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Effect of Natural Preservatives (Moringa Leaf and Ginger Root) on Nutrients and Shelf Life of Smoked African Catfish

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Abstract: This research investigates the effectiveness of Moringa, Ginger, and their combination as bio-preservatives for smoked catfish. The study assessed these treatments' impacts on proximate composition, biochemical and microbiological properties, and sensory attributes over a 12 week storage period. The combination of Moringa and Ginger (T4) significantly improved the nutritional quality of smoked catfish, achieving the lowest moisture content (4.84±0.13%) and the highest protein content (66.18±0.88%). This treatment also resulted in the lowest peroxide value (PV) (6.10±1.80 meq/kg), thiobarbituric acid reactive substances (TBAR) (1.64±0.47 mg malondialdehyde/kg), total volatile base nitrogen (TVB-N) (13.21±5.73 mg N/100g), and trimethylamine nitrogen (TMA-N) (3.61±2.95 mg N/100g), indicating reduced lipid oxidation and protein degradation. Microbiological analysis revealed the lowest total viable count (TVC) (0.71±0.82×105 CFU/g) and yeast and mould count (0.09±0.04×103 CFU/g), suggesting better microbial stability. These findings confirm that Moringa and Ginger, especially in combination, are effective natural preservatives for improving the quality and extending the shelf life of smoked catfish. Their leaves contain vital phytochemicals and have intriguing applications in the pharmaceutical, cosmetic, and food industries, and this is due to the many applications that can be found for their versatility, high levels of nutrition, and potential nutraceutical benefits. The study recommends adopting these bio-preservatives in fish processing, further research on their application across different fish species, and developing training programs for fish processors on their use.
Keywords: African catfish; *Moringa oleifera*; *Zingiber officinale*; Storage stability

1 Introduction

Fish has high protein content and low saturated fat content, which is considered as highly valuable food (EPSA, 2016). In particular, fish is the primary dietary source of omega-3 polyunsaturated fatty acid (PUFA), including docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), both of which are well-known for the anti-inflammatory action and protective effects on cardiovascular disease (Nestel et al., 2015; Vilavet et al., 2017). The World Health Organization (WHO) recommends a regular fish consumption of 1~2 servings per week to provide the equivalent of 200~500 mg of omega-3 PUFA (Tediosi et al., 2015; Wallin et al., 2015).

According to statistics, fresh and live fish account for about half of the total seafood consumed by human beings. The word "fresh" refers to fish that have not been frozen, including still alive fish as well as kept in the cold but not frozen section or packed in modified atmosphere (Mcmanus et al., 2014). Unlike frozen fish, the fresh fish cannot stay as inventory for one month (Hicks, 2016). For consumers, freshness is also often associated with safety, reassurance and superior taste. In most cases, the customers believe that the fish sold in market in China are caught recently. However, it could take more than a week to arrive at these stores. Consumers are still unsure whether the "fresh" product is really fresh or has been frozen and then thawed.(Wakamatsu and Miyata, 2015, Bruhn, 2016).

In recent years, researchers have put much effort into searching natural preservatives that could inhibit the growth of bacteria and fungi in food. Meanwhile, a growing number of consumers are aware of the potential negative health effects of chemical preservatives, which has prompted the food industry to find natural products used and developed as alternatives. Natural preservatives are available from a variety of sources including plants, animals, bacteria, algae, and fungi (Ghanbari et al., 2013; Hassoun and Coban, 2017). Microbial derived preservatives (e.g., bacteriocin), plant derived preservatives (thyme essential oil, tea polyphenols, rosemary extract, etc.), and animal derived preservatives (e.g., chitosan from crab or shrimp shells) have been demonstrated to have antimicrobial or antioxidant properties. In addition, antimicrobial compounds produced by algae and fungal (mushroom) could be served as potential sources of new antimicrobial substances for use as natural preservatives in food.

Fresh fish can easily deteriorate after being captured due to the endogenous enzyme and rapid microbial growth naturally present in fish or from contamination (Jiang et al., 2018). In the process of fish decay decomposition of various components and formation of new compounds occur. What is more, changes in composition during fish decay lead to protein degradation and lipid oxidation, as well as changes in fish odor, flavor, and texture. Therefore, it has become inevitable to develop effective treatment methods to extend the shelf life of fish (Campos et al., 2012).

Soft or mushy texture of fish limits the shelf life, thereby impeding its marketing. During postmortem handling and storage, the holding temperature, oxygen, endogenous or microbial proteases, moisture can result in detrimental changes in the color, odor, texture, and flavor of fish (Sriket et al., 2010). Therefore, fish have traditionally been cooled and stored in flake ice, refrigerated sea water, or ice slurries or they have been preserved by exposure to chemical agents. At the same time, the fishery industry is always looking for new preservation methods to extend the fish shelf life and provide consumers with the best quality in terms of sensory and nutritional levels (Rey et al., 2012). The study hypothesis that Moringa leaf, Ginger root and their combination could serve as bio-preservatives for smoked catfish.

2 Materials and Methods

2.1 Study area

A 12weeks completely randomized design (CRD) feeding trial was conducted at the Department of Fisheries Technology, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria.

2.2 Procurement of fish sample

A total of 8000 g of fresh African catfish (*Clarias gariepinus*) was procured from a reputable Fish farm and processed at the Department of Fisheries Technology, Federal Polytechnic Ado Ekiti.

2.3 preparation of moringa seed and ginger root powder

Dry *Moringa oleifera* seed and ginger root was procured from a reputable farm and air-dried at average room temperature. They were kept away from high temperatures and direct sun light to avoid destroying active compounds. The dried Moringa seed and ginger root was grounded separately to fine powder using electric blender. 20 gramme of the powdered Moringa seed and ginger root were added to 1 liter of water to form 2 % of Moringa aqueous and ginger aqueous solution respectively (Samira et al., 2022).

2.4 Experimental design

The fish were randomly assigned to four dietary experimental treatments and replicated thrice. The first treatment (T1) is the control, without extract. The second treatment (T2) was Moringa seed powder (M); Treatment (T3), ginger root powder (G); the fourth treatment (T4), mixture of two powder (M and G). Each with a concentration of 2%. The experimental design with replicate as adopted by Abdurrazzaq et al. (2019) (Table 1). The fish was later soaked in the respective solutions (M,G and mixture of MG) for 30 minutes.

Table 1 Composition of experimental diets

Treatments	Ingredients	Concentration (%)
T1 (Control)	Without extract	-
T2	Moringa seed powder extract	2.0
T3	Ginger root powder extract	2.0
T4	Mixture of Moringa seed powder and Ginger root powder	2.0

2.5 Experimental procedure

The fish samples procured was weighed to determine its average mean weight, washed in clean water, and made inactive by dipping fish in a brine solution containing 20 g table salt/kg, allow in a plastic container for 10 minutes. Thereafter, the fish was degutted and washed in portable water as reported by Salami et al. (2024). The fish were then placed on wire mesh and allow to drain under shed. Light was set for the smoking kiln to glow for ten minutes. Then the fish were arranged based on their treatments and replications in the smoking kiln and charcoal was used for the ignition. After the smoking, the smoked-dried fish was allowed to cooled and pack in different cartons based on their treatments and transferred to a cooled-dry place save from any contamination in the laboratory for storage (Salami et al., 2024).

2.6 Storage for shelf life study

The oven-dried fish samples were packed in transparent polythene bags. Bags were sealed by using transparent cellotape. After that, the sampled fish product were kept for storage at room (26 °C~31 °C) temperature for further analysis. according to Olatunde et al. (2013).

2.7 Qualitative phytochemical analysis of moringa seed and ginger root

Phytochemical analysis of the extracts was carried out qualitatively using accepted laboratory techniques as described by (Nagalingam et al., 2012). Basic phytochemical screening was carried out using simple chemical tests to detect the presence of secondary plant constituents such as saponins, flavonoids, tannin, alkaloid and phenol were conducted accordingly. The methods used were those outlined by Nagalingam et al. (2012).

2.7.1 Test for saponins

The test was carried with froth test method.1 gram of each sample were weighed into a separate conical flask, which contained 10ml of distilled water and was boiled for 5 minutes. The two mixtures were filtered and 2.5 ml of the filtrate were added to 10ml of sterile distilled water in a test tube. The test tube was subjected to shaken vigorously for about 30 seconds and was then allowed to stand for half an hour. Honeycomb froth indicated the presence of saponins (Nagalingam et al., 2012).

2.7.2 Test for flavanoids

Five millilitre of dilute ammonia solution were added to a portion of the aqueous filtrates of the sample followed by addition of concentrated H_2SO_4. Formation of yellow colour observed in each sample indicated the presence of flavonoids (Nagalingam et al., 2012).

2.7.3 Test for tannins

The sample was mixed with basic lead acetate solution. Formation of white precipitate indicated the presence of Tannins.

2.7.4 Test for alkaloids

Two drops of Mayers’s reagent were added along the side of test tubes containing few ml of both samples. Appearance of white creamy precipitate indicates the presence of alkaloids.

2.7.5 Test for phenol

The test was carried out using Ferric chloride test to check for the presence of phenolic compounds. 50(mg) of each samples were dissolved in 5 mL of distilled water. Few drops of neutral 5% Ferric chloride solution was added both mixtures. Presence of phenolic compound indicates a dark green colour (Nagalingam et al., 2012)

2.8 Proximate composition

After processing, the fresh oven-dried sample was and sample stored for twelve weeks at room temperature were collected for proximate analysis. Proximate chemical composition analysis which includes determination of moisture content, crude protein, crude fat and total ash of the oven-dried fish sample was done according to AOAC official methods.

2.9 Quality deterioration evaluation

Fresh and stored oven-dried was examined for quality deterioration assessment to know the degree of freshness and quality. Sample were assessed for peroxide value (PV), thiobarbituric acid value (TBARS), total volatile basic nitrogen (TVB-N) and pH Value of oven-dried fish sample according to Tran et al. (2021).

2.10 Microbiological evaluation

Total viable count and mould count was determined using the methods adopted by Kefas et al. (2022).

2.11 Statistical analysis

Data obtained in this study were analyzed using analysis of variance (ANOVA) procedures (SPSS 11.0 for Windows). Differences between the mean values of the treatments were determined by the least significant difference (LSD) test and the significance will be define at $p<0.05$.

3 Results

3.1 Proximate composition of smoked catfish treated with bio-preservatives

The mean proximate composition of smoked catfish treated with bio-preservatives (Moringa, Ginger, and their combination) compared to the control group (Table 2). The parameters measured include moisture, protein, ash, fibre, fat, and carbohydrate contents. Each value is expressed as a percentage along with its standard deviation. The moisture content of the smoked catfish varied significantly among the different treatments. The control group (T1) shows highest moisture content at 7.90±1.21%. Moringa treatment (T2) shows reduced moisture content to 5.43±0.03%, while the Ginger treatment (T3) had a moisture content of 6.18±0.28%. The combination of Moringa and Ginger (T4) resulted in the lowest moisture content at 4.84±0.13%. Protein content was significantly higher in the treated groups compared to the control. The control group (T1) had a protein content of 59.59±1.58%.

Moringa treatment (T2) increased the protein content to 63.10±0.50%, while the Ginger treatment (T3) had a protein content of 61.74±0.38%. The combination treatment (T4) resulted in the highest protein content at 66.18±0.88%. Ash content showed slight variations across the treatments. The control group (T1) had an ash content of 8.55±0.10%. Moringa treatment (T2) slightly increased the ash content to 8.89±0.06%. Ginger treatment (T3) had the lowest ash content at 8.32±0.24%, while the combination treatment (T4) had an ash content of 8.36±0.34%. Fibre content was highest in the combination treatment (T4) at 1.53±0.15%, followed by the Moringa treatment (T2) at 1.43±0.14%, and the Ginger treatment (T3) at 1.36±0.12%.

The control group (T1) had the lowest fibre content at 1.21±0.01%. Fat content varied significantly among the treatments. The control group (T1) had the highest fat content at 10.92±0.13%. Moringa treatment (T2) had the lowest fat content at 9.22±0.03%, followed by the combination treatment (T4) at 9.05±0.24%. Ginger treatment (T3) had a fat content of 10.50±0.05%. Carbohydrate content was relatively similar across treatments, with the control group (T1) having a content of 11.64±0.32%. Moringa treatment (T2) had a carbohydrate content of 11.67±0.56%, while the Ginger treatment (T3) had a content of 11.87±0.79%. The combination treatment (T4) resulted in the lowest carbohydrate content at 10.01±1.44%.

Table 2 Proximate composition of the smoked catfish treated with bio-preservatives

Parameters (%)	T_1 (Control)	T_2 (Moringa)	T_3 (Ginger)	T_4 (Moringa & Ginger)
Moisture	7.90 ± 1.21^a	5.43 ± 0.03^c	6.18 ± 0.28^b	4.84 ± 0.13^d
Protein	59.59 ± 1.58^d	63.10 ± 0.50^b	61.74 ± 0.38^c	66.18 ± 0.88^a
Ash	8.55 ± 0.10^b	8.89 ± 0.06^a	8.32 ± 0.24^c	8.36 ± 0.34^c
Fibre	1.21 ± 0.01^d	1.43 ± 0.14^b	1.36 ± 0.12^c	1.53 ± 0.15^a
Fat	10.92 ± 0.13^a	9.22 ± 0.03^c	10.50 ± 0.05^b	9.05 ± 0.24^c
Carbohydrate	11.64 ± 0.32^b	11.67 ± 0.56^b	11.87 ± 0.79^a	10.01 ± 1.44^c

Note: $^{a-d}$ means with different superscript along row are significantly different ($p<0.05$)

3.2 Biochemical and microbiological evaluation of smoked catfish treated with bio-preservatives

The mean biochemical and microbiological analyses of smoked catfish treated with bio-preservatives (Moringa, Ginger, and their combination) compared to the control group (Table 3). The parameters measured include peroxide value (PV), thiobarbituric acid reactive substances (TBAR), total volatile base nitrogen (TVB-N), trimethylamine nitrogen (TMA-N), total viable count (TVC), and yeast and mould count. Each value is expressed along with its standard deviation. Peroxide value, which indicates the extent of lipid oxidation, varied significantly among the different treatments. The control group (T1) had the highest PV at 11.68±4.13 meq/kg. Moringa treatment (T2) reduced the PV to 9.23±2.77 meq/kg, while the Ginger treatment (T3) had a PV of 10.14±3.45 meq/kg. The combination of Moringa and Ginger (T4) resulted in the lowest PV at 6.10±1.80 meq/kg. Reactive Substances (TBAR), which measures the malondialdehyde content as an indicator of lipid peroxidation, showed significant differences across treatments. The control group (T1) had the highest TBAR at 5.03±2.08 mg malondialdehyde/kg. The Moringa treatment (T2) lowered the TBAR to 2.91±1.44 mg malondialdehyde/kg, while the Ginger treatment (T3) had a TBAR of 4.28±2.36 mg malondialdehyde/kg. The combination treatment (T4) had the lowest TBAR at 1.64±0.47 mg malondialdehyde/kg.

Total Volatile Base Nitrogen (TVB-N), an indicator of protein degradation, varied significantly among the treatments. The control group (T1) had the highest TVB-N at 24.17±0.42 mg N/100g. Moringa treatment (T2) reduced the TVB-N to 16.38±6.67 mg N/100g, while the Ginger treatment (T3) had a TVB-N of 20.05±9.36 mg N/100g. The combination treatment (T4) had the lowest TVB-N at 13.21±5.73 mg N/100g. Trimethylamine Nitrogen (TMA-N), another indicator of protein degradation, showed significant differences across treatments. The control group (T1) had the highest TMA-N at 6.39±4.11 mg N/100g. Moringa treatment (T2) lowered the TMA-N to 4.62±3.45 mg N/100g, while the Ginger treatment (T3) had a TMA-N of 5.58±3.99 mg N/100g. The combination treatment (T4) had the lowest TMA-N at 3.61±2.95 mg N/100g. Total Viable Count (TVC), which indicates the overall microbial load, varied among the treatments. The control group (T1) had a TVC of 1.49±1.72 x 10^5 CFU/g. Moringa treatment (T2) had a TVC of 1.26±1.45 × 10^5 CFU/g, while the Ginger treatment (T3) had the highest TVC at 1.81±2.09 × 10^5 CFU/g. The combination treatment (T4) had the lowest TVC at 0.71±0.82 × 10^5 CFU/g. Yeast and Mould Count showed significant differences across treatments.

The control group (T1) had a yeast and mould count of 2.42±2.53 × 10^3 CFU/g. Moringa treatment (T2) significantly reduced the count to 0.83±0.86 × 10^3 CFU/g, while Ginger treatment (T3) had a count of 1.14±1.20 × 10^3 CFU/g. The combination treatment (T4) had the lowest count at 0.09±0.04 × 10^3 CFU/g.

Table 3 Quality deterioration and microbiological parameters of the smoked catfish treated with bio-preservatives

Parameters	T_1 (Control)	T_2 (Moringa)	T_3 (Ginger)	T_4 (Moringa & Ginger)
PV (meq /kg)	11.68±4.13^d	9.23±2.77^b	10.14±3.45^c	6.10±1.80^a
TBAR (mg) (malondialdehyde/kg)	5.03±2.08^d	2.91±1.44^b	4.28±2.36^c	1.64±0.47^a
TVB-N (mgN /100g)	24.17±0.42^d	16.38±6.67^b	20.05±9.36^c	13.21±5.73^a
TMA-N (mg N/100g	6.39±4.11^d	4.62±3.45^b	5.58±3.99^c	3.61±2.95^a
TVC (x 10^5 CFU/g)	1.49±1.72^b	1.26±1.45^{ab}	1.81±2.09^b	0.71±0.82^a
Yeast and Mould (×10^3 Cfu/g)	2.42±2.53^b	0.83±0.86^a	1.14±1.20^{ab}	0.09±0.04^a

Note: $^{a-d}$ means with different superscript along row are significantly different ($p<0.05$)

3.3 Sensory evaluation of smoked catfish treated with bio-preservatives

The sensory evaluation of smoked catfish treated with bio-preservatives (Moringa, Ginger, and their combination) compared to the control group (Table 4). The parameters evaluated include odour, flavour, taste, texture, appearance, and overall acceptance. Each value is expressed along with its standard deviation. Odour of the smoked catfish varied significantly among the treatments. The control group (T1) had the lowest odour score at 6.50±0.99. Moringa treatment (T2) had an odour score of 7.82±0.50, while Ginger treatment (T3) had a score of 7.05±0.81. The combination of Moringa and Ginger (T4) had the highest odour score at 8.33±0.28. Flavour showed significant differences across the treatments. The control group (T1) had a flavour score of 7.15±0.93. Moringa treatment (T2) improved the flavour score to 7.93±0.55, while Ginger treatment (T3) had a score of

7.33±0.90. The combination treatment (T4) had the highest flavour score at 8.40±0.82. Taste of the smoked catfish also showed significant variations. The control group (T1) had a taste score of 6.68±1.65.

Moringa treatment (T2) had a taste score of 7.33±1.19, while Ginger treatment (T3) had a score of 7.20±0.98. The combination treatment (T4) had the highest taste score at 8.40±0.18. Texture scores were significantly different across treatments. The control group (T1) had a texture score of 7.03±0.84. Moringa treatment (T2) improved the texture score to 8.33±0.28, while Ginger treatment (T3) had a score of 7.95±0.47. The combination treatment (T4) had the highest texture score at 8.50±0.26. Appearance of the smoked catfish varied among the treatments. The control group (T1) had an appearance score of 7.13±0.67. Moringa treatment (T2) had a score of 7.88±0.55, while Ginger treatment (T3) had a score of 7.73±0.55. The combination treatment (T4) had the highest appearance score at 8.43±0.17. Overall acceptance scores were significantly different across treatments. The control group (T1) had an overall acceptance score of 7.23±1.07.

Moringa treatment (T2) improved the overall acceptance to 8.13±0.50, while Ginger treatment (T3) had a score of 7.83±0.61. The combination treatment (T4) had the highest overall acceptance score at 8.75±0.41.

Table 4 Sensory Evaluation of the smoked catfish treated with bio-preservatives

Parameters	T_1 (Control)	T_2 (Moringa)	T_3 (Ginger)	T_4 (Moringa & Ginger)
Odour	$6.50±0.99^d$	$7.82±0.50^b$	$7.05±0.81^c$	$8.33±0.28^a$
Flavour	$7.15±0.93^c$	$7.93±0.55^b$	$7.33±0.90^c$	$8.40±0.82^a$
Taste	$6.68±1.65^c$	$7.33±1.19^b$	$7.20±0.98^b$	$8.40±0.18^a$
Texture	$7.03±0.84^d$	$8.33±0.28^b$	$7.95±0.47^c$	$8.50±0.26^a$
Appearance	$7.13±0.67^c$	$7.88±0.55^b$	$7.73±0.55^b$	$8.43±0.17^a$
Overall Acceptance	$7.23±1.07^d$	$8.13±0.50^b$	$7.83±0.61^c$	$8.75±0.41^a$

Note: $^{a-d}$ means with different superscript along row are significantly different (p<0.05)

4 Discussions

The result from the proximate composition (Table 2) revealed that highest protein content was observed in the combination treatment (T4) (66.18±0.88%), significantly higher than the control (59.59±1.58%). This suggests that the bio-preservatives help preserve the protein quality during the smoking and storage process. There was a significant difference (P<0. 05) among the treatments. This result was similar to the report of Sunday and Toyosi, (2023) who reported better crude protein in fish treated with spices compared to the control. The combination of Moringa and Ginger (T4) resulted in the lowest moisture content (4.84±0.13%) compared to the control (7.90±1.21%). This indicates that bio-preservatives effectively reduced the water activity, which is critical for prolonging the shelf life of smoked fish by inhibiting microbial growth. Significant difference existed among the treated fish sample in moisture content and protein content (p<0.05). But there was no significant difference between the ash content of fish smoked with Ginger and the combination of Moringa and Ginger smoked fish. This could be due to the high oxidative value of ginger as reported by (Utah et al., 2021).

The Moringa and Ginger combination (T4) had the lowest fat content (9.05±0.24%), indicating that the bio-preservatives might help reduce lipid oxidation, thus preserving the fat quality in smoked catfish which agree with the work of Hassan et al. (2013); Abdul and Aktar, (2011) reported an increase in the moisture content as the length of storage increased and a decrease in crude protein, and lipid as the storage period increased which was in accord with the present findings. Carbohydrate content was relatively similar across treatments, with the combination treatment (T4) showing the lowest value (10.01±1.44%), possibly due to the more effective preservation method reducing the need for carbohydrates as a preservative.

The results of quality deterioration and microbiological parameters revealed that Peroxide Value (PV), Thiobarbituric Acid Level (TBA), Total Volatile Basic Nitrogen (TVB-N), and Trimethylamine (TMA) were decreased in the treated groups compared to the control. However, the combination treatment (T4) had better values of PV, TBA, TVB-N and TMAN at 12 weeks storage. This is because these bio-preservatives possessed phenolic compounds (phenolic acids, polyphenols and flavonoids) which helps to prevent oxidative rancidity and prolong the shelf life of the fish in the treated groups. These results were in accord with the report of Sunday and Toyosi, (2023) who reported that application of spices inhibits the free-radical mediated damages like lipid oxidation thus preventing oxidative rancidity. Also, the present study supports the report of Abdul and Aktar (2011); and Farid et al. (2014) who reported that the nutritional value of dried fish deteriorates with the increase in storage period.

Small-scale and large scale fish processors provide important nutrient-rich source of vitamins and minerals to the consumer diet and improve their livelihood. Improved fish processing techniques also improve the working conditions for the vast number of women in processing centers. The fish processsors gain income and food from their employment. The consumption of processed fish reduced risk of heart disease, I.e. Omega-3 fatty acids in catfish contribute to lower levels of bad cholesterol and increased good cholesterol, reducing heart disease risk. It regulates blood pressure, i.e. the potassium in catfish helps regulate blood pressure. The high protein and low-calorie content make catfish an excellent choice for those aiming to lose or manage weight. Phosphorus in catfish contributes to stronger bones and teeth. Omega-3 fatty acids are crucial for brain health and can improve mood and cognitive function (Yusbay, 2023).

Plants have ability to synthesize various chemical compounds and these antimicrobial components enhance the defense mechanism of plant against natural infections.Vaishali et al. (2019) reported that many herbs and spices such as moringa leaf, ginger, cloves (*Carophyllus aromaticus*), cinnamon, guar gum, mustard seed and garlic have antimicrobial properties. When added in food products, the antimicrobial properties associated with such herbs and spices offer them competency to prevent food from spoilage and exercise food safety by controlling growth of spoilage and pathogenic microorganisms. He reported that there are number of plants which are recognized as herbs or spices and are part of culinary practices followed in different countries to improve the sensory quality and shelf life of food products as well as owing to their nutritional, antimicrobial and health promoting properties (Vaishali et al., 2019). The main advantage of using herbs and spices in food as preservatives is due to their ‘generally recognized as safe’ (GRAS) status because their use in human diet is time tested.

Alex and Eagappan, (2017); Taniya and Kannan, (2016); Kumolu-Johnson et al. (2015) reported that application of herbs and species that possessed antioxidant and anti- bacterial properties helps to prevent the microbial growth and increasing the shelf life of the product. The results show that the Total viable counts and Mould, Yeast counts were higher in the control than in the treated groups, the values of Total viable counts and Mould, Yeast counts increased at 12 weeks storage. The result of the microbiological evaluation of this study suggest that Moringa and Ginger are effective in inhibiting microbial and fungal growth in smoked catfish. The combination of moringa and ginger recorded the lowest Total viable counts and Mould, Yeast counts at 12 weeks of storage. There was a significant difference ($P< 0.05$) among the treatments. This study was in concordance with the report of Taniya and Kannan, (2016) who reported higher bacterial counts as the storage period increases in all the treatments with a reduction in microbial count in treated groups compared to the control.

Sensory Evaluation of the smoked catfish treated with bio-preservatives is shown (Table 4). The combination of Moringa and Ginger (T4) consistently received the highest scores across all sensory parameters, indicating a significant improvement in the overall sensory quality of smoked catfish. Moringa (T2) generally performed better than Ginger (T3) in terms of odour, flavour, texture, and overall acceptance, although both treatments were significantly better than the control. These results suggest that the application of Moringa and Ginger, particularly in combination, can significantly enhance the sensory attributes of smoked catfish, making them more appealing to consumers. This study shows that combination of a mixture of moringa and ginger gave a better acceptability of preserving fish products as they sustained longer shelf life, reduced bacterial and enzymatic activities and a better sensory score than that of control fish. This study supports the report of Alex and Eagappan, (2017) and Akter et al. (2012) who reported that dried fish treated with spices and herbs had better shelf life and flesh quality than the control.

5 Conclusion

This study evaluated the impact of Moringa, Ginger, and their combination on the quality of smoked catfish. The combination of Moringa and Ginger was found to be the most effective in enhancing the nutritional quality, reducing spoilage indicators, and improving sensory attributes. Specifically, the combined treatment resulted in lower moisture content and higher protein levels, indicating better preservation of nutritional value. It also showed the lowest levels of lipid oxidation and protein degradation, along with the best microbial stability.

Sensory evaluation revealed that the combination treatment consistently received the highest scores in odour, flavour, taste, texture, appearance, and overall acceptance. These results highlight the effectiveness of Moringa and Ginger as natural preservatives in improving the quality, safety, and consumer appeal of smoked catfish.

6 Recommendations

The study suggests that fish processors should use Moringa oleifera seed and Ginger rhizome as natural preservatives for smoked catfish to improve quality, shelf life, and sensory attributes. Further research should explore their effects on different fish species and consumer acceptance. Training programs and regulatory guidelines are also recommended. Natural preservatives combined with either lower levels of synthetic/chemical ones, or with other hurdles, such as non-thermal sterilization processing, modified atmosphere packaging, and edible films and coatings, could also enhance the performance of various natural preservatives.

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Authors' Contributions

COR and SRS conceived and planned the experiment. All the authors participated in design and coordination. All the authors performed the experiments, contributed to sample preparation, interpreted the results, and took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analyze, and write the manuscript.

Animal Welfare Statement

Ethics approval

The authors confirm that the ethical policies of the journal, as noted in the journal authors guide lines, have been adhered to. Approval to perform the research and use animals was obtained from the Ethics Committee of the Federal Polytechnic, Ado-Ekiti, Ekiti state, Nigeria.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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