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Original research article

Antimicrobial Effects of Bay Leaf (*Laurus nobilis*) and Sesame (*Sesamum indicum*) Essential Oils on Dried African Catfish (*Clarias gariepinus*) During Storage in North-Central Nigeria

NYAMNGEE AMASE [1]*, YUSUF KAYODE ABEL [1] & SANJIB ADHIKARI [2]

[1]Department of Medical Microbiology and Parasitology, Faculty of Basic Clinical Science, College of Health Sciences, University of Ilorin, Nigeria.

[2]Central Department of Microbiology, Tribhuvan University, Nepal

Corresponding author: anyamngee2010@yahoo.com; nyamngee.a@unilorin.edu.ng

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ABSTRACT

Contamination and postharvest losses determine the availability of fish in marketplaces and have raised public health concerns regarding their quality. We examined the antimicrobial effects of bay leaf (*Laurus nobilis*) and Sesame seed (*Sesamum indicum*) oils in preventing deterioration and extending the shelf life of African catfish (*Clarias gariepinus*). Sixty pieces of freshwater catfish were selected from different spots along the River Niger by randomised mixed sampling method and weighed (26 kg). These samples were divided into three equal (8.6 kg) groups (A, B & C) based on their method of drying: sun-dried (4.2 kg), smoked using firewood (3.9 kg), or smoked in a smoking kiln (3.8 kg). Isolation and identification of spoilage pathogens were performed using selective media, wet preparations, and molecular characterisation before and after drying. Essential oils of *Laurus nobilis* and *Sesamum indicum* were extracted through cold press and Soxhlet extraction methods and used at 0.02 mL/g of the fish to coat the dried catfish for preservation. Aliquots from the preserved fish were examined through serial dilution every month for three months. Essential oils from bay leaf inhibited microbial growth and preserved the stored catfish samples better than Sesame seed oil and ordinary drying methods, with microbial reduction count $3.1x10^3$CFU/g against $4.0x10^3$ CFU/g of sesame oil and $11.3x10^3$ CFU/ g of the control; hence, it is recommended for preservation of dried fish.

Key words: Effects, Essential Oils, Postharvest, Catfish, Nigeria.

RÉSUMÉ

La contamination et les pertes après récolte déterminent la disponibilité du poisson sur les marchés et ont suscité des préoccupations de santé publique quant à sa qualité. Nous avons examiné les effets antimicrobiens des huiles de feuilles de laurier (*Laurus nobilis*) et de graines de sésame (*Sesamum indicum*) pour prévenir la détérioration et prolonger la durée de conservation du poisson-chat africain (*Clarias gariepinus*). Soixante spécimens de poissons-chats d'eau douce ont été sélectionnés à différents endroits le long du fleuve Niger selon une méthode d'échantillonnage aléatoire mixte et pesés (26 kg). Ces échantillons ont été divisés en trois groupes égaux (8,6 kg) (A, B et C) selon leur méthode de séchage ; puis séchés au soleil (4,2 kg), fumés au bois de chauffage (3,9 kg) ou fumés dans un séchoir-fumoir (3,8 kg). L'isolement et l'identification des agents pathogènes responsables de l'altération ont été effectués à l'aide de milieux sélectifs, d'examens à l'état frais et d'une caractérisation moléculaire avant et après le séchage. Les huiles essentielles de *Laurus nobilis* et de *Sesamum indicum* ont été extraites par des méthodes d'expression à froid et d'extraction au Soxhlet, puis utilisées à raison de 0,02 mL/g de poisson pour enrober le poisson-chat séché en vue de sa conservation. Des aliquotes de poisson conservé ont été examinées par dilutions en série chaque mois pendant trois mois. Les huiles essentielles de feuilles de laurier ont mieux inhibé la croissance microbienne et mieux conservé les échantillons de poisson-chat stockés que l'huile de graines de sésame et les méthodes de séchage ordinaires, avec un décompte de réduction microbienne de $3,1×10^3$ UFC/g contre $4,0×10^3$ UFC/g pour l'huile de sésame et $11,3×10^3$ UFC/g pour le témoin ; elles sont donc recommandées pour la conservation du poisson séché.

Mots-clés: Effets, Huiles essentielles, Post-récolte, Poisson-chat, Nigéria.

1. INTRODUCTION

Processing fish by drying to a safe moisture content (10–15%) does not entirely prevent deterioration, particularly in countries with variable temperatures and humidity like Nigeria, where dried produce can absorb moisture and encourage microbial invasion, leading to growth of mould (Olayemi *et al*. 2011). Essential oils such as those from cloves (0.25, 0.5 & 1 mL/70g), Moringa oleifera (1.25 - > 5 mg/mL and 0.25 – 2.0%v/v), Sesame (10 – 500µL/mL), bay leaf (0.25 – 0.4 µL/mL), cinnamon, oregano, ginger, and garlic have been reported to possess strong antimicrobial activities against selected foodborne microorganisms (Suomalainen *et al,* 2005).

The use of biological means (essential oils) has gained wide acceptance over chemical methods due to concerns about the presence of pesticide residues such as malathion (0 - 0.3 mg/kg), mancozeb (0 - 0.3 mg/kg), cypermethrin (0 - 0.2 mg/kg) in food, which can cause acute and chronic toxicities when consumed (Olajide *et al*. 2020). Essential oils contain potent antioxidants and phytochemicals including epoxides, esters, phenols, alkaloids, flavonoids, tannins, saponins, phytates, and ketones. These compounds may have exert antimicrobial activity against microbial pathogens by altering or destroying nuclear material through oxidation (Sundramurthy *et al*. 2020; Onyedineke *et al*. 2010).

Various studies have shown that fresh African catfish contains various microorganisms, including *Aeromonas hydrophilia, Staphylococcus spp, Pseudomonas aeruginosa, Trichodina spp and Aspergillus* (Immaculate *et al*. 2012, Ranasinghe *et al*. 2012, Enyidi and Eneje 2015).

Postharvest losses of African catfish (*Clarias gariepinus*) due to microbial pathogens could decrease supply, potentially contributing to malnutrition and poverty. Therefore, to protect consumer health and reduce postharvest losses, preserving food against microbial attack and maintaining quality should be a major global priority. For many years, the most effective means of preventing food contamination by microbial pathogens has been to avoid microbial growth (FAO 2020). Microbial attack of food products is linked to high moisture, temperature, and humidity. Hence, drying remains a primary means of preventing microbial attack and further deterioration. Although drying fresh fish to a safe moisture content may not entirely prevent deterioration and mycotoxin production, it would delay further spoilage and extend the product's shelf life (Olayemi *et al*. 2011).

Fish is a savoury ingredient in many dishes across Nigeria and other African countries, with African catfish being the most common. Fish is a major source of high-quality animal protein (40%) for most Nigerians, particularly in rural areas (Fafioye & Fafioye 2013). It is also a major source of protein for older adults who are advised to avoid red meat, especially beef. Consequently, public health concerns regarding the quality of fish available in the market have risen. Fungal, bacterial, parasitic, and chemical contaminants in fish cause off-flavours and an unpalatable taste; hence, they are considered the main causes of spoilage in fish. Microbial pathogens, including mycotoxigenic moulds, are dangerous when consumed and can cause economic losses due to contamination; they produce mycotoxins such as aflatoxin, ochratoxin, patulin, and zearalenone (Oluorin & Somorin, 2006). These compounds are potential carcinogens and cause some degree of acute toxicity when consumed in high amounts. For instance, in Nigeria, *Flavobacterium sp., Micrococcus sp., and Staphylococcus sp.,* the major bacteria causing ulceration of the intestinal mucosa, were isolated from *Clarias* by Khasnavis & Pahan (2012). Pramaziyah *et al*. (2021), identified *E. coli* in catfish as one of the major causes of food poisoning. Mycotoxicosis has been linked to cancer (Serpe *et al*. 2010) and parasitic infection (*Helminths and Nematodes*) in catfish, causing anisakiasis and diphyllobothriasis. A major gateway to secondary infection has also been reported in a study conducted on African catfish in Nigeria by Omeji *et al*. (2011). Preventing microbial and mycotoxin contamination in fish could significantly improve public health in low-income countries, and therefore deserves substantial attention. Postharvest losses in African catfish (Clarias gariepinus) are also observed in areas where human and industrial activities contribute to increased concentrations of chemical residues, as well as microbial and parasitic pathogens. This leads to a decrease in the profit of the fish farmer, scarcity, and unavailability for consumption. Therefore, there is a need to characterize these areas and the negative effects of the contamination on the economy. Additionally, new, safe fish-processing methods and antimicrobial agents that could extend the shelf life of processed fish are needed to prevent severe fungal and microbial infections. This study will ultimately lead to improved economic sustainability of the industry, enhanced food safety efforts, and improved public health. Therefore, we evaluate the efficacy of different fish drying methods for adoption of a standard operating and processing procedure.

2. MATERIALS AND METHODS

2.1. Study Area

This study was conducted in North-Central Nigeria, where riverine communities in Kwara and Niger states were selected for sample collection. The cumulative and monthly rainfall in the region are 1247±166.68 mm and 103.96 mm, respectively. It occurs from May through October with peak in August. The mean annual temperature ranges from 22.55±0.42°C to 33.54±0.23°C. The North-Central region is located in the centre of Nigeria, around the confluence of the rivers Niger and Benue; thus, it is a significant area for artisanal fisheries due to the presence of the rivers Niger and Benue. Both rivers are the third-longest rivers in Africa, and they play a vital role in the region's ecology, economy, and culture.

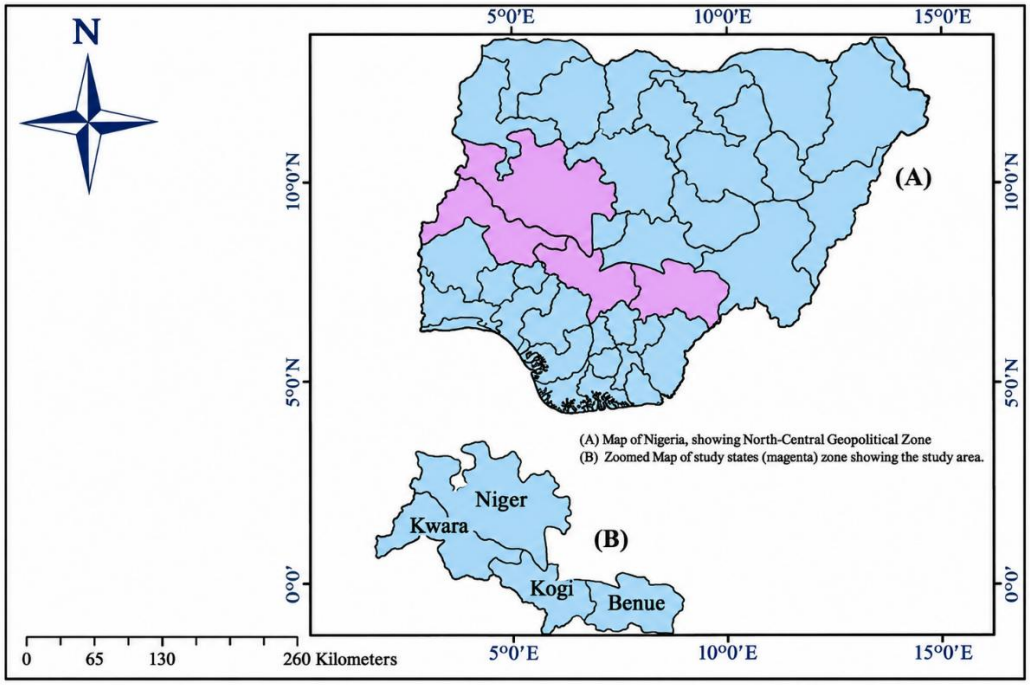


Figure 1. Map of Nigeria showing the North Central geopolitical zones (A) and sketch map of the North Central geopolitical zone showing the study areas (B).

2.2. Sample Collection

Wild catfish farmers from the study areas were informed about the need for fresh catfish from their wild habitat, and the samples were caught and purchased directly from them. A total of 60 live catfish samples (*Clarias gariepinus*) of various sizes, weighing a total of 26 Kg were purchased and transported with a clean, insulated Nigerian Stored Products Research Institute (NSPRI) fish ice box to avoid further personal contamination, to the laboratory for further treatment and analysis. The NSPRI fish ice box was preferred over other ice boxes because it has an insulated, double-walled, food-grade plastic body with a tight-fitting lid.

2.3. Reagents

All chemicals used were High-Performance Liquid Chromatography (HPLC) grade. Standard mycotoxigenic strains, diatomaceous earth, sodium chloride, anhydrous sodium sulphate, acetic acid and tetrahydrofuran were obtained from Sigma-Aldrich (Sigma, St. Louis, MO, USA), while food-grade acetone, hexane, methanol, chloroform, toluene, ethyl acetate, formic acid, orthophosphoric acid, Tris-Hydrochloric acid, acetonitrile, glacial acetic acid, and HPLC water were obtained from Merck Inc. (Merck, Darmstadt, Germany).

2.4. Sterilisation of Materials

The glassware used for this study was properly washed with detergent, rinsed and sterilised in a dry ventilated oven at 160 ^{O}C for 1 h. All the culture media used during the course of this work were properly sterilised by autoclaving at 121 ^{O}C for 15 min. The inoculating needles were sterilised by flaming with 70% ethanol (Fafioye and Fafioye 2013).

2.5. Study design

The wild freshwater catfish samples (*Clarias gariepinus*) of various sizes and weights purchased from the fishermen were transported in the NSPRI fish ice boxes to the laboratory for processing, treatment and analysis. Spoilage parasites, bacteria, and fungi was isolated using selective media (for bacteria and fungi), and wet preparation (for parasites). Isolated spoilage bacteria and fungi from the fresh catfish were identified through molecular characterization. Fresh catfish samples were further processed to prevent deterioration and spoilage using the three commonly used methods of drying (Smoking kiln, firewood, and sun-dry). After drying, we assessed the microbial load and parasitic counts of the catfish samples dried using the different drying methods. Each whole catfish sample was divided into three equal portions, one for each and treated/coated *Laurus nobilis* and *Sesamu indicum* essential oils then the remaining one portion as control and stored for 3 months. All samples were stored at ambient temperature and subjected to the same condition of storage. The microbial level of the stored samples were observed and recorded weekly and monthly.

2.6. Processing of Fresh Catfish against Spoilage Microorganisms

Deterioration of fish starts when the fish is killed; high moisture content encourages further microbial attack of the fish sample. Hence, processing the fish samples into dry products to reduce further deterioration is required. We employed two conventional methods used by fish processors (Smoking and Sun-drying) and the modern method of drying of fish (Smoking Kiln). All the sampled fish were killed, beheaded, eviscerated and washed thoroughly. They were soaked in brine prepared by adding 10g salt to 1litre of water. The fish sample was divided into three equal parts (8.6 kg each) 'A', 'B' and 'C'. Those in sample A were sun-dried as described by Fitri *et al*. (2022), those in sample B were smoked as described by Omodara *et al*. (2019) and Akinola *et al*. (2017), while those in sample C were dried using the modern NSPRI smoking kiln as described by Olayemi *et al*. (2011) and Ogunjinrin *et al*. (2019), where time, temperature and ambient conditions of the operation were properly monitored. The effectiveness of the three drying methods was noted and compared.

2.7. Oil Extraction and Analysis of Sesame Seed (*Sesamum Indicum*)

Cold-pressed sesame seed oil was extracted using the Cheesebrough method with slight modification. Sesame seeds were purchased from a known market in Kwara state, properly washed under running tap water, and rinsed with sterile water. The seeds were oven-dried, milled, mixed, and kneaded with intermittent sprinkling of warm sterile water to press out the oil. The oil was allowed to settle and was later decanted into a container. The oil was filtered using filter paper and stored in amber or transparent plastic bottles at 4°C (Nogueira *et al*. 2019).

2.8. Oil Extraction and Analysis of Bay Leaf (*Laurus Nobilis*)

Exactly 300g of dried leaves of *Laurus nobilis L*. (Bay leaf) was bought from a known market in Ilorin metropolis; it was thoroughly washed with warm water, rinsed with sterile water, and dried in an oven at 37°C for 2h. They were finely ground using a coffee grinder and weighed using a scale. The powder was then placed in a beaker and percolated with 300mL each of 80% ethanol, distilled cold water, hot water (100°C), and n-extract, sieved through a muslin cloth, filtered through a Whatman (No.1) filter paper, and concentrated using a rotary evaporator at 45°C. The dried mass was stored in a sterile McCartney bottle and kept in the refrigerator at 4°C for 24h before testing for Hexane. However, it was allowed to stand for 3 days at room temperature with agitation at intervals (Nogueira *et al*. 2019).

2.9. Sterility of the Oils

Sterility of the oil extracts of *Laura nobilis* and *Sesamum indicum* was confirmed using the agar pour plate method of Balouri *et al*. (2016) with little modification. About 10mL of nutrient agar was poured in a sterile petri dish and allowed to cool and solidify. A mL of each oil was spread across separate plates. The plates were incubated for 24h at 37°C and observed for any visible bacterial growth. A similar set up was performed on potato dextrose agar and observed for any visible fungal growth. Each set up experimental plates was incubated for at least 48 hours and were observed for possible contamination of the oil.

2.10. Treatment of the Dried Fish Sample with Antimicrobial Agent (Edible Films)

Each dried fish sample, A (4.20 kg), B (3.90 kg), and C (3.80 kg), was sub-divided into three equal parts: A (1.40 kg each); B (1.30 kg each); C (1.26 kg each). The first part was coated with 0.5mL/g of *Sesamum indicum* oil by spraying, the second part was coated with 0.5 mL/g of *Laurus nobilis* oil, and the third portion was left uncoated. All the samples were stored at room temperature. Samples were observed daily for any visible changes. Shelf-

life, as well as Microbial, Physicochemical, Sensory, and aflatoxin analysis of the experimental fish samples were monitored.

2.11. Statistical Analysis

All data were analyzed using Statistical Package for the Social Sciences Version 23.00 and presented as mean ± SE. One-way Analysis of Variance (ANOVA) was used for the proximate analysis data and two-way Analysis of Variance was used for sensory evaluation data. Comparison between different methods and study site was made using Duncan multiple range test for proximate analysis data while Least Significant Difference (LSD) test was used to separate the means of the sensory evaluation data. Statistical significance was drawn at 95% with a P value at 0.05.

3. RESULTS

3.1. Microbial Analysis of Fresh and Dried Catfish (Clarias Gariepinus) Samples from Kwara and Niger States.

Table 1 below shows the microbial enumeration of freshwater catfish samples caught in Kwara and Niger States. Microbial counts of the fresh catfish samples were determined and compared with the dried samples. Smoking-kiln significantly ($p<0.05$) reduced microbial proliferation and load in the fish samples compared to other methods.

Table 1: Microbial count of fresh and dried catfish samples (Kwara and Niger states)

Treatment	States	NA	MSA	EMB	SSA	MEA
Fresh	Kwara	54.67 ± 4.91^{b}	37.33 ± 17.57^{a}	22.00 ± 3.46^{b}	0.00 ± 0.00	21.33 ± 4.06^{b}
Smoking-kiln		11.33 ± 1.86^{a}	0.00 ± 0.00	6.33 ± 2.96^{a}	0.00 ± 0.00	0.00 ± 0.00
Firewood		41.67 ± 1.20^{b}	38.67 ± 9.33^{a}	9.67 ± 2.33^{a}	28.00 ± 6.08^{a}	11.33 ± 1.33^{a}
Sundry		125.33 ± 10.48^{c}	36.00 ± 5.51^{a}	104.33 ± 9.26^{c}	48.00 ± 8.39^{b}	16.67 ± 2.96^{ab}
Fresh	Niger	302.67 ± 7.36^{c}	0.00 ± 0.00	64.67 ± 1.76^{c}	179.00 ± 3.79^{c}	15.00 ± 1.00^{b}
Smoking-kiln		176.33 ± 3.93^{a}	0.00 ± 0.00	35.00 ± 1.73^{a}	0.00 ± 0.00	0.00 ± 0.00
Firewood		211.67 ± 5.36^{b}	65.67 ± 2.03^{a}	56.00 ± 2.08^{b}	128.00 ± 6.08^{a}	10.33 ± 0.33^{a}
Sundry		221.00 ± 1.53^{b}	70.33 ± 1.20^{b}	93.33 ± 3.18^{d}	158.00 ± 2.65^{b}	21.00 ± 1.73^{c}

NA, Nutrient Agar; MSA, Mannitol Salt Agar; EMB, Eosin Methylene Blue Agar; SSA, Salmonella Shigella Agar; MEA, Malt Extract Agar. Results are presented as mean± Standard error (SE) of triplicate readings. Means in the same column with unshared superscript are significantly different ($p<0.05$)

3.2. Microbial Enumeration of Treated Catfish Samples from Kwara State Under Storage

Table 2 below shows the microbial counts for catfish samples from Kwara State (*Clarias gariepinus*) dried using three different methods, treated with antimicrobial essential oils of *Laura nobilis* (Bay leaf) and *Sesamum indicum* (Sesame oil), and stored for 90 days (3 months). Bay leaf oil-coated samples reduced microbial count and, to some extent, decreased microbial proliferation. Additionally, there was a significantly higher ($p<0.05$) increase in the microbial load of samples coated with bay leaf oil extract with storage period compared with that of samples treated with sesame seed oil extract. Both oils showed antimicrobial effects; however, bay leaf showed superior microbial inhibition.

3.3 Microbial Enumeration of Treated Catfish Samples from Niger State Under Storage.

Table 3 below shows the microbial load counts of Niger State Catfish (*Clarias gariepinus*) samples dried using three different methods, treated with essential oils of *Laura nobilis* (bay leaf) and *Sesamum indicum* (Sesame) and stored for 90 days (3 months). The samples dried with a smoking kiln and coated with bay leaf essential oils had a lower microbial load and decreased microbial growth. Additionally, for the control samples, the microbial load increased with time. Whereas, microbial count of the samples coated with bay leaf decreased significantly ($p<0.05$), compared with those coated with sesame seed oil extract. Also, control samples showed some microbial contamination, which was more visible from the first month.

Table 2. Microbial load of treated Catfish samples from Kwara State under Storage.

Drying method	Treatment (Oil)	Storage Period	NA	MSA	EMB	SSA	MEA
Smoking-kiln	Control	Month 1	11.15±0.50^{c}	1.70±0.44^{a}	6.40±0.27^{d}	0.00±0.27	0.00±0.30
Firewood			41.80±0.50^{e}	38.50±0.44^{f}	8.95±0.27^{e}	3.20±0.27^{b}	9.45±0.30^{c}
Sundry			112.70±0.50^{g}	34.25±0.44^{e}	98.20±0.27^{h}	30.60±0.27^{e}	14.80±0.30^{d}
Smoking-kiln	Bay leaf		3.45±0.50^{b}	0.00±0.44	3.70±0.27^{b}	0.00±0.27	0.00±0.30
Firewood			1.70±0.50^{a}	18.40±0.44^{c}	2.35±0.27^{a}	1.70±0.27^{a}	4.35±0.30^{a}
Sundry			40.75±0.50^{e}	11.80±0.44^{b}	39.25±0.27^{f}	22.40±0.27^{c}	6.65±0.30^{b}
Smoking-kiln	Sesame		4.30±0.50^{b}	0.00±0.44	4.85±0.27^{c}	0.00±0.27	0.00±0.30
Firewood			18.90±0.50^{d}	27.55±0.44^{d}	4.40±0.27^{bc}	1.95±0.27^{a}	6.25±0.30^{b}
Sundry			64.05±0.50^{f}	28.25±0.44^{d}	54.20±0.27^{g}	27.15±0.27^{d}	8.85±0.30^{c}
Smoking-kiln	Control	Month 2	14.05±0.43^{d}	3.20±0.29^{a}	9.80±0.32^{c}	2.50±0.36^{a}	4.25±0.25^{ab}
Firewood			53.65±0.43^{f}	42.85±0.29^{e}	10.65±0.32^{c}	6.65±0.36^{b}	10.90±0.25^{d}
Sundry			127.00±0.43^{g}	43.70±0.29^{e}	102.60±0.32^{f}	39.90±0.36^{f}	16.25±0.25r
Smoking kiln	Bay leaf		2.90±0.43^{b}	0.00±0.29	2.50±0.32^{a}	0.00±0.36	0.00±0.25
Firewood			1.35±0.43^{a}	13.30±0.29^{c}	1.95±0.32^{a}	8.95±0.36^{c}	3.50±0.25^{a}
Sundry			29.65±0.43^{e}	7.30±0.29^{b}	32.15±0.32^{d}	15.20±0.36^{d}	4.65±0.25^{b}
Smoking kiln	Sesame		3.95±0.43^{b}	0.00±0.29	4.25±0.32^{b}	0.00±0.36	0.00±0.25
Firewood			13.60±0.43^{d}	21.60±0.29^{d}	3.00±0.32^{a}	1.55±0.36^{a}	4.40±0.25^{b}
Sundry			61.35±0.43^{c}	21.90±0.29^{d}	45.90±0.32^{e}	20.70±0.36^{e}	7.80±0.25^{c}
Smoking kiln	Control	Month 3	17.90±0.29^{f}	6.00±0.16^{a}	11.90±0.32^{d}	0.00±0.27	0.00±0.49
Firewood			69.15±0.29^{h}	48.75±0.16^{f}	19.60±0.32^{e}	14.65±0.27^{d}	16.70±0.49^{c}
Sundry			128.75±0.29^{i}	48.20±0.16^{f}	110.65±0.32^{h}	42.40±0.27^{f}	23.70±0.49^{d}
Smoking kiln	Bay leaf		2.60±0.29^{b}	0.00±0.16	2.10±0.32^{ab}	0.00±0.27	0.00±0.49
Firewood			1.10±0.29^{a}	9.50±0.16^{c}	1.45±0.32^{a}	0.35±0.27^{a}	3.20±0.49^{ab}
Sundry			22.25±0.29^{g}	5.20±0.16^{b}	28.55±0.32^{f}	9.95±0.27^{c}	3.15±0.49^{ab}
Smoking kiln	Sesame		3.70±0.29^{c}	0.00±0.16	3.65±0.32^{c}	0.00±0.27	0.00±0.49
Firewood			10.15±0.29^{e}	18.15±0.16^{d}	2.70±0.32^{bc}	1.25±0.27^{b}	2.65±0.49^{a}
Sundry			58.55±0.29^{d}	20.10±0.16^{e}	39.25±0.32^{g}	18.45±0.27^{e}	4.60±0.49^{b}

NA, Nutrient Agar; MSA, Mannitol Salt Agar; EMB, Eosin Methylene Blue Agar; SSA, Salmonella Shigella Agar; MEA, Malt Extract Agar. Results are presented as mean ± Standard error (SE) of triplicate readings. Means in the same month with unshared superscript are significantly different ($p<0.05$)

Table 3: Microbial load of treated Catfish samples from Niger State under Storage.

Drying method	Treatment (Oil)	Storage Period	NA	MSA	EMB	SSA	MEA
Smoking kiln	Control	Month 1	17.55±0.36^{b}	0.00±0.32	35.55±0.53^{c}	0.00±0.29	0.00±0.34
Firewood			21.70±0.36^{d}	58.45±0.32^{d}	58.75±0.53^{f}	12.00±0.29^{c}	9.10±0.34^{b}
Sundry			22.10±0.36^{d}	64.65±0.32^{e}	88.15±0.53^{h}	16.05±0.29^{e}	21.85±0.34^{e}
Smoking kiln	Bay leaf		11.95±0.36^{a}	0.00±0.32	27.80±0.53^{a}	0.00±0.29	0.00±0.34
Firewood			17.35±0.36^{b}	48.40±0.32^{b}	41.30±0.53^{d}	7.75±0.29^{a}	5.40±0.34^{a}
Sundry			19.95±0.36^{c}	30.95±0.32^{a}	59.00±0.53^{f}	12.30±0.29^{c}	15.85±0.34^{c}
Smoking kiln	Sesame		17.70±0.36^{b}	0.00±0.32	30.55±0.53^{b}	0.00±0.29	0.00±0.34
Firewood			19.65±0.36^{c}	52.10±0.32^{c}	47.70±0.53^{e}	10.00±0.29^{b}	6.00±0.34^{a}
Sundry			22.15±0.36^{d}	51.45±0.32^{c}	64.80±0.53^{g}	14.80±0.29^{d}	18.85±0.34^{d}
Smoking kiln	Control	Month 2	23.05±0.23^{e}	8.55±0.36^{a}	41.60±0.45^{e}	15.25±0.40^{d}	11.30±0.34^{c}
Firewood			29.35±0.23^{g}	62.85±0.36^{g}	61.90±0.45^{h}	22.45±0.40^{e}	13.50±0.34^{d}
Sundry			26.30±0.23^{f}	59.55±0.36^{f}	62.30±0.45^{h}	39.70±0.40^{f}	25.95±0.34^{f}
Smoking kiln	Bay leaf		13.00±0.23^{a}	0.00±0.36	19.40±0.45^{a}	0.00±0.40	0.00±0.34
Firewood			18.50±0.23^{d}	38.30±0.36^{d}	31.10±0.45^{c}	5.55±0.40^{a}	4.80±0.34^{a}
Sundry			15.40±0.23^{b}	27.65±0.36^{b}	32.65±0.45^{d}	9.45±0.40^{b}	10.60±0.34^{c}
Smoking kiln	Sesame		16.50±0.23^{c}	0.00±0.36	24.85±0.45^{b}	0.00±0.40	0.00±0.34
Firewood			22.40±0.23^{e}	40.70±0.36^{e}	53.20±0.45^{f}	6.80±0.40^{a}	5.95±0.34^{b}
Sundry			16.30±0.23^{c}	35.05±0.36^{c}	45.95±0.45^{g}	12.70±0.40^{c}	14.95±0.34^{e}
Smoking-kiln	Control	Month 3	27.95±0.34^{d}	12.00±0.35^{d}	48.20±0.37^{g}	21.60±0.45^{c}	19.60±0.41^{d}
Firewood			35.50±0.34^{e}	69.55±0.35^{f}	73.00±0.37^{h}	31.65±0.45^{d}	14.85±0.41^{c}
Sundry			81.55±0.34^{f}	67.85±0.35^{e}	72.65±0.37^{h}	44.65±0.45^{e}	32.70±0.41^{e}
Smoking kiln	Bay leaf		6.45±0.34^{a}	0.00±0.35	3.15±0.37^{a}	0.00±0.45	0.00±0.41
Firewood			11.05±0.34^{c}	8.95±0.35^{bc}	10.55±0.37^{e}	5.00±0.45^{a}	3.50±0.41^{a}
Sundry			9.80±0.34^{b}	5.70±0.35^{a}	7.70±0.37^{c}	6.60±0.45^{b}	3.95±0.41^{ab}
Smoking kiln	Sesame		7.50±0.34^{a}	0.00±0.35	4.80±0.37^{b}	0.00±0.45	0.00±0.41
Firewood			11.70±0.34^{c}	9.85±0.35^{c}	12.35±0.37^{f}	6.10±0.45^{ab}	5.05±0.41^{b}
Sundry			11.20±0.34^{c}	8.55±0.35^{b}	9.20±0.37^{d}	6.85±0.45^{b}	5.10±0.41^{b}

NA, Nutrient Agar; MSA, Mannitol Salt Agar; EMB, Eosin Methylene Blue Agar; SSA, Salmonella Shigella Agar; MEA, Malt Extract Agar. Results are presented as mean ± Standard error (SE) of triplicate readings. Means in the same month with unshared superscripts are significantly different ($p<0.05$)

4. DISCUSSION

The Contamination of processed African catfish (*Clarias gariepinus*) by pathogenic micro-organisms which usually raised public health concerns and postharvest losses were determine by our study with a view of proffering solutions on preservation of this commonly consumed species (African catfish) in **our** communities. The potency of antimicrobial effects of bay leaf (*Laurus nobilis*) and Sesame seed (*Sesamum indicum*) oils (essential oils) in preventing deterioration and extending the shelf life of African catfish for healthy consumption were determined. Additionally, the microbial load of dried *Clarias gariepinus* samples treated with bay leaf extract and sesame seed oil for 3 months showed lower microbial proliferation than the dried stored samples treated with both bay leaf and sesame seed oil. However, the lowest microbial load was found among the samples that were treated and stored with bay leaf extract. Bay leaf extract was active against enteric coliform bacteria and aflatoxigenic fungi (e.g. *Aspergillus flavus*). The microbial load reduced significantly with increase in storage duration. Meaning that the longer the storage period, the higher the efficacy of the coated oil extracts and the weaker the spoilage by microbial pathogens, which is consistent with previous studies (Mousavi *et al*. 2021, Odoh *et al*. 2019, Kawe, *et al*. 2016). We recorded a higher viable microbial load in the firewood method of drying than the Improved Smoking kiln method. This is due to contamination during and after the processing, resulting from handling. It may also be because heat was not well distributed, as it was an open method of drying which allows escape of heat.

Bay leaf extract showed greater antimicrobial activity against spoilage microbes than sesame seed oil, as it had the lowest microbial load in the stored *Clarias gariepinus* for 3 months in all the three methods of drying. Bay leaves contain antibacterial compounds with high tannin, terpenoid and Flavonoids content which could inhibit the growth and survival of microbes. Flavonoid inhibit bacterial growth by forming complex compounds with extracellular proteins through hydrogen bonds that degrade bacterial cell wall membranes. Hydrogen and Flavonoids bonds cause unstable cell wall structure, cell membrane and cellular deterioration. Tannins shrink the cell walls and membranes, interfering with cell permeability, which can potentially inhibit bacterial growth or kill the bacteria. Also, terpenoid react with porins in the cell wall (transmembrane protein) to form a strong polymer bond. These bonds cause the porin to deteriorate, reducing the permeability of the bacterial cell wall; this can cause the bacterial cell to lack the essential nutrients inhibiting bacterial growth (Ismaila *et al*. 2025). Our findings are in line with the work of Olayemi *et al*. (2011) who worked on the effect of bay leaf extract on shelf life of preserved Scad fish which showed that bay leaf extract is an excellent antibacterial compound with the lowest bacteria count which decreased with increase in the number of treated hours.

Throughout the 3 months of storage, bay leaf and sesame seed essential oils showed some antimicrobial activity; however, bay leaf oil was more effective than sesame seed oil. Samples dried with a smoking kiln had only heterotrophic and Escherichia bacteria for the first 30 days of storage, with bay leaf-treated samples showing more affinity and potency for microbial inhibition than those treated with sesame indicum oil extract. Smoking kiln-dried samples treated with both oils (bay leaf and *sesame indicum oils*) showed strong inhibition of Staphylococcus spp., Salmonella spp., and fungi. At 60 and 90 days of storage, control samples showed further deterioration as the number of storage days increased with further contamination with Staphylococcus, Salmonella and fungi species, but the sample treated with both oils extended the shelf life of the samples prevented microbial proliferation and attack. Viable E. coli counts of the samples treated with bay leaf and stored for 30 to 90 days were below the International Microbiology guideline for ready-to-eat food (2007)-recommended limit for consumption. This shows the effectiveness the smoking kiln. The kiln dried samples to below safe moisture content and relative humidity, preventing further microbial attack. The temperature in the kiln was high enough to kill all microbial pathogens and reduce the moisture content below the level where microorganisms could survive. Also, bay leaf oil extracts showed stronger microbial inhibition than sesame indicum seed oil extract. These findings are in line with those of Olayemi *et al*. (2012) and Omojowo *et al*. (2010), that showed that the improved modern smoking kiln is the best drying technology for agricultural produce, as it prevents microbial attack and extends their shelf life. These results are also in line with those of Omeji *et al*. (2011) and Abel *et al*. (2021) that reported the efficacy of bay leaf and sesame seed oil extracts for the inhibition of enteric coliform (E. coli) bacteria and aflatoxigenic fungi (*A. flavus)*.

5. CONCLUSION

The treatment of the dried catfish with bay leaf extract extended the shelf life and significantly reduced microbial load. Therefore, treatment of dry fish with bay leaf oil extract should be adopted as to ensure the safety of the products. However, there is a need to identify the minimum inhibitory concentration (MIC) of these essential oils. This could reveal more about sesame seed oil that was less active.

ABBREVIATIONS. NA, Nutrient Agar; MSA, Mannitol Salt Agar; EMB, Eosin Methylene Blue Agar; SSA, Salmonella Shigella Agar; MEA, Malt Extract Agar; SE, *Standard error*

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DATA SHARING STATEMENT. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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