumer acceptability. The inferior sensory quality of neem wood-smoked fish was attributed to the bitter phytochemical constituents released during the combustion of neem wood, whereas the stable combustion characteristics of hard wood charcoal produced a more desirable colour, aroma, texture, and taste. The study concludes that hard wood charcoal is a superior smoking fuel for

producing sensory acceptable smoked wild African catfish and recommends its adoption by artisanal and commercial fish processors to improve product quality, consumer acceptance, and marketability.

## Introduction

Fish is an indispensable component of global food security, providing high-quality animal protein, essential fatty acids, vitamins, and minerals to billions of people worldwide. Among the commercially important freshwater species in Africa, the African catfish (*Clarias gariepinus*) is highly valued because of its nutritional quality, adaptability, rapid growth, and widespread distribution. Wild populations of *C. gariepinus* inhabit rivers, lakes, reservoirs, and floodplains, where they feed opportunistically on insects, crustaceans, molluscs, smaller fish, and organic detritus. Consequently, the nutritional composition of wild fish is largely influenced by natural ecological conditions rather than formulated feeds used in aquaculture (Bruton, 1979).

The nutritional characteristics of wild-caught fish often differ from those of cultured fish due to variations in feeding habits, environmental conditions, activity levels, and growth rates. The diverse natural diet of wild African catfish may influence muscle composition and contribute to differences in flavour, texture, and overall eating quality. These attributes are particularly important because they directly affect consumer preference and market value. Despite the abundance of wild African catfish in Nigerian inland water bodies and its significant contribution to household nutrition and rural livelihoods, substantial post-harvest losses continue to occur because fresh fish deteriorates rapidly under tropical environmental conditions. The limited availability of cold storage and refrigeration facilities in many fishing communities necessitates immediate preservation after harvest. Consequently, smoking remains the most widely practiced traditional preservation method across Nigeria and many parts of West Africa.

Fish smoking extends shelf life by reducing moisture content and depositing antimicrobial and antioxidant compounds generated during the combustion process. These effects inhibit microbial growth, delay spoilage, and enable smoked fish to remain safe and acceptable for consumption for several weeks or months without refrigeration (Adeyeye, 2019; Fanyam et al., 2024).

Beyond preservation, smoking enhances product appearance, imparts a characteristic smoky flavour and aroma, improves texture, and increases the commercial value of fish products. These advantages make smoking an indispensable post-harvest technology for artisanal fisheries, allowing fishers to minimize losses, stabilize income, and distribute products to distant markets.

Traditional fish smoking in Nigeria primarily utilizes two fuel sources: firewood and hard wood charcoal. Firewood, obtained from different tree species, burns with relatively high smoke production and variable heat output depending on wood species, moisture content, and combustion efficiency. Hard wood charcoal, produced through the pyrolysis of wood under limited oxygen conditions, burns more uniformly, generates relatively stable temperatures, and produces less smoke. These differences in combustion characteristics may influence the physicochemical and sensory qualities of smoked fish by affecting heat transfer, moisture removal, colour development, and the deposition of smoke-derived flavour compounds.

In northern Nigeria, neem wood (*Azadirachta indica*) is frequently used as a smoking fuel because of its widespread availability and affordability. However, neem wood contains several biologically active phytochemicals, including azadirachtin, nimbin, salannin, and related limonoids, which may undergo thermal

degradation during combustion and influence the sensory properties of smoked fish. In contrast, hard wood charcoal generally produces a milder and more consistent smoke profile that may enhance consumer acceptability. Nevertheless, the selection of smoking fuel by artisanal processors is often determined by availability, cost, and local tradition rather than scientific evidence regarding product quality (Kwaghvihi et al., 2020).

Although several studies have examined the effects of smoking on fish quality, limited information is available regarding the comparative sensory characteristics of wild African catfish smoked with neem wood and hard wood charcoal. Such information is essential because consumer acceptance ultimately determines the commercial success of smoked fish products. Understanding the influence of different fuel sources on sensory quality will provide evidence-based recommendations for improving traditional fish smoking practices and enhancing the marketability of smoked fish in Nigeria and other West African countries. Therefore, this study evaluated and compared the sensory characteristics and consumer acceptability of wild African catfish (*Clarias gariepinus*) smoked using neem wood (*Azadirachta indica*) and hard wood charcoal in order to identify the most suitable smoking fuel for artisanal and commercial fish processors.

## Materials and Methods

### Study Area

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

### Experimental Design

The experiment was arranged in a Completely Randomized Design (CRD) comprising two treatments with three replicates per treatment. A total of 45 wild African catfish (*Clarias gariepinus*), each weighing between 300 and 400 g, were used. The experimental treatments were as follows:

**$T_1$:** Catfish smoked using neem wood (*Azadirachta indica*).

**$T_2$:** Catfish smoked using hardwood charcoal.

### Fish Procurement and Handling

Wild African catfish (*Clarias gariepinus*) were obtained from artisanal fishers operating at Tiga Dam, located approximately 65 km southeast of Kano metropolis. Fish were collected during early morning fishing operations using traditional gill nets with mesh sizes ranging from 60 to 80 mm to ensure maximum freshness.

Approximately 15 kg of healthy live fish, with individual body weights ranging from 300 to 400 g, were selected based on the absence of visible injuries, disease symptoms, parasitic infestation, or other physical abnormalities. The selected fish were transported to the laboratory in oxygenated plastic containers containing ice packs to maintain a temperature of 4–8°C throughout the 1.5–2 h journey.

Upon arrival at the Department of Fisheries and Aquaculture, the fish were transferred into a 1,000-L circular fiberglass holding tank supplied with continuously aerated water. The fish were acclimatized for 24 hrs, before processing to minimize handling stress and allow physiological stabilization.

### Fuel Material Collection and Preparation

Dry branches and stems of mature neem trees (*Azadirachta indica*) were collected from various locations within Kano metropolis, particularly around Bayero University where neem trees are abundant. The wood was further air-seasoned under shade for 60 days to reduce its moisture content to approximately 15–18%, thereby ensuring efficient combustion.

Before use, the seasoned wood was cut into uniform pieces measuring approximately 18–25 cm in length and 6–10 cm in diameter to promote consistent burning and heat production.

Commercial hardwood charcoal was purchased from Yan Kaba Market, Kano. The hard wood

charcoal originated from mixed indigenous hardwood species, including *Prosopis africana*, *Anogeissus leiocarpus*, and *Parkia biglobosa*. Only high-quality hard wood charcoal characterized by a uniform black colour, metallic sound when struck, minimal friability, and low dust content was selected. The hard wood charcoal was stored in airtight containers under dry, well-ventilated conditions until use.

## Fish Preparation and Smoking Procedures

The fish were humanely stunned using a wooden mallet before processing. Each fish was eviscerated through a ventral incision extending from the urogenital opening to the opercular region, after which the visceral organs were carefully removed. The dressed fish were thoroughly washed with potable running water to remove blood, mucus, and tissue residues.

Each carcass was butterfly split dorsally through the vertebral column while maintaining skin integrity. The prepared fish were rinsed again and placed on elevated stainless-steel mesh trays to drain for 60 min before smoking. (Uba, 2026).

## Neem Wood Smoking ($T_1$)

Smoking with neem wood was carried out using a locally fabricated steel-drum smoking kiln. Seasoned neem wood pieces were arranged within the combustion chamber and ignited with a small quantity of kindling. The fuel was allowed to burn for approximately 15–20 min until a stable combustion rate and continuous smoke production were achieved.

Butterfly-split fish were arranged uniformly on wire mesh racks positioned 70–90 cm above the combustion chamber. The internal kiln temperature was monitored every 30 min using a calibrated digital probe thermometer and maintained between 75 and 95°C throughout the smoking process.

To ensure uniform heat distribution and smoke exposure, each fish was manually turned through 180° at 30-min intervals. Smoking continued for 6.5–7.5 h until the fish developed a firm texture, characteristic golden-brown colour, and desirable smoked aroma, indicating adequate processing (Uba & Moses, 2026).

## Hard wood charcoal Smoking ($T_2$)

Hard wood charcoal smoking was performed using the same kiln design to eliminate equipment-related variation. The combustion chamber was fueled exclusively with pre-ignited hardwood charcoal, which was ignited using an electric starter to achieve uniform combustion.

Once a stable combustion temperature was established, prepared fish were arranged on wire mesh racks positioned 70–90 cm above the heat source. Temperature monitoring, rack arrangement, fish rotation intervals (30 min), and total smoking duration (6.5–7.5 h) were identical to those employed for the neem wood treatment. (Uba & Moses, 2026).

Upon completion of smoking, the fish were removed from the kiln and transferred to clean stainless-steel cooling racks within a screened and well-ventilated environment. Samples were allowed to cool for approximately 2.5–3 h until they reached ambient temperature before packaging (Adeyeye et al., 2016).

## Sensory Evaluation

Sensory evaluation was conducted using a panel of 20 semi-trained assessors comprising staff and students of the Department of Fisheries and Aquaculture, Bayero University, Kano. Panelists were selected based on their familiarity with smoked fish products and their willingness to participate in the evaluation.

The smoked fish samples from the two smoking treatments were coded with randomly generated three-digit numbers to eliminate bias and presented to each panelist under standardized conditions of adequate lighting and ventilation. Samples were served at room temperature on clean white plates, and potable drinking water was provided for palate cleansing between evaluations.

The sensory attributes evaluated were appearance, flavour, texture, and taste. Each attribute was scored using a 4-point sensory quality rating scale as follows:

4 = Excellent, 3 = Very Good, 2 = Good, 1 = Fair

Individual scores were recorded on structured evaluation sheets, and mean sensory scores were calculated for each treatment (Uba, 2026).

### Statistical Analysis

Data obtained from the sensory evaluation were analyzed using the Statistical Package for the Social Sciences (SPSS), Version 20. Descriptive statistics were used to summarize the sensory responses. Differences among treatment means were evaluated using Analysis of Variance (ANOVA). Where significant differences ($P < 0.05$) were detected, post hoc multiple comparison tests were performed to separate treatment means. Statistical significance was accepted at the 95% confidence level ($P < 0.05$).

## Results and Discussions

### Results

The results for sensory evaluation of neem wood-smoked and hard wood charcoal-smoked catfish are presented in Table 1.0 below. Panelists rated both products on appearance, flavour, texture, and taste using a four-point scale (Excellent, Very Good, Good, Fair). Overall, hard wood charcoal-smoked fish consistently attracted higher positive ratings across all sensory attributes compared to neem wood-smoked fish.

**Table 1:** Sensory evaluation ratings of neem wood-smoked and hard wood charcoal-smoked wild catfish

| Treatment | Parameter | Excellent | | Very Good | | Good | | Fair | |
|---|---|---|---|---|---|---|---|---|---|
| | | F | % | F | % | F | % | F | % |
| Neem | Appearance | 0 | 0.00±0.00 | 6 | 30.00±0.09 | 9 | 45.00±0.08 | 5 | 25.00±0.07 |
| | Flavour | 0 | 0.00±0.00 | 3 | 15.00±0.03 | 6 | 30.00±0.09 | 11 | 55.00±0.11 |
| | Texture | 1 | 5.00±0.03 | 3 | 15.00±0.04 | 6 | 30.00±0.07 | 10 | 50.00±0.04 |
| | Taste | 0 | 0.00±0.00 | 4 | 20.00±0.05 | 4 | 20.00±0.05 | 12 | 60.00±0.08 |
| Charcoal | Appearance | 7 | 35.00±0.10 | 6 | 30.00±0.03 | 4 | 20.00±0.04 | 3 | 15.00±0.06 |
| | Flavour | 2 | 10.00±0.05 | 4 | 20.00±0.03 | 10 | 50.00±0.50 | 4 | 20.00±0.05 |
| | Texture | 2 | 10.00±0.06 | 7 | 35.00±0.10 | 5 | 25.00±0.09 | 6 | 30.00±0.08 |
| | Taste | 0 | 0.00±0.00 | 9 | 45.00±0.08 | 8 | 40.00±0.10 | 3 | 15.00±0.09 |

Key; F = Frequency; % = Percentage of panelists (n = 20). Ratings: Excellent (4), Very Good (3), Good (2), Fair (1).

The appearance as indicated in Table 1.0 above, hard wood charcoal-smoked fish received significantly ($P < 0.05$) higher appearance ratings, with 35.00% of panelists rating it Excellent and 30.00% Very Good, giving a combined top-two ratings of 65.0%. In contrast, neem wood-smoked fish received no Excellent ratings, with 30.00% Very Good, 45.00% Good, and 25.00% Fair, indicating significantly ($P < 0.05$) lower overall visual acceptability.

The flavour of hard wood charcoal-smoked fish recorded significantly ($P < 0.05$) higher ratings, 10.00% Excellent, 20.00% Very Good, and 50.00% Good ratings, with 80.00% of panelists rating it Good or better. Neem wood-smoked fish received no Excellent flavour ratings, with 15.00% Very Good, 30.00% Good, and a majority of 55.00% rating it only Fair, reflecting significantly ($P < 0.05$) lower flavour acceptability. Texture ratings showed a similar pattern. Hard wood charcoal-smoked fish was rated Excellent by 10.00% of panelists and Very Good by 35.00%, for a combined top-two ratings of 45.00%. Neem wood-smoked fish received only 5.00% Excellent and 15.00% Very Good texture ratings, with 50.00% rating it only Fair. Taste showed the starkest contrast between treatments. Hard wood charcoal-smoked fish received 45.00% Very Good and 40.00% Good taste ratings, with only 15.00% rating it Fair. Neem wood-smoked fish received no Excellent ratings, with 60.00% of panelists rating the taste only Fair, 20.00% Good, and 20.00% Very Good, indicating widespread poor palatability.

## Discussion

The findings of this study demonstrate that the type of smoking fuel significantly influences the sensory characteristics and consumer acceptability of wild African catfish (*Clarias gariepinus*). Hard wood charcoal-smoked fish consistently received higher sensory ratings than neem wood-smoked fish in terms of appearance, flavour, texture, and taste, indicating that the choice of fuel source plays an important role in determining the quality attributes of smoked fish products.

The superior appearance of hard wood charcoal-smoked catfish compared with neem wood-smoked samples may be associated with differences in combustion characteristics and smoke composition between the two fuel sources. Hard wood charcoal produces a more stable and uniform heat supply, which promotes consistent drying and controlled surface browning during smoking. The resulting golden-brown coloration is associated with desirable consumer perception and improved visual appeal. In contrast, neem wood combustion may produce variable smoke intensity and uneven deposition of smoke compounds, resulting in darker and less uniform surface coloration. Similar observations have been reported by Leroi and Joffraud (2000), who noted that smoke composition and processing conditions influence colour development and overall appearance of smoked fish products.

The differences observed in flavour and taste further highlight the influence of fuel type on the sensory quality of smoked fish. Hard wood charcoal-smoked fish achieved substantially higher flavour and taste acceptance, with the majority of panelists rating the product as good or better. This may be attributed to the relatively mild and consistent smoke profile generated during hard wood charcoal combustion, which allows the development of desirable smoky aromas without excessive deposition of undesirable compounds. Conversely, the lower flavour and taste scores observed for neem wood-smoked fish may be associated with the presence of naturally occurring phytochemicals in *Azadirachta indica*. During combustion, compounds such as limonoids, including azadirachtin, nimbin, and salannin, may undergo thermal degradation, potentially producing smoke-derived compounds that contribute to bitter, acrid, or otherwise less desirable sensory characteristics in fish products (Olanrewaju & Adeyemo, 2023).

The texture characteristics observed in this study also favored hard wood charcoal smoking. Fish smoked with hard wood charcoal received higher ratings for texture compared with neem wood-smoked samples. The improved textural quality may be attributed to the ability of hard wood charcoal to maintain a relatively stable combustion temperature, thereby facilitating uniform moisture removal and controlled protein denaturation. These conditions promote the development of desirable firmness while preventing excessive surface hardening. In contrast, variations in heat intensity during wood combustion may result in inconsistent drying rates and uneven textural properties (Okonkwo et al., 2022). The findings agree with previous reports indicating that smoking conditions, including fuel type, temperature, and smoke composition, have significant effects on the sensory properties of processed fish. Although traditional fuel sources remain widely used because of availability and affordability, their suitability should also be evaluated based on the quality characteristics of the final product. Consumer acceptance is a critical factor determining the commercial success of smoked fish, as nutritional and preservation benefits can only be fully realized when the product is acceptable to consumers.

The higher sensory acceptability of hard wood charcoal-smoked catfish observed in this study suggests that hard wood charcoal may be a more appropriate smoking fuel for artisanal fish processors seeking to produce products with greater market appeal, particularly in urban and peri-urban communities in northern Nigeria. However, considering the availability of neem wood and its potential role in local smoking practices, further studies should investigate

whether blending neem wood with other conventional smoking materials at controlled ratios could reduce undesirable flavour compounds while maintaining acceptable preservation and sensory qualities.

Overall, the results indicate that hard wood charcoal smoking provides a more favorable sensory outcome for wild African catfish compared with neem wood smoking. Adoption of improved smoking practices based on scientifically validated fuel selection could enhance product quality, increase consumer acceptance, and support the sustainability of traditional fish processing enterprises.

## Conclusion

This study concludes that the choice of smoking fuel has a significant influence on the sensory quality and consumer acceptability of wild African catfish (*Clarias gariepinus*). Fish smoked with neem wood (*Azadirachta indica*) exhibited lower sensory acceptability, particularly in terms of flavour and taste, which limited its suitability as a fuel source for producing commercially acceptable smoked fish products. The undesirable sensory characteristics observed in neem wood-smoked fish may be associated with smoke-derived compounds originating from the phytochemical composition of neem wood. In contrast, hard wood charcoal smoking produced fish with superior sensory attributes, including improved appearance, flavour, texture, and taste. The consistent combustion characteristics of hard wood charcoal contributed to the production of a more acceptable smoked fish product with greater potential for consumer preference and marketability. Therefore, hard wood charcoal represents a more suitable smoking fuel for processing wild African catfish under the conditions evaluated in this study.

It is recommended that artisanal and commercial fish processors, particularly those operating in northern Nigeria, consider the use of charcoal as a preferred smoking fuel for African catfish processing. Fisheries extension services and regulatory agencies should incorporate scientifically validated smoking practices and fuel selection guidelines into training programs for fish processors, including women-led fish processing groups.

Further research should investigate the effects of combining neem wood with other fuel sources at different ratios to determine whether undesirable sensory compounds can be minimized while maintaining effective preservation characteristics. Additional studies evaluating the chemical composition of smoke, nutritional changes, shelf stability, and consumer preferences across different regions would provide further insight into optimizing traditional fish smoking technologies.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

## Limitations of the Study

The use of a four-point sensory rating scale (Excellent, Very Good, Good, and Fair) represents a limitation of the present study, as the scale provides a relatively narrow range of response options and does not include a neutral or intermediate category. Consequently, subtle differences in panelists' perceptions of appearance, flavour, texture, and taste may not have been fully captured. In addition, the sensory evaluation involved only 20 semi-trained panelists, whose individual preferences and familiarity with smoked fish products may have influenced the ratings. Therefore, the findings interpreted within the context of the sensory assessment procedure and may not fully represent the preferences of the wider consumer population. Future studies could employ a larger and more diverse consumer panel and a broader hedonic scale, such as a 7- or 9-point scale, to provide greater sensitivity in measuring consumer acceptability.

## Author Contribution

The authors confirm contribution to the paper as follows: **study design:** Author Muhd I.U, **data collection:** Author Ngadina, E.Y; **analysis and interpretation of results:** Author Muhd I.U; **draft manuscript preparation:** Author Muhd I.U. All authors reviewed the results and approved the final version of the manuscript.

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