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Effect of moringa (*Moringa oleifera*) leaf and ginger (*Zingiber officinale*) rhizome marinades on the proximate and sensory qualities of smoked African catfish (*Clarias gariepinus*, Burchell 1822)

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Abstract
A lot of fish are lost after harvest due to inefficient processing and preservation techniques. This study investigated the incorporation of plant additives into smoking process of African catfish to improve its proximate and sensory properties. Fourty fish of 523.25 g average weight were randomly distributed into four groups. Three different marinades; T_1 (4% moringa leaf powder), T_2 (4% ginger rhizome powder), T_3 (2% moringa +2% ginger) were prepared. The fish were separately marinated and hot-smoked using modified drum smoking kiln for 10 hours. Proximate analysis revealed significant differences ($p<0.05$) among the treatments. The T_3 exhibited highest moisture (9.080%) and crude protein (52.633%) levels, while the T_2 had the maximum ash (11.893%) and fat (16.350%) contents. Sensory evaluation indicated no significant differences ($p>0.05$) among the treatments. The study concluded that marination of African catfish using combined moringa leaves and ginger rhizome significantly improved the proximate and sensory qualities of the fish.

Keywords: Kiln, marinade, nutrient, post-harvest and preservation

1. Introduction
In Nigeria, where fish plays important role in meeting the population's animal protein needs, the demand for fish exceeded domestic production levels [1]. Despite the country's estimated annual fish production of around 800,000 metric tonnes, the fish demand stands at approximately 2.1 million metric tonnes per year, resulting into a deficit of about 1.3 million metric tonnes [2]. Additionally, a significant volume of fresh fish are also loss after harvest due to inefficient processing and preservation techniques thereby exacerbating the fish demand-supply gap of the country [3] This disparity underscores the need for effective preservation techniques to address the shortfall and meet the growing demand for fish products.
Fish, being one of the most delicate and perishable product after capture faces obstacles in its preservation primarily due to its high moisture content (75-80%) [4]. This moisture creates a conducive environment for the growth of various bacteria [5]. The activities of lipoxidases and lipases produced by these bacteria contribute significantly to the deterioration of fish quality. In response to this challenge, methods such as smoking and sun drying are extensively employed in developing countries to preserve fresh fish [6]. However, these techniques can cause oxidation of fatty acids in fish. The food industry has begun exploring natural sources of antioxidants to address the challenges with fatty acids oxidation associated with these traditional fish preservation techniques [4].
Moringa leaves, known for their rich nutritional values and antioxidant properties [7], may mitigate nutrient degradation, while ginger, known with high antioxidative and antimicrobial characteristics [8], could further enhance preservation and sensory qualities. Previous studies have demonstrated the efficiency of moringa and ginger in preserving nutrients and improving sensory attributes in many food products [9, 10, 11], suggesting their potential use in smoked African catfish.

Understanding the impact of these natural additives on smoked catfish is essential for optimizing food preservation, quality, and nutrition. This study hereby investigates impact of moringa leaves and ginger rhizome marinades on smoked African catfish. The study will focus on the impact of the treatments on the nutritional and sensory qualities of the resultant fish product.

2. Materials and Methods

2.1 Experimental site

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 [12]. Approximately 1,000mm mean annual rainfall is experienced in the southern parts of the state while little less than 800mm is experienced in the extreme north. The state experiences 3-5 months rainy season with mean ambient temperature reaching 41ºC peak and 16ºC during period of cool season [13, 14].

2.2 Procurement and treatment of moringa leaf and ginger rhizome

Fresh moringa leaves and dry ginger rhizomes were purchased from Kasuwan-rimi market in Kano State. The moringa leaves were shade-dried for 5 days. The two products were milled into fine powder and packed in separate polythen bags. They were kept in clean and dry place until when needed.

2.3 Fish procurement

The catfish samples were purchased from Sareji Intergrated Farms located in Kano State, Nigeria. A total of 40 healthy African catfish (*Clarias gariepinus*) of average weight of 523.25 g were acquired for the study. The fish were transported live to the Department of Fisheries and Aquaculture hatchery unit farm, Bayero University, Kano, Nigeria. Upon arrival, the fish were held in a concrete tank and acclimated for 2 days prior to beginning of the experiment.

2.4 Experimental design

The procured fish were randomly distributed into four experimental groups in a complete randomized design. The treatment groups were: T_1 (4% moringa leaf powder marinade), T_2 (4% ginger powder marinade), T_3 (2% moringa + 2% ginger powder marinade) and Control treatment.

2.5 Preparation of treatments' marinades

The moringa leaf and ginger rhizome powder marinades were prepared by dissolving the powder in boiled water and kept for 7 hours to adequately get dissolved. Preparation of the different concentrations of the marinade was done in the following way;

4% moringa leaf marinade.
10 litres of water was used

Given that 1litre of water = 1000 g

Weight of water = 10 × 1000 g = 10,000 g

$$\text{Weight of moringa powder} = \frac{4}{100} \times 10{,}000\ \text{g} = 400\ \text{g}$$

4% ginger rhizome marinade.

$$\text{Weight of ginger powder} = \frac{4}{100} \times 10{,}000\ \text{g} = 400\ \text{g}$$

The combined 2% moringa + 2% ginger marinade.

$$\text{Weight of moringa powder} = \frac{2}{100} \times 10{,}000\ \text{g} = 200\ \text{g}$$

$$\text{Weight of ginger powder} = \frac{2}{100} \times 10{,}000\ \text{g} = 200\ \text{g}$$

2.6 Fish processing and smoking procedure

The catfish samples were stunned and moved to a processing table. Subsequently, they were gutted and washed with clean water. The fish were allowed to drain for 10 minutes and subsequently underwent a 15-minute marination process in each of the treatments' solutions.

For smoking, a modified drum-type smoking kiln with charcoal heating was utilized. Marinated fish were arranged in a single layer and subjected to smoking. Throughout the 10-hour smoking period, they were periodically turned to ensure uniform drying and smoking.

2.7 Proximate analysis

The smoked catfish samples were subjected to proximate analysis. Crude protein content, ash content, crude fat, nitrogen-free extract, and moisture content were analyzed using standard methods on the collected samples [15].

2.8 Sensory evaluation

Twenty panelists were trained and tasked with rating of the smoked fish samples. The organoleptic assessment done are flavour, taste, texture and appearance using a hedonic scale ranging from 1 to 9 in ascending order of ranking. The assessments took place in separate partitioned booths, with palate cleansers offered between samples to prevent any lingering taste effects.

2.9 Data analysis

The sensory scores and proximate composition parameters ware analyzed using the Kruskal-Wallis test to determine significant differences between the treatments (P<0.05). Dunn method of joint ranking was used as *post hoc* test to determine treatment pairs with significant treatment. Non parametric test was done due to the non-normality of the proximate data. All statistical analyses were done in JMP (version 17.0) statistical software.

3. Results

3.1 Proximate composition of the four smoked fish treatments

Table 1 presents the mean and standard deviation values for various proximate parameters of the four treatments. The combined ginger and moringa treatment (T_3) showcased the highest moisture content (9.08%) and crude protein level (52.63%), while exhibiting the lowest fat (10.57%) and crude fiber (1.16%) contents. In contrast, the ginger treatment (T_2) demonstrated the maximum ash (11.89%) and fat (16.35%) contents, alongside the lowest crude protein value (42.39%). The Moringa treatment (T_1) displayed moderate levels of moisture (7.84%), ash (9.643%), fat (13.33%), crude protein (46.58%), and carbohydrates (21.24%). Additionally, the control group exhibited the lowest moisture content (7.07%),

yet the highest crude fiber (2.59%) and carbohydrate (24.83%) contents, with moderate levels of ash (8.59%), fat (12.70%), and crude protein (44.22%) contents.

The results depicted in Table 2, analyzed using the Kruskal-Wallis test highlight significant variations (p<0.05) in proximate composition across the four smoked fish treatments. Notably, T_3 had significantly higher (p<0.05) moisture content than the control and also higher crude protein than T_2 treatment. Similarly, ash content was significantly higher (p<0.05) in T_2 than the control as it also had higher fat content than T_3. The control however, had significantly higher (p<0.05) higher crude fibre than T_3.

Table 1: Mean (±SD) of proximate parameters of each treatment group

Parameter	T_1	T_2	T_3	Control
%MC	7.836±0.180	8.400±0.151	9.080±0.180	7.067±0.094
%ASH	9.643±0.129	11.893±0.948	9.437±0.071	8.587±0.463
%FATS	13.333±1.250	16.350±0.937	10.573±0.935	12.700±0.223
%CP	46.577±1.809	42.390±1.749	52.633±0.881	44.223±0.590
%CF	1.373±0.120	1.560±0.185	1.160±0.128	2.593±0.172
%CHO	21.237±0.661	19.407±3.508	17.117±1.654	24.830±0.541

MC=Moisture content, CP =Crude protein, CHO =Carbohydrate, CF =Crude fibre, FAT=Crude fat, SD= Standard deviation

Table 2: Comparison between proximate parameters of the different treated smoked fish

Parameter	T_1	T_2	T_3	Control	Chi-square value
	Mean rank	Mean rank	Mean rank	Mean rank	
%MC	5.000^{ab}	8.000^{ab}	11.000^{a}	2.000^{b}	10.3846
%ASH	7.833^{ab}	11.000^{a}	5.167^{ab}	2.000^{b}	10.2023
%FATS	7.000^{ab}	11.000^{a}	2.000^{b}	6.000^{ab}	9.4615
%CP	8.000^{ab}	2.333^{b}	11.000^{a}	4.667^{ab}	9.9744
%CF	5.167^{ab}	7.500^{ab}	2.333^{b}	11.000^{a}	9.3532
%CHO	7.000^{a}	5.000^{a}	3.000^{a}	11.000^{a}	8.0769

Treatments' mean ranks with different superscripts within the same row are significantly different from each other (p<0.05)

3.2 Sensory evaluation of the four smoked fish treatments

Sensory evaluation of the smoked fish under the four treatments were statistically evaluated (Table 3). Even though no significant difference (p>0.05) exist among the treatments for each of the four organoleptic tests, the result indicated T_3 produced best fish with highest ranking for flavour and appearance while still ranking second highest in taste. The control treatment had best rating in texture and second best in flavour while T_2 had best rating in taste and ranked second in Texture and appearance. T_1 was also lowest in flavor and appearance.

Table 3: Comparison between the treatments' evaluated sensory parameters

Parameter	T_1	T_2	T_3	Control	Chi-square value
	Mean rank	Mean rank	Mean rank	Mean rank	
Flavour	33.375^{a}	38.550^{a}	45.600^{a}	44.475^{a}	3.8192
Appearance	34.500^{a}	42.275^{a}	47.200^{a}	38.025^{a}	3.5202
Taste	37.575^{a}	44.500^{a}	42.575^{a}	37.350^{a}	1.5028
Texture	40.225^{a}	41.150^{a}	39.400^{a}	41.225^{a}	0.0867

Treatments' mean ranks with different superscripts within the same row are significantly different from each other (p<0.05)

4. Discussion

The findings of this study on the incorporation of ginger and moringa marinades into the smoking process of African catfish are in consistence with previous studies indicating the potential of these plant materials to positively impact the proximate composition of the fish [7, 16]. Notably, the moisture content of the fish treated with moringa (T_1) was significantly low, this could be attributed to compounds in moringa such as calcium salts with reasonable dehydrating properties [17]. The high dehydration effect of moringa on the processed fish and its inherent protein composition could be reason for the high protein content of treatment T_1 and it possible impact on T_3 [7]. On the other hand, higher fat content in T_2 could be attributed to high fat profile of many indigenous ginger spices in Nigeria [16]. Overall, the proximate analysis underscores the effectiveness of ginger and moringa as natural additives in improving the nutritional profile of smoked catfish.

Sensory evaluation of the treatments revealed the potentials in the treatment composed of ginger and moringa (T_3) towards improving the flavour and general appearance of smoked fish. This result align with previous findings suggesting that ginger and moringa enhances the sensory attributes of smoked fish, making it more appealing to consumers [3, 18]. Ability of ginger when heated to produce a flavour enhancing gingerol could be attributed to the improved flavour of the ginger marinated catfish [19]. Contribution of moringa to this achievement might result from it production of a potential antioxidant (Zeatin) and a flavonoid (quercetin) known to neutralize free radicals and relieve inflammation[20].

5. Conclusion and Recommendations

The incorporation of combined ginger and moringa marinade into the smoking process of catfish significantly influences its proximate composition and sensory qualities. The marination resulted in smoked catfish with favorable moisture content, protein levels, and sensory attributes. These findings underscore the potential of natural additives in improving the nutritional value and overall appeal of smoked fish products.

Based on these results, we recommend the adoption of combined ginger and moringa marinade as alternative additives in the smoking process of catfish to improve its quality and marketability. Further work could explore optimal

concentrations and application methods of these additives to maximize their efficiency in preserving nutrients and enhancing sensory attributes. Additionally, studies focusing on consumer acceptance and market preferences could provide valuable insights into the commercial viability of ginger and moringa marinated smoked fish products. Overall, integrating natural additives like ginger and moringa presents a promising approach towards addressing the challenges of fish preservation and meeting the increasing demand for high-quality fish products.

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