TES Trends in
Environmental Sciences

OPEN ACCESS

Assessment of Proximate Composition, Microbial Load, and Sensory Attributes of Spice-Treated Smoked *Clarias gariepinus*

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ABSTRACT

Background and Objective: Preservation of smoked fish often faces challenges related to nutrient loss, microbial spoilage, and reduced sensory quality. Natural spices may offer a dual benefit by enhancing flavor and extending shelf life. This study aimed to evaluate the effects of three natural spices; ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), and lemongrass (*Cymbopogon flexuosus*) on the proximate composition, microbial load, and sensory attributes of smoked African catfish (*Clarias gariepinus*). **Materials and Methods:** Twenty live catfish (average weight: 700 g) were treated with aqueous extracts of the spices and smoked for 12 hrs. Proximate analysis was conducted using AOAC (2005) standard methods. Total viable counts were assessed using Nutrient Agar and MacConkey Agar after serial dilution. Sensory evaluation was performed using a hedonic scale (10 to 2) by 30 randomly selected panelists. Data were analyzed using one-way ANOVA in IBM SPSS Statistics version 20.0. **Results:** Crude protein content was significantly highest in the control (33.24±0.01%), followed by turmeric (25.33±0.08%) and ginger (24.49±0.01%), with the lowest in lemongrass-treated samples (7.57±0.01%). Lipid content was highest in ginger-treated fish (32.70±0.01%) and lowest in the control (17.76±0.01%). Microbial load was lowest in lemongrass-treated fish (6.00×10^2 CFU/mL) and highest in turmeric-treated samples (10.00×10^2 CFU/mL). Ginger-treated fish received the highest overall sensory score (134.20), while lemongrass-treated samples had the lowest (113.17). **Conclusion:** Ginger treatment enhanced sensory quality, while lemongrass demonstrated strong antimicrobial activity. These findings support the potential use of natural spices to improve the quality and safety of smoked catfish. Further research may explore spice combinations and long-term storage effects.

KEYWORDS

Clarias gariepinus, smoking, spices, microbial counts, hedonic scale

ISSN: 3080-0943 (Online)
ISSN: 3080-0951 (Print)
https://doi.org/10.17311/tes.2025.270.279

Received: 24 Mar. 2025
Accepted: 02 Jul. 2025
Published: 30 Sep. 2025

INTRODUCTION

Fish is no doubt an essential component of the human diet globally, especially in developing nations where it contributes significantly to both food security and economic livelihoods[1,2]. According to the Food and Agriculture Organization[3], Fish represents over 17% of animal protein intake in Sub-Saharan Africa. The role of fish in meeting dietary demands and generating income cannot be overemphasized in Nigeria. The African catfish (*Clarias gariepinus*) is reportedly one of the most commercially important fish species due to its hardy nature. It is capable of exhibiting high fecundity, rapid growth, and it is widely accepted among consumers[4]. Fish, however, spoils quickly after death due to the presence of high moisture and protein content, which provides a conducive environment for microbial growth[5,6]. The market value of fish is thus reduced by this spoilage and at the same time results to significant post-harvest losses. Out of the total quantity of fish produced in Nigeria, about 30-50% is lost as a result of inadequate preservation and storage techniques[3]. Given this, there is a need for stakeholders in the fisheries sector, particularly in areas with no access to modern preservation methods such as refrigeration and freezing, to intensify efforts towards post-harvest processing and preservation[7-9].

Smoking, along with other traditional preservation techniques such as drying and salting, remains the most used preservation method by artisanal fish processors[10,11]. Reports show that smoking is one of the most effective and popular preservation methods due to its ability to simultaneously dehydrate and infuse antimicrobial and antioxidant compounds into the fish through smoke exposure[12-14]. Through smoking, the shelf life of fish is extended by reducing water activity and keeping microbial proliferation under control[9,15]. Furthermore, sensory qualities like flavour, colour, and texture are equally enhanced[16]. Smoked fish is also prone to spoilage, especially when handling and storage conditions are poor[17].

In order to improve the effectiveness of traditional smoking, researchers have explored the use of plant-based spices as fish preservatives[13,18]. Spices such as ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), and lemongrass (*Cymbopogon flexuosus*) have been widely used in food processing[19,20]. This is due to their culinary and medicinal properties. These spices are rich in bioactive compounds that possess antimicrobial, antifungal, antioxidant, and anti-inflammatory properties, thus making them potential natural alternatives to synthetic preservatives[21]. Ginger, for instance, produces compounds such as gingerol and shogaol, which have demonstrated significant antimicrobial activity against a range of foodborne pathogens, while turmeric, on the other hand, contains a curcuminoid compound which is a strong antioxidant with proven efficacy against bacteria and fungi[22]. The oil content in lemongrass, specifically citral is widely known to inhibit microbial growth and prolong the shelf life of perishable foods[23,24]. The use of these spices in fish processing has gained attention because of the growing demand for safe, natural, and minimally processed food products. Several studies have reported the efficacy of natural plant additives in preserving the quality of smoked fish[13,18,25]. Adibe *et al.*[26], assert that the use of natural spices significantly improved the sensory attributes of smoked *C. gariepinus*. Linus-Chibuezeh *et al.*[13], stated that pretreatment methods enhance the quality and shelf life of smoked-dried sardine fish, with yaji and brine treatments being the most favourable. This means the application of spices can serve as an effective method of value addition, thus increasing consumer attraction.

As promising as these findings seem, there is a paucity of comprehensive studies that compare the effects of different spices on the sensory, nutritional, and microbial characteristics of smoked *C. gariepinus*. The majority of existing research has focused on single spices, which most time evaluate fish quality parameters in isolation. There is therefore, a need for a more integrated approach that simultaneously examines proximate composition, microbial load, and sensory qualities across multiple spice treatments. Moreover, the deeper comprehension of how each spice interacts with fish tissue during processing could inform the development of more effective preservation techniques, which are equally economical. The present study, thus, seeks to assess the effect of three selected spices (ginger, turmeric, and lemongrass) on the carcass quality of smoked *C. gariepinus*. The specific objective of this research is to determine the impact of each spice treatment on proximate composition, microbial stability, and organoleptic quality. This study will contribute to existing knowledge on sustainable fish preservation using natural additives and provide practical solutions to post-harvest losses in resource-limited communities.

MATERIALS AND METHODS

Study area: This study was conducted at the Fisheries Research Farm of the Department of Fisheries and Aquaculture, Federal University Wukari, Taraba State, Nigeria. The farm is located within the Northern Guinea Savannah Zone[27]. It experiences an average annual rainfall of approximately 1,050 mm and a temperature range of between 12 and 40°C. The relative humidity ranges between 20 and 80%, depending on the season[28]. The current research was completed within two months (March-April, 2024).

Fish sample collection and preparation: A total of twenty live specimens of African *C. gariepinus* with an average weight of 700 g were bought from the Ama Fish Farm of Wukari LGA, Taraba State. The processing of fish for smoking was done according to Okeke *et al.*[29]. The fish samples were eviscerated by cutting ventrally using a sharp knife, then saline water was used to wash carefully. The specimens were then randomly grouped into four treatments: Ginger-treated, turmeric-treated, lemongrass-treated, and a control without any spice, with each group comprising 5 fish specimens.

Preparation of specimens: Ginger (*Z. officinale*), turmeric (*C. longa*), and lemongrass (*C. flexuosus*) were procured fresh, sun-dried, and ground into powder. About 25 g of each spice was soaked in 50 mL of distilled water for 24 hrs. The fish specimens were then marinated in the filtrates of the solutions for 30 min before being set aside for smoking according to Adibe *et al.*[26].

Smoking procedure: Smoking was done in a traditional kiln using firewood (*Tectona grandis*) and coconut husk (*Cocos nucifera*) as fuel sources. The marinated fish were laid on wire mesh trays and smoked at an average temperature of 25°C for 12 hrs. Fish were turned at 30 min intervals to ensure even smoking. Thereafter, samples were cooled, labeled, and stored in airtight containers at room temperature for further analysis.

Methods of proximate analysis: The proximate analysis of processed samples was conducted[11]. This analysis included the determination of moisture, ash, lipid, fibre, crude protein, and nitrogen-free extract content for both control, ginger, turmeric, and lemongrass-treated fish specimens. The procedures that were followed are as follows.

Moisture content: Determination of moisture content was done by weighing 10 g of each sample, which was then oven-dried at 105°C for 6 hrs. It was then taken out in a desiccator and allowed to cool, and was weighed at intervals according to AOAC[30]:

$$\text{Moisture content (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100 \quad (1)$$

Ash content: Determination of ash content involved measuring approximately 3 g of each sample and placing in a crucible that was pre-weighed. The sample was then burnt in a muffle furnace at 550°C for 12 hrs. Ash content was calculated as the cooled residue (mineral content) as follows:

$$\text{Ash content (\%)} = \frac{\text{Weight of mineral content}}{\text{Weight of sample}} \times 100 \quad (2)$$

Lipid content: The lipid content of all the spice-treated specimens was analyzed using the Soxhlet extraction method. About 5 g of each sample was placed in a muslin cloth bag and put into a Soxhlet extractor, which contained 65% petroleum ether (boiling point range 60-80°C) as the solvent. The extraction lasted for 6 hrs, after which the solvent was evaporated, and the weight of the extracted fat was used to calculate lipid content:

$$\text{Lipid content (\%)} = \frac{w_1 - w_2}{w_1} \times 100 \tag{3}$$

Where:

w_1 = Weight of muslin cloth bag with sample
w_2 = Weight of cleaned empty muslin cloth bag

Fibre content: Crude fibre was determined using the trichloroacetic acid method. The control, ginger, turmeric, and lemon-treated samples were digested to remove soluble components, and the remaining residue was dried and weighed. Crude fibre was then calculated as the difference in weight of the sample as stated in the formula below:

$$\text{Crude fibre (\%)} = \frac{w_1 - w_2}{w_3} \times 100 \tag{4}$$

Where:

w_1 = Final weight
w_2 = Initial weight
w_3 = Weight of processed sample

Crude protein: The determination of crude protein was carried out using the Kjeldahl method[31]. The crude protein in all the fish samples was calculated by multiplying the total nitrogen by an empirical factor of 6.25:

$$\text{Crude protein} = \text{Nitrogen (\%)} \times 6.25 \tag{5}$$

Nitrogen-free extract (NFE): The nitrogen-free extract, which is an estimate of water-soluble polysaccharides, was calculated by subtracting the sum of percentages of moisture, ash, lipid, fibre, and crude protein from 100. It was calculated as follows:

$$\text{NFE (\%)} = 100\text{-(Moisture+ash+lipid+fibre+crude protein (\%))} \tag{6}$$

Microbial analysis: Microbial stability of spice-treated specimens and controls was assessed using total viable count (TVC) and coliform count. Serial dilutions of homogenized fish samples were cultured using nutrient agar (NA) and MacConkey Agar (MCA) according to Onjong *et al.*[32]. Plates were incubated at 37°C for 24 hrs, and results were expressed as Colony-Forming Units per Millilitre (CFU/mL).

Organoleptic assessment: A structured questionnaire based on a 10-point Hedonic scale (10: Excellent, 8: Very Good, 6: Good, 4: Fair, and 2: Poor) was used to quantify preferences. A sensory panel of 30 judges was constituted to include both staff and students. The panel was made up of 15 females and 15 males for fair representation[26]. They were guided on the criteria for scoring points on seven attributes, which were appearance, taste, colour, aroma, dryness, chewability, and overall acceptability. Both control and spice-treated specimens of *C. gariepinus* were then consistently presented to the panel in a blind-tested format for rating based on their perceptions.

Statistical analysis: Data obtained from proximate composition, microbial counts, and organoleptic assessment were subjected to One-way Analysis of Variance (ANOVA). Means were separated using Tukey's HSD test at a 5% significance level ($p<0.05$) with SPSS version 20.0.

Ethical statement: This study followed ethical guidelines for food research. No live animals were handled, as fish samples were purchased from a reputable fish farm and were used only for academic purposes. Analyses were conducted using standard AOAC[30] procedures in an accredited laboratory.

RESULTS

Proximate composition: Table 1 shows the proximate composition of smoked *C. gariepinus* treated with ginger, turmeric, lemongrass, and control. There was a significant difference ($p<0.05$) in the moisture content across the three treatments with lemongrass-treated fish recording the highest moisture content (39.81±0.01), followed by ginger (6.27±0.01) and control (5.57±0.01) while turmeric-treated samples had the lowest moisture content (4.66±0.01). The ash content ranged from 5.94±0.01 in lemongrass to 7.95±0.01 in ginger, while turmeric-treated specimens recorded 5.98±0.01 and the control 7.43±0.01. Crude protein was significantly higher ($p<0.05$) in the control group (33.24±0.01) followed by ginger (24.49±0.01) and turmeric (25.33±0.08). Lemongrass-treated specimens had the lowest protein content (7.57±0.01%). Lipid content was lowest (17.76±0.01) in the control, while the highest lipid value was recorded in the ginger-treated specimen (32.70±0.01). Turmeric and lemongrass recorded 31.47±0.01 and 28.29±0.01, respectively. For fibre content, values ranged from 8.19±0.01 in turmeric to 14.08±7.06 for the control. Ginger and lemon grass specimens recorded 12.87±0.01 and 12.49±0.01, respectively. Nitrogen-free extract (NFE) was highest in the control (26.92±0.02) and lowest in lemon grass (5.90±0.01).

Microbial analysis: The result for microbial counts of the treated fish samples using nutrient agar and MacConkey agar is presented in Table 2. Lemongrass had the lowest count (6.00×10^2 CFU/mL), followed by ginger-treated specimens with 7.00×10^2 CFU/mL while the highest microbial load was recorded in turmeric-treated fish (10.00×10^2 CFU/mL) and control with 8.00×10^2 CFU/mL. Microbial counts ranged from 1.20 (ginger-treated specimen) to 1.40 (turmeric-treated specimen) on MacConkey agar.

Table 1: Proximate composition of smoked *Clarias gariepinus* with different spices

Parameter (%)	Control	Ginger	Turmeric	Lemon grass
Moisture content	5.57±0.01^c	6.27±0.01^b	4.66±0.01^d	39.81±0.01^a
Ash content	7.43±0.01^b	7.95±0.01^a	5.98±0.01^c	5.94±0.01^c
Crude protein	33.24±0.01^a	24.49±0.01^c	25.33±0.08^b	7.57±0.01^d
Lipids	17.76±0.01^d	32.70±0.01^a	31.47±0.01^b	28.29±0.01^c
Crude fiber	14.08±7.06^a	12.87±0.01^a	8.19±0.01^b	12.49±0.01^a
CHO	26.92±0.02^a	15.73±0.01^c	24.34±0.01^b	5.90±0.01^d

*Means with different superscripts across rows are significantly different ($p<0.05$)

Table 2: Microbial count on the smoked *Clarias gariepinus* with different spices, ginger

Parameter	Control	Ginger	Turmeric	Lemon grass
MCA ($\times10^2$ CFU/mL)	1.10±0.00^c	1.20±0.00^b	1.40±0.00^a	1.20±0.00^b
NA ($\times10^2$ CFU/mL)	8.00±0.00^b	7.00±0.00^c	10.00±0.00^a	6.00±0.00^d

*Means with different superscripts across rows are significantly different

Table 3: Organoleptic attributes of smoked *Clarias gariepinus* treated with different spices

Treatment	Appearance	Taste	Colour	Aroma	Dryness	Chewability	Overall acceptability	p-value
Control	21.84±1.05	21.94±0.17	21.74±0.17	21.67±1.15	22.66±0.81	22.96±2.01	132.81	0.0001*
Ginger	21.69±0.17	23.19±0.10	21.44±0.78	22.81±0.04	22.50±0.33	22.57±0.19	134.20	0.0000*
Turmeric	20.98±0.05	20.92±1.23	20.93±0.44	21.54±0.83	22.26±0.28	20.88±0.46	127.51	0.0000*
Lemongrass	18.40±0.25	17.34±0.08	17.82±0.09	18.78±1.67	22.08±0.06	18.75±0.34	113.17	0.0000*

*Significant at 95% confidence level (p<0.05)

Organoleptic assessment: Results of the organoleptic quality of the differently treated specimens are presented in Table 3. Significant differences (p<0.05) were observed across all sensory parameters. Ginger-treated samples were rated highest for taste (23.19), followed by control (21.94) and turmeric (20.92). Lemongrass-treated specimens, however, recorded the lowest mean score for the taste category (17.34). For aroma, ginger similarly had the highest rating (22.81) while lemongrass scored lowest (18.78). The control specimen without any treatment had the best appearance score (21.84) and highest colour rating (21.74) while lemongrass had the least rating for both appearance and colour with 18.40 and 17.82, respectively. In terms of dryness and chewability, ginger-treated fish were preferred for texture and dryness, with the highest in chewability (22.97) and dryness (22.50). Lemongrass-treated fish were, however, the least preferred in these parameters. Ginger-treated specimens were most accepted (134.20 total score), while lemongrass recorded the lowest overall acceptability with a total score of 113.17.

DISCUSSION

The major determinant of shelf life in smoked fish is moisture content[33]. This is because high moisture levels promote microbial activity and spoilage. Turmeric-treated fish recorded the lowest moisture content in the present study, while lemongrass-treated fish had the highest. The significantly lower moisture content in turmeric-treated specimens is consistent with the findings of Olalekan[18], who reported that ginger and garlic-treated *Chrysichthys nigrodigitatus* samples had reduced moisture retention as a result of the osmotic properties of the spices, which may accelerate dehydration. Linus-Chibuezeh *et al.*[13] recorded moisture contents as low as 10.46% in spice-treated sardine samples. This affirms the capacity of natural spice treatments to reduce the moisture content of fish. Ash content, which represents mineral content, was highest in ginger-treated samples. Spices have been reported to exhibit protective effects on fish during processing, thus improving mineral retention[34]. An explanation for the moderate ash value in turmeric-treated and control specimens could be due to partial mineral leaching or thermal degradation during smoking[10]. Protein content, which is a major nutritional index, was highest in the control specimens. This finding partially corroborates the report of Kapile and Kapute[35], who documented better protein retention in untreated smoked *Oreochromis shiranus*. Tenyang *et al.*[36] and Olalekan[18], however, found that ginger and garlic improved protein stability. A possible reason for the lower protein content in lemongrass-treated fish could be attributed to its higher moisture retention capacity compared to the other spices[19]. It could also be due to the leaching of protein compounds during marination. Fish species, treatment time, and marination concentrations may also be responsible for the differences in the findings of these studies[25,36].

Lipid content was highest in ginger-treated fish specimens. This is possibly due to the rich antioxidant profile of ginger, thus reducing the rate of lipid oxidation during smoking[24,26]. Linus-Chibuezeh *et al.*[13] also documented lipid content ranges of 5.81-9.24, stating the potential of spices to protect lipids from rancidity. The lower values recorded by lemongrass and turmeric-treated specimens could be that they have lesser efficacy in acting against the oxidation of lipids. Results of the current study also show that ginger and lemongrass-treated specimens had higher crude fibre content. Even though fibre is not typically a major component of fish flesh, it could be that residues from the fibrous spice components made an increase to the values recorded. These values are comparable to those reported by Olalekan[18], who linked fibre variation to spice concentration and handling techniques during marination.

Nitrogen-free extract (NFE), which measures digestible carbohydrate, was highest in the control, then followed by turmeric-treated specimens. This corroborates the research of Ayeloja[12], who stated that garlic-ginger homogenate treatments yielded lower carbohydrate values, which could be a result of increased microbial metabolism. An explanation for the high NFE in this study could be attributed to limited microbial degradation in turmeric samples, or the inherent composition of the fish tissues may have influenced the type of spice.

The result of microbial analysis showed that lemongrass-treated fish had the lowest total viable count on nutrient agar. This finding supports the report of Teng *et al.*[37], who identified the antimicrobial efficacy of lemongrass due to citral and other essential oils, which disrupt microbial cell membranes. Olalekan[18], similarly, reported inverse relationships between microbial counts and the presence of clove, ginger, and garlic. Abdul Ibrahim *et al.*[7], reported that ginger-spiced *C. gariepinus* had lower microbial loads compared to control specimens during long-term storage. The finding of the present study is in agreement with this observation, as ginger-treated fish had microbial counts of 7.00×10^2 CFU/mL compared to 8.00×10^2 CFU/mL in the control. The highest microbial load was, however, recorded by the turmeric-treated specimen. This could be due to the limited antimicrobial activity of the spice or degradation of active compounds during smoking. Again, Linus-Chibuezeh *et al.*[13] observed variable microbial inhibition based on the spice type. Yaji-treated fish showed better microbial stability than nutmeg-treated samples in their research.

Sensory characteristics are used in determining consumer acceptance. Ginger-treated samples were rated highest across nearly all parameters, including taste, aroma, and overall acceptability. This is consistent with findings from Ayeloja[12], who reported that ginger-preserved catfish had high scores for odour and taste. The aromatic compounds in ginger are possibly responsible for favourable ratings by the sensory panel. Interestingly, lemongrass-treated fish had the lowest sensory scores across taste, aroma, appearance, and chewability. These results contradict the report of Linus-Chibuezeh *et al.*[13], who stated that spice-treated sardines, including those with/nutmeg, had high consumer acceptance. The discrepancy could stem from fish species differences or the pungency and flavour profiles of lemongrass, which some panelists might have found overpowering. Control specimens scored highest in appearance and chewability. A possible reason could be due to the absence of marination residue or colour alteration by spices. Olalekan[18] also reported similar findings, stating a negative correlation between spice concentration and some sensory parameters like taste and aroma at higher spice doses, thus establishing the need for optimal spice levels.

The current findings support the growing body of literature on the role of natural spices in enhancing fish preservation. Ginger offers the dual benefit of microbial suppression and sensory improvement, while lemongrass, even though less favourable in flavour, effectively controls microbial spoilage. Turmeric, which is traditionally acclaimed for medicinal benefits, however, underperformed in this context, which could be due to the poor heat stability of its active components. The discrepancies in the results of the present study and previous researches[12,13,18] could be explained by several factors, including differences in spice preparation (for example, fresh or dry spices), marination time, spice concentration, fish species and sizes, and storage duration. Moreover, the sensory perception of consumers can differ across regions based on cultural dietary preferences.

CONCLUSION

The inclusion of natural spices such as ginger, turmeric, and lemongrass into the traditional smoking process of *Clarias gariepinus* significantly influenced the quality of the smoked *C. gariepinus*. Ginger-treated fish specimens resulted in the best sensory appeal in terms of taste, aroma, and overall acceptability. Lemongrass, on the other hand, exhibited superior microbial suppression even though it recorded lower sensory ratings. Turmeric showed moderate effects in both sensory and microbial parameters. It is concluded that ginger can be used to enhance consumer preference, while lemongrass may serve as an effective natural preservative in smoked fish production. The study recommends the inclusion of ginger in commercial fish smoking processes to improve consumer appeal. Lemongrass could be adopted where microbial stability is the primary concern. There is a need to investigate the nutritional implications of long-term spice treatment of smoked fish.

SIGNIFICANCE STATEMENT

This study identified the differential effects of ginger, turmeric, and lemongrass on the nutritional, microbial, and sensory qualities of smoked *Clarias gariepinus*, which could be beneficial for improving product quality, safety, and consumer acceptance in fish processing industries. This study will assist researchers in uncovering critical areas of natural spice applications in fish preservation and processing that have remained unexplored by many. Consequently, a new theory on the synergistic use of natural bio-preservatives in enhancing both shelf life and sensory quality of smoked fish may be developed.

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