

EVALUATION OF ORGANOLEPTIC PROPERTIES AND MICROBIAL LOADS OF SMOKED *Clarias gariepinus* TREATED WITH SOME NATURAL SPICES

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ABSTRACT

This study investigated the effect of some natural spices on organoleptic properties and microbial load of smoked Clarias gariepinus. Clove, garlic, and ginger were procured and utilized in the research. The spices were processed into powder form, with 20 grams allocated for each treatment. The samples were divided into four groups: T1 (salt control), T2 (clove), T3 (garlic), and T4 (ginger) before undergoing hot smoking. Organoleptic evaluation was carried out using open-ended structured questionnaires employing the 9-point hedonic scale. Data from the organoleptic assessment and microbial analysis were analyzed using one-way analysis of variance. The results of the organoleptic assessment revealed a significant difference ($p < 0.05$) among the scored parameters, with the highest overall acceptance observed in T4 (ginger) scoring 8.05. Microbial analysis indicated that T3 (garlic) and T4 (ginger) exhibited inhibitory effects on bacteria and coliforms, with counts of 4.70×10^3 cfu/g and 3.50×10^3 cfu/g, respectively, falling within the acceptable limits set by ICMSF. Staphylococcus aureus and Escherichia coli were the only bacteria detected after six months of storage. In conclusion, T4 (ginger) and T2 (clove) were favored by the panelists, while T3 (garlic) demonstrated effective prevention of bacterial infestation. The spices utilized in this study have proven to be efficacious.

Keyword: African catfish, microbial analysis, organoleptic properties, pre-storage, post-storage, spices,

INTRODUCTION

Fish is an affordable source of protein and vital nutrients needed in human diets. It serves as a significant source of animal protein for many Nigerians, with an estimated annual per capita fish consumption of 13.3 kg in 2013 (FAO, 2017). Fish is prone to spoilage at room temperature, which often encourages bacterial activity, enzymatic processes, and chemical fat oxidation after capture (Nur et al., 2020). Nigeria accounts for approximately 30-50% of fish postharvest losses due to inadequate handling (Kuley et al., 2017). Microbial spoilage accounts for 30% of global fish losses.

Food spoilage impacts the texture, nutritional value, and flavor of food, rendering it unsuitable for consumption (Yoganathan, 2020). Once fish is caught, a complex series of enzymatic, bacterial, and chemical transformations begins (Adeyeye, 2016). The digestive system of fish naturally contains enzymes that help break down food particles in a living fish (Romero et al., 2014; Rawat, 2015; Egerton et al., 2018). However, these enzymes begin to break down the fish's stomach as soon as the fish dies, subsequently moving to the flesh and leading to its decay. Ultimately, the fish becomes soft, and a strong odor is detected. Measures for food

preservation and safety can be implemented to inhibit the growth and activity of food-borne pathogens, ensuring they remain at acceptable levels (Yoganathan, 2020). The main goal of fish processing and preservation is to minimize the biochemical processes (including enzymatic, microbial, and chemical reactions) that contribute to the spoilage of fresh fish (Gonugodugu et al., 2017). Preservation also ensures that fish is available both during the season and off-season (Oluborode, 2015). Fish preservation has been part of seafaring cultures for centuries. Different preservation techniques are used to prevent postharvest losses and spoilage. Frying, fermentation, drying, salting, and smoking are among the traditional methods of processing and preservation (Legese, 2021). For many years, smoking has been used as a method to extend microbial loads and improve food flavor (Chakraborty & Chakraborty, 2017). In Nigeria, the primary reasons for smoking fish vary, including preservation, flavor enhancement, and maintaining protein availability for consumers whenever needed (Hoffman et al., 2017).

Spices are consumable plant substances that have antioxidant, antiseptic, and bacteriostatic qualities. They are incorporated into foods to delay the onset of spoilage, such as rancidity, and serve as seasonings to enhance the flavor of foods (Kefas et al., 2022). Incorporating spices into food extends its shelf life, reducing food waste due to their antioxidant and antimicrobial properties (Amuneke et al., 2020; Ekelemu et al., 2021). African catfish is one of the most popular freshwater fish species in the world (Ayoola & Bamiro, 2017; Marimuthu et al., 2017) and has been cultured intensively and extensively in Nigeria (Adeniyi et al., 2021). The aim of this study was to evaluate the organoleptic properties and microbial loads of smoked *Clarias gariepinus* treated with some natural spices.

MATERIALS AND METHODS

Study Area

The study was conducted at the teaching and

research fish farm of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University Dutse, Jigawa state located on latitude 11° 42' North and longitude 9° 22' East and altitude of 436m above sea level (Compass, 2024). It is within the Sudan Savannah agro-ecological zone of Nigeria and is characterized by dry climate which starts from October to May; cold dry climate starting from November to February and hot dry climate during March to May. The rainy season usually begins from June to September with mean annual rainfall of 638mm per annum (Climate-data, 2024), relative humidity of 15 to 20% (City-population, 2024) and atmospheric temperature of 27.1°C and can reach up to 41°C during April and May and may fall below 20°C during December and January (Climate-data, 2024).

Experimental Design

The experiment consisted of four (4) treatments: T1 (salt as control), T2 (clove), T3 (garlic), and T4 (ginger), with three (3) replicates each, allocated in a completely randomized design (CRD).

Fish Sample Collection and Preparation

Fresh samples of *Clarias gariepinus* were procured from the landing site of Kafin Gana Reservoir, Birnin Kudu Local Government Area, Jigawa State, in the early morning hours (8 a.m.) and transported to the Teaching and Research Fish Farm of the Department of Fisheries and Aquaculture, Federal University Dutse, Jigawa State, in an icebox container. The 24 kg (84 pieces) of purchased fish samples, with an average weight of 268 g and an average standard length of 24.7 cm, consisting of 21 pieces per treatment, were degutted, cut along the sides, and washed to remove external dirt. The fish samples were then soaked in a saline solution for about 30 minutes, after which the solution was drained, and the fish samples were divided into respective treatments.

Spice Preparation and Application

The natural spices—clove, garlic, and ginger—were purchased from Dutse Ultra-

Modern Market, Jigawa State. The spices were crushed into powdered form using a local mortar and pestle. Twenty grams (20 g) of the ground spices were weighed using a sensitive scale (Digital Pocket Scale BP-N Series, with 7 weighing modes). The samples were assigned to each treatment: T2 (clove), T3 (garlic), and T4 (ginger). The spices were mixed properly and allowed to stand for 30 minutes on a wire mesh sieve before smoking, to allow ample time for the treatments to penetrate the fish samples (Makinde and Babalola, 2011). Each batch of treatments was smoked separately in a smoking kiln. The department's traditional smoking kiln, made from a 400 L drum with a length of 90 cm and a diameter of 58 cm, was used for the smoke-drying process. The drum was cut midway, and the base was used as a combustion chamber with a firebox of $22 \times 22 \text{ cm}^2$. The kiln has four chambers, with a carrying capacity of 30–50 fish. The firing section of the kiln was filled with hardwood to produce smoke, and the stem of the Ebony (*Diospyros ebenum*) tree was used as firewood. The fish samples were introduced into the smokehouse (preheated for 30 minutes). The temperature of the smoking chamber was maintained between 60 and 70°C by adjusting the firewood burning in the chamber. The treated fish were smoked for 3 to 4 hours and allowed to cool overnight (Iheanacho et al., 2017).

Samples for proximate composition, organoleptic tests, and microbial loads were selected from each treatment and separately packaged in polyethylene bags, labeled according to their respective treatments (T1, T2, T3, and T4), sealed (to prevent dust, dirt, and flies), and stored at room temperature for six (6) months.

Organoleptic Assessment

The organoleptic testing was conducted using open-ended structured questionnaires with the 9-point hedonic scale (Iwe, 2014) and distributed to thirty (30) evaluators of different genders for *Clarias gariepinus*. Scoring of flavor, taste, color, appearance, and general acceptability of the products by evaluators was conducted by ranking as follows: 9 – liked

extremely, 8 – liked moderately, 7 – liked very much, 6 – liked slightly, 5 – neither liked nor disliked, 4 – disliked slightly, 3 – disliked very much, 2 – disliked moderately, and 1 – disliked extremely. The experimental process was fully explained to the evaluators before allowing them to participate in the organoleptic testing. They were briefed about the fish species they would taste, the source of the fish, and the processing method. The study was conducted before storage, within the time frame when the fish were assumed to be in a condition that was acceptable to consumers.

Microbial Loads Determination

The microbial loads of the experimental fish were determined before and after storage for a period of 6 months. Microbial test was conducted to assess the spices that are more effective. The appearance, color, texture, and smell of the smoked fish was also assessed by regular physical examination on any signs of spoilage, such as discoloration, off-putting odors, or texture changes, might indicate that the fish has exceeded its shelf life. Microbial analysis was conducted on the sample where bacterial and coliform were counted and identified.

Preparation of Media

Nutrient agar (NA) and MacConkey agar was used for enumeration of aerobic mesophilic bacteria and coliforms, respectively, from the smoked fish samples. Mannitol salt agar and Salmonella-Shigella agar was used to assess the presence of *Staphylococcus aureus* and *Salmonella* species. Nutrient agar, MacConkey agar, Mannitol salt agar, and Salmonella-Shigella agar was also prepared according to the manufacturers' instructions (Ikpi and Offem, 2011). The media was dissolved in distilled water, heated to dissolve the agar completely, and then autoclaved at 121°C for 15 minutes. The sterilized media was cooled and poured into sterile Petri dishes. Except SSA which was heated on a magnetic stirrer until it has dissolved, and then dispensed on to petri dishes without autoclaving.

Sample Preparation

One gram of the smoked fish samples was collected aseptically and homogenized in 10 ml of sterile peptone water. The homogenate was subjected to a 10-fold serial dilution using sterile peptone water as the diluent, with 10^{-2} and 10^{-3} dilutions prepared for plating (Ezeama, 2007).

Aerobic Mesophilic Bacterial Count

For the enumeration of aerobic mesophilic

bacteria, 0.1 ml of each dilution (10^{-2} and 10^{-3}) was transfer onto separate nutrient agar plates. The samples were spread evenly across the surface using a sterile spreader after which the plates were incubated aerobically at 37°C for 24h. Post incubation, the number of colonies on each plate was counted. The Colony formation units (CFU) per gram of sample was calculated using the formula:

$$\text{CFU/G} = \text{NUMBER OF COLONIES} / \text{VOLUME PLATED} \times \text{DILUTION FACTOR}$$

Where CFU = Colony formation units

The final CFU per gram was obtained by averaging the results from the 10^{-2} and 10^{-3} dilution plates.

Coliform Count

To enumerate coliforms, 0.1 ml of each dilution (10^{-2} and 10^{-3}) was transferred onto MacConkey agar plates and spread evenly. The plates were also incubated at 37°C for 24h. Coliform colonies, a typically pink was counted, and the CFU per gram was also calculated using the same formula as above. The results from the 10^{-2} and 10^{-3} dilution plates were obtained from the final count.

Assessment for *Staphylococcus aureus*

To detect *Staphylococcus aureus*, 0.1 ml of the homogenized sample was obtained and transferred onto Mannitol salt agar plates and spread evenly. The plates were incubated at 37°C for 24 h. the bright yellow colonies indicative of mannitol fermentation was then sub-cultured onto fresh Mannitol salt agar plates and incubated for an additional 24 hours. A coagulase test was performed on suspected colonies by introducing a small amount of the colony into blood plasma; the formation of clots or coagulation confirmed the presence of *Staphylococcus aureus*.

Assessment for *Salmonella spp.*

For the detection of *Salmonella* species, 0.1 ml of the homogenized sample was transferred onto *Salmonella-Shigella* agar plates and spread evenly. The plates were incubated at 37°C for 24

hours. Black colonies, indicative of hydrogen sulfide production, was counted to determine the presence of *Salmonella* species.

Assessment of *Escherichia coli*

This was done using Eosine Methylene Blue Agar at 37°C for 24 h. Colonies with green metallic sheen was counted as *E. coli*.

Identification of Bacteria

Identification of the isolate's bacteria were carried out based on colonial, morphological and biochemical test according to Bergey's Manual of Systematic Bacteriology (Amagliani *et al.*, 2012). Microscopic examination of surface colonies on nutrient agar medium was used to determine the shape and arrangement of microorganisms. Morphological characteristics were studied on the oil immersed slide under the microscope after gram staining. The use of biochemical tests, such as catalase, oxidase, coagulase, indole, citrate and mannitol test, which interpret the bacterial genus and species according to Clinical and Laboratory Standards Institute (CLSI) guideline (CLSI, 2016) was carried out.

Gram Staining

The Gram's staining technique is carried out to differentiate the bacterial isolates into Gram positive and Gram-negative bacteria based on

their cell wall composition. A loopful of a 24h culture is picked and used to make a smear on a clean, greased slide. The smear was heat fixed by passing over a flame and subsequently, the smear is flooded with crystal violet for one minute and rinsed under slow running tap. The smear is flooded with iodine for one minute and rinsed under slow running water. Thereafter, the smear is decolorized using 95% alcohol for 30 seconds or until smear no longer washes off if held at an angle and rinsed with water. Furthermore, the smear is counter stain with safranin for 30 seconds and rinsed with water. Then it is allowed to air dry. Thereafter, a drop of immersion oil is placed on the smear and viewed under the light microscope using oil immersion objective lens. Cells that appeared purple were recorded as Gram- positive cells while cells that appeared pink under the microscope are taken as Gram-negative cells.

Results

Organoleptic Properties of *Clarias gariepinus*

The organoleptic properties of treated smoked *Clarias gariepinus* is shown in Table 1 indicating the difference ($p < 0.05$) between the means, for appearance T1 (salt) was recorded with highest value 8.30 and the lowest in T2 (clove) 6.75. The highest taste/flavor score was observed in T2 (clove) 7.95 and the lowest was found in T1 (salt) 6.70. High texture percentage was in T2 (clove) 7.90 while T3 had the lowest value with 6.90. T4 (ginger) recorded 7.75 as the highest score of aroma/smell while 6.45 from T1 (salt) had the lowest percentage. Maximum overall acceptance was recorded in T4 (ginger) 8.05 whereas the minimum was observed in T1 (salt) 6.60.

Table 1: Sensory scores of smoked *Clarias gariepinus* with natural preservatives

Parameter	Treatments			
	T1 (Salt)	T2 (Clove)	T3 (Garlic)	T4 (Ginger)
Appearance	8.30±1.17 ^a	6.75±1.62 ^b	7.40±1.70 ^{ab}	7.60±0.75 ^{ab}
Taste/Flavor	6.70±1.34 ^b	7.95±1.01 ^a	6.85±1.81 ^b	7.90±0.97 ^a
Texture	7.25±1.25 ^{ab}	7.90±1.67 ^a	6.90±1.97 ^b	7.55±1.05 ^{ab}
Aroma/Smell	6.45±1.45 ^b	7.45±0.89 ^a	7.05±1.15 ^{ab}	7.75±1.12 ^a
Overall acceptance	6.60±1.19 ^b	7.80±1.06 ^a	7.45±1.32 ^a	8.05±0.83 ^a

Mean value within the same row with similar superscripts are not significantly different ($p > 0.05$).

Bacteria and Coliform Count on *Clarias gariepinus* smoked and treated with different spices

The results presented in Table 2 shows the bacteria and coliform count of pre-storage and post storage smoked treated *Clarias gariepinus*, and it was found that T1 (salt) had the highest bacteria count at 0.84×10^3 cfu/g and also the highest coliform count at 0.55×10^3 cfu/g. Conversely, T2 (clove) exhibited the lowest bacterial percentage of 0.36×10^3 cfu/g and a coliform count of 0.2×10^3 cfu/g. T3 (garlic) and T4 (ginger) both yielded zero counts, from the result of pre-storage sample.

The result obtained after six (6) months storage,

indicated significant difference between the means, T1 (salt) $8.55 \pm 0.35 \times 10^3$ had the highest bacteria count and coliform count $5.50 \pm 0.14 \times 10^3$. While the least bacteria and coliform count were found in T3 (ginger) $4.70 \pm 0.14 \times 10^3$ and $3.50 \pm 0.28 \times 10^3$. All the value obtained from the treatments are within the maximum recommended value of bacteria count for good quality fish products which is 5×10^5 colony forming unit per gram according to (ICMSF, 2005). And the Microbiological Guideline for Ready to –eat – Food which is less than 10^6 (2007), except T1 salt (control) and T2 (clove) with $5.50 \pm 0.14 \times 10^3$.

Table 2: Bacteria and Coliform Count *Clarias gariepinus*

Treatment	Pre-storage		Post storage	
	Bacteria count (cfu/g)	Coliform count (cfu/g)	Bacterial count (cfu/g)	Coliform count (cfu/g)
T1 (control) salt	0.84×10^3	0.55×10^3	$8.55 \pm 0.35^a \times 10^3$	$5.50 \pm 0.14^a \times 10^3$
T2 (clove)	0.36×10^3	0.2×10^3	$5.90 \pm 0.00^b \times 10^3$	$4.60 \pm 0.28^b \times 10^3$
T3 (garlic)	NIL	NIL	$4.70 \pm 0.14^c \times 10^3$	$3.50 \pm 0.28^{bc} \times 10^3$
T4 (ginger)	NIL	NIL	$5.10 \pm 0.14^c \times 10^3$	$4.00 \pm 0.14^c \times 10^3$

Characterization and Identification of the Bacteria Isolates in *Clarias gariepinus*

Table 3 present the result from isolated and identified bacteria found in this study. *Staphylococcus aureus* and *Escherichia coli* are the two identified bacteria. it also indicates the presence of both Gram positive and Gram-

negative bacteria. T1 and T2 recorded *Staphylococcus aureus* and *Escherichia coli* bacteria, while *Escherichia coli* was the only bacteria identified in T3 (garlic), and *Staphylococcus aureus* was found in T4 (ginger).

Table 3: Characterization and Identification of the Bacteria Isolates in *Clarias gariepinus*

Sample	Media	Gramstain			Biochemical tests				Inference
			IND	MTR	VP	CRT	CAT	COA	
T1	MSA (+)	+ve cocci	-	+	+	+	+	+	<i>S. aureus</i> present
	SSA (-)	-	-	-	-	-	-	-	<i>Salmonella spp</i> or <i>Shigella spp</i> absent
T2	EMB (+)	-bacilli	+	+	-	-	+	-	<i>E. coli</i> present
	MSA (+)	+ve cocci	-	+	+	+	+	+	<i>S. aureus</i> present
	SSA (-)	-	-	-	-	-	-	-	<i>Salmonella spp</i> or <i>Shigella spp</i> absent
T3	EMB (+)	- bacilli	+	+	-	-	+	-	<i>E. coli</i> present
	MSA (-)	-	-	-	-	-	-	-	<i>S. aureus</i> absent
	SSA (-)	-	-	-	-	-	-	-	<i>Salmonella spp</i> or <i>Shigella spp</i> absent
T4	EMB (+)	+ bacilli	+	+	-	-	+	-	<i>E. coli</i> present
	MSA (+)	+ cocci	-	+	+	+	+	+	<i>S. aureus</i> present
	SSA (-)	-	-	-	-	-	-	-	<i>Salmonella spp</i> or <i>Shigella spp</i> absent
	EMB (-)	-	-	-	-	-	-	-	<i>E. coli</i> absent

Discussion

Organoleptic Properties of *Clarias gariepinus*

The final finding of this research, has showed that the use of natural spice on fish sample have a great effect toward the consumers acceptability because it enhances the taste, texture, aroma and general appearance of the fish. This agreed with a previous study by (Nicholas *et al.*, 2023) who noted that dipping fish into a concentration of ginger before smoking has positive effects on the general quality of the final products. Chibuezeh *et al.*, (2022) in his research reported that the appearance of the control sample and Sample B (containing only salt) were the least preferred by the panelists with mean scores of 7.05 and 7.33 respectively which translates to “Like moderately” on the Hedonic scale, this defers with this study which show the least preferred sample in T2 (clove) with 6.75. Kutte, (2022) result shows that control sample (T0) with no treatment received lower panel scores than the spice treated samples with regards to appearance, juiciness, flavor, rancidity, texture and general acceptability throughout the storage period, this agreed with finding of this research with only difference in the appearance were sample T1(salt) had the highest score by the panelist. Chibuezeh *et al.*, (2022) further reported the best rates in terms of taste and aroma were sample E (Yaji + brine) with a sensory score of 8.05 and 7.90 for taste and aroma respectively, this slightly agreed with the present study which score 7.95 T2 (clove) and T4 (ginger) 7.75 for taste and aroma. They also stated that control (sample A) was least preferred by the panelists with a sensory score of 6.14 and 6.24 for taste and aroma respectively. This statement is in agreement with this current research as T1 salt (control) has the least score by the panelist. Kefas *et al.*, (2022) in his final report present that the highest overall acceptability was obtained in SCL (Drum Kiln Clove) and SCB (Drum Kiln Combine ginger and clove) 7.63 ± 0.74 and the lowest overall acceptability was obtained in SCT (Drum Kiln whole control) 6.25 ± 0.71 after preservation.

This disagreed with this report where the overall acceptability was recorded in T4 ginger (8.05 ± 0.83) and the lowest Vasala, 2004 in T1 salt (6.60 ± 1.19). It also concurs with the reported of Ihuahi *et al.*, (2006) stated that treated *Clarias gariepinus* with mixture of pepper and garlic paste take more acceptable organoleptic possessions. This collaborates with the finding of this study. Iheagwara, (2013); Taniya and Kannan, (2016) documented that natural spices have favored results on the organoleptic properties of smoked *C. gariepinus* in terms of taste, flavor, appearance and general acceptability, which agreed with this findings as treated *C. gariepinus* showed the same result by the panelist. Ibrahim *et al.*, (2017) stated that the 50 g/kg ginger extract during storage period shows the highest overall acceptability during the organoleptic assessment obtained by the panelist, this tally with the finding of this research. Also, this research finding aligns with the report by Diah and Th., (2017) who reported that spice smoked tilapia perform well in terms of appearance and texture, according to sensory evaluation by the panelist. According to the finding of Adibe, (2018) samples treated with natural spices gave the most desirable results in terms of taste, appearance, flavor and general acceptability. He further reported that samples treated with natural spices gave longer shelf life, this result is in accordance to this present report as spices prolong the sample fish shelf life. Ayeloja, (2019) in his report stated that African mud catfish is better spiced with garlic–ginger homogenate as the taste panelist preferred the odor, flavor, and texture of smoked garlic–ginger spiced smoked catfish than when garlic or ginger is used singly or when no preservative was added This is not in line with this study because it revealed that the used of single ginger or garlic is also effective and is widely accepted by the consumers which are the major concern.

Microbial loads of *Clarias gariepinus*

Research findings suggest that natural spices are effective in preventing microbial activity in fish

by extending the duration of microorganism onset. Clove (T2) is outperformed by garlic (T3) and ginger (T4) in terms of effectiveness against bacteria at low concentrations, whereas salt (T1) is found to have the least impact. The antioxidants present in the smoked-dried fish could be one factor contributing to the low microbial count observed in this study, which keeps the fish within the acceptable limit of 5×10^5 cfu/g as specified by the International Commission on Microbiological Safety for Food (ICMSF, 2005) for a good quality fish product. This research supported the statement that garlic possesses the ability to slow down microbial activity, which aligns with the findings of Nicholas (2023), who noted that garlic exhibits the lowest mean bacterial population count, thereby demonstrating its effectiveness in preservation. According to Bhatwalkar *et al.* (2021), garlic (*Allium sativum*) exhibits a broad range of properties, encompassing antifungal, antibacterial, and anti-oxidative effects. The report of (Kombat *et al.*, 2017) similarly concur to this research findings as revealed in his study, that garlic can capably delay microbial growth and prolong the shelf-life of fresh fish (Nile tilapia) under ambient storage conditions for days. (Rajsekhar *et al.*, 2023) reported that the antibacterial activity of garlic conferred by allicin has demonstrated the ability to inhibit gram-positive growth like *Staphylococcus aureus* (Li *et al.*, 2011) and gram-negative bacteria as

Escherichia coli and *Aeromonas salmonicida* (Nya *et al.*, 2010; Oosthuizen *et al.* 2018) this agreed to the statement that garlic has the ability to inhibit the growth of gram-positive *Staphylococcus aureus* this go along with this current study. Tamakloe (2018) noted that ginger was used to preserve a fresh Nile Tilapia for a period of two days, thereby effectively inhibiting microbial growth and lengthening the shelf-life of the fish.

CONCLUSION

The study found that using clove, garlic and ginger before smoking can enhance consumer acceptance and preference, while also lowering food waste by slowing down the growth of microorganisms in the fish processing stage. This research indicates that each of the three spices possess a considerable impact, with ginger standing out as the leader in terms of sensory attributes, and garlic has been shown to effectively prevent bacterial infestation by prolonging the fish shelf life. The spices employed in the study have been found to be effective.

RECOMMENDATION

It is recommended to pretreat fish with some natural spices especially ginger before smoke-drying to improve and preserve the fish nutrients and consumers acceptability.

REFERENCES

- Adeniyi, O. V., Olaifa, F. E., Emikpe, B. O., & Ogunbanwo, S. T. (2021). Effects of *Tamarindus indica* (Linnaeus 1753) pulp-fortified diets on the gut microflora and morphometry in African catfish *Clarias gariepinus* (Burchell 1822). *Aceh Journal of Animal Science*, 6(2), 45-51.
- Adeyeye, S. A. O. (2016). Traditional fish processing in Nigeria: A critical review. *Nutrition & Food Science*, 46(3), 321-335. <https://doi.org/10.1108/NFS-11-20150148>
- Adibe, A. C., Okeke, P. A., & Arinze, O. M. (2018). Evaluation of the organoleptic properties of *Clarias gariepinus* smoked with natural and artificial spices. *Biomedicine and Nursing*, 4(4), 92-96. ISSN 2379-8211 (print); ISSN 379-8203 (online). <http://www.nbmedicine.org>
- Amagliani, G., Brandi, G., & Schiavano, G. F. (2012). Incidence and role of salmonella in seafood safety. *Food Research International*, 2, 780-788.
- Amuneke, K. E., Oguntade, O. R., Ikeogu, F. C., & Nomeh, U. A. (2020). Effect of natural preservatives on the organoleptic characteristics and storage stability of smoked *Heterotis niloticus*. *Journal of Tropical Agriculture, Food, Environment and Extension*, 31-35.
- Ayeloja, A. A. (2019). Sensory quality of smoked *Clarias gariepinus* (Burchell, 1822) as affected by spices packaging methods. *International Journal of Food Properties*, 22(1), 704-713.
- Ayoola, S. O., & Bamiro, A. A. (2017). Genotoxicity, haematological and growth performance of the African catfish *Clarias gariepinus* fingerlings fed walnut *Tetracarpidium conophorum* leaves to substitute for rice bran. *Aceh Journal of Animal Science*, 2(2), 64-76. <https://doi.org/10.13170/ajas.2.2.6352>
- Bhatwalkar, S. B., Mondal, R., Krishna, S. B. N., Adam, J. K., Govender, P., & Anupam, R. (2021). Antibacterial properties of organosulfur compounds of garlic (*Allium sativum*). *Frontiers in Microbiology*, 12.
- Chakroborty, T., & Chakraborty, C. S. (2017). Comparative analysis of nutritional composition and microbial quality of salt-smoke-dried mirror carp (*Cyprinus carpio* var. *Specularis*) during storage at 22-28°C and 4°C. *International Journal of Food Science and Nutrition*, 1, 86-89.
- Chibuezeh, L. A., Ndife, J., Chidiamara O. A. & Nwodo C. N. (2022). Nutritional assessment of smoked dried fish pretreated with natural spices. *Indonesian Food Science and Technology Journal IFSTJ: Vol (5) No: 2* (PP: 63-70). ISSN: 2615-367X. <https://doi.org/10.22437/iftstj.v5i2.17598>.
- City-population. (2024). <http://www.citypopulation.de/Nigeria>. Retrieved on September 2, 2024.
- Climate-data. (2024). <http://www.climate-data.org/location/46667/>. Retrieved on September 2, 2024
- Clinical Laboratory Standards Institute (CLSI). (2006). Performance standards for antimicrobial susceptibility testing. National Committee for Clinical Laboratory Standards, Wayne, PA.
- Compass. (2024). AndroiTS GPS Test android mobile application. Accessed on September 2, 2024.
- David, R. P., & Norman, F. G. (2003). Advanced taste test method. Quarter Master Food and Container Institute for the Armed Forces. *Journal of Food Engineering*, 20(1), 27.
- Diah, I. S., & Th. D. S. (2017). Proximate composition and sensory characteristics of traditional and oven-drying smoked Tilapia fillets enriched with olive oil. *Squalen Bulletin of Marine and Fish Postharvest and Biotechnology*, 12(3), 1 2 7 - 1 3 7 . <https://doi.org/10.22271/fish.2023.v11.i5b.2859>
- Egerton, S., Culloty, S., Whooley, J., Stanton, C., & Ross, R. P. (2018). The gut microbiota of marine fish. *Frontiers in Microbiology*, 9, 1 - 17 . <https://doi.org/10.3389/fmicb.2018.00873>
- Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E.,

- & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality and microbial loadsof smoked catfish. *Scientific African*, 13, 1-7.
- Ezeama, C. F. (2007). *Food Microbiology: Fundamentals and Applications*. Natural Prints Ltd., Lagos. Pp.196
- FAO. (2017). United Nations: Food and Agriculture Organization. Fishery statistics of Nigeria.
- Gonugodugu Praveen Kumar, K. A., Martin Xavier, B., Nayak, B. B., Sanath Kumar, H., Venkateshwarlu, G., & Balange, A. K. (2017). Effect of different drying methods on the quality characteristics of *Pangasius hypophthalmus*. *International Journal of Current Microbiology and Applied Sciences*, 6(10), 184-195.
- Hoffman, A., Barranco, J. B., & Dieney, J. G. (2017). The effect of processing and storage upon the nutritive value of smoked fish from Africa. *Tropical Science*, 19(1), 41-43. <https://doi.org/10.33003/fjs-2022-0602-904>
- Ibrahim, F. M., Abdelhamid, K. E., & Ambaraka, E. H. (2017). Effects of garlic or ginger extracts on quality characteristics of catfish (*Clarias gariepinus*) fillets smoked during refrigeration storage period. *Abbassa International Journal of Aquaculture*, 1, 157-177.
- ICMSF. (2005). Fish and fish products (microorganisms in fish products). In *Microorganisms in Foods 6: Microbial Ecology of Food Commodities*. Kluwer Academic/Plenum Publishers, New York, USA, pp. 172-249.
- Iheagwara, M. C. (2013). Effect of ginger extract on stability and sensoriality of smoked mackerel (*Scomber scombrus*) fish. *Journal of Nutritional Food Science*, 3, 199.
- Iheanacho, S. C., Nworu, S. A., Ogueji, E. O., Nnatuanya, I., Mbah, C. E., Anosike, F., Okoye, C., Ibrahim, U. B., Kogi, E., & Haruna, M. (2017). Comparative assessment of proximate content and organoleptic quality of African catfish (*Clarias gariepinus*) processed by smoking and solar drying methods. *African Journal of Agricultural Research*, 12 (3 8) , 2 8 2 4 - 2 8 2 9 . <https://doi.org/10.5897/AJAR2017.12599>
- Ihuahi, J. A., Omojowo, F. S., & Ugoala, E. (2006). Effect of spice treatment on the quality of hot-smoked catfish (*Clarias gariepinus*). In *Proceedings of 21st Annual Conference Fisheries Society of Nigeria*, 363-369.
- Ikpi, G., & Offem, B. (2011). Bacterial infection of mudfish *Clarias gariepinus* (Siluriformes: Clariidae) fingerlings in tropical nursery ponds. *Revista de Biologia Tropical*, 2, 751-759.
- Iwe, M. O. (2014). *Handbook of Sensory Methods and Analysis* (2nd ed.). Rejoint Communication Services Ltd, Uwani-Enugu. Pp. 70-72.
- Kefas, M., Kolapo, A., Jauro, I. A., & Haziell, H. (2022). Effects of ginger (*Zingiber officinale*) and clove (*Syzygium aromaticum*) extracts on the quality of *Clarias gariepinus* processed with Kainji modified drum kiln. *FUDMA Journal of Sciences*, 6 (6) , 8 9 - 9 6 . <https://doi.org/10.33003/fjs-2022-0606-1144>
- Kombat, E. O., Bonu-Ire, M. S. T., Adetunde, L. A., Owusu, F. M., & Angyiereyiri, E. D. (2017). Preservative effect of garlic (*Allium sativum*) pastes on fresh Nile tilapia, *Oreochromis niloticus* (Cichlidae). *Ghana Journal of Science, Technology and Development*, 5(1), 2343-6727.
- Kuley, E., Durmus, M., Balicki, E., Ucar, Y., Regenstein, J. M., & Özoğul, F. (2017). Fish spoilage bacterial growth and their biogenic amine accumulation: Inhibitory effects of olive byproducts. *International Journal of Food Properties*, 20(5), 1029-1 0 4 3 . <https://doi.org/10.1080/10942912.2016.1193516>
- Kutte, M. M. (2022). Effect of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) on the microbial and sensorial quality of smoked mackerel fish (*Scomber scombrus*). *International Journal of Biology Sciences*, 4(1), 188-191.

- Legese, (2021). Smoking methods and microbiological characteristics of smoked fishes: A review. *Journal of Food and Nutrition Sciences*, 9(5), 113-116. <https://doi.org/10.11648/j.jfns.20210905.11>
- Li, M., Muthaiyan, A., O'Bryan, C. A., Gustafson, J. E., Li, Y., Crandall, P. G., & Ricke, S. C. (2011). Use of natural antimicrobials from a food safety perspective for control of *Staphylococcus aureus*. *Current Pharmaceutical Biotechnology*, 12, 1240-1254.
- Makinde, Y. O., & Babalola, D. A. (2011). Diet and hypertension: A comparative analysis of four diet groups in southwestern Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, 11 (6) , 23 - 40 . <https://doi.org/10.4314/ajfand.v11i1.65882>
- Marimuthu, K., Palaniandy, H., Z. A., & Muchlisin. (2019). Effect of different water pH on hatching and survival rates of African catfish *Clarias gariepinus* (Pisces: Clariidae). *Aceh Journal of Animal Science*, 4(2), 80-88. <https://doi.org/10.13170/AJAS.4.2.13574>
- Microbiological Guideline for Ready-to-Eat Food. (2007). Centre for Food Safety, Food and Environmental Hygiene Department. 43/F, Queensway Government Offices, 66 Queensway, Hong Kong.
- Msusa, N., Likongwe, J., Kapute, F., Mtethiwa, A., & Sikawa, D. (2017). Effect of processing method on proximate composition of gutted fresh Mcheni (*Rhamphochromis species*) (Pisces: Cichlidae) from Lake Malawi. *International Food Research Journal*, 24 (4) , 1513 - 1518 . <https://api.semanticscholar.org/CorpusID:204826376>
- Ndife, J., Onwuzuruike, U. A., Ebeleagu, S. B., & Okwunodulu, N. I. (2022). Influence of meat type on processed meat (Kilishi) quality. *FUDMA Journal of Sciences*, 6(2), 160-168.
- Nicholas, D., Daniel, N. A., & Elliot, H. A. (2023). Effects of indigenous household preservatives on fresh African catfish, *Clarias gariepinus* (Burchell, 1822). *International Journal of Fisheries and Aquatic Studies*, 11(5), 145-153.
- Nur, I. T., Ghosh, B. K., & Acharjee, M. (2020). Comparative microbiological analysis of raw fishes and sun-dried fishes collected from the Kawran bazaar in Dhaka city, Bangladesh. *Food Research*, 4 (3) , 846 - 851 . [https://doi.org/10.26656/fr.2017.4\(3\).368](https://doi.org/10.26656/fr.2017.4(3).368)
- Nya, E. J., Dawood, Z., & Austin, B. (2010). The garlic component, allicin, prevents disease caused by *Aeromonas hydrophila* in rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Journal of Fish Diseases*, 33, 293–300. <https://doi.org/10.1111/j.1365-2761.2009.01121>
- Oluborode, G. B., Adelowo, E. O., & Adenike, U. (2015). The use of spice in prolonging the shelf-life of smoked *Clarias gariepinus*. In *Proceedings of 30th Annual Conference Fisheries Society of Nigeria*.
- Oosthuizen, C. B., Reid, A. M., & Lall, N. (2018). Garlic (*Allium sativum*) and its associated molecules, as medicine. In N. Lall (Ed.), *Medicinal Plants for Holistic Health and Well-Being* (pp. 277–295). Elsevier Inc.
- Rajsekhar, S., Kuldeep, B., Chandaker, A., & Upmanyu, N. (2013). Spices as antimicrobial agents: A review. *International Research Journal of Pharmacy*, 3(2), 4-9.
- Rawat, S. (2015). Food spoilage: Microorganisms and their prevention. *Asian Journal of Plant Science and Research*, 5(4), 47-56.
- Romero, J., Ringø, E., & Merrifield, D. L. (2014). The gut microbiota of fish. In D. Merrifield & E. Ringø (Eds.), *Aquaculture nutrition: Gut health,*



- probiotics, and prebiotics* (pp. 75-100). John Wiley & Sons. <https://doi.org/10.1002/9781118897263.ch4>
- Tamakloe, H. (2018). Preservative effects of ginger (*Zingiber officinale*) paste on fresh *Oreochromis niloticus*. B.Sc. Thesis, University for Development Studies, Ghana.
- Taniya, A., & Kannan, E. (2016). Effect of spices and herbs for enhancing microbial quality and microbial loadsof dried Indian oil sardine (*Sardinella longiceps*) fish during storage at room temperature. *Journal of Environmental Science, Technology, and Food Technology*, 5, 23-40.
- Vasala, P. A. (2004). Ginger. In P. K. V. (Ed.), *Handbook of Herbs and Spices, Vol. 1* (pp. 212–222). Cochin, India.
- Wichchukit, S., & O'Mahony, M. (2014). The 9-point hedonic scale and hedonic ranking in food science: Some reappraisals and alternatives. *Journal of the Science of Food and Agriculture*, 94(3), 741-748.
- Yoganathan, T. (2020). Effects of turmeric on quality attributes of brine salted dried Atlantic Pollock (*Pollachius virens*). *UNESCO GRO Fisheries Training Programme, Iceland*. Final project (47 pp).