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Effect of Natural Preservatives (O*cimum Gratissimum* and *Zingiber Officinale*) on Shelf Life and Storage Stability of Smoked African Catfish

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ABSTRACT

This study investigated the impact of various bio-preservatives on the proximate composition, quality deterioration, and sensory attributes of smoked catfish. Specifically, the effects of Scent leaves (*Ocimum gratissimum*), Ginger rhizome (*Zingiber officinale*), and their combination on smoked catfish were evaluated. The results demonstrated significant variations in proximate composition across different treatments. Ginger-treated fish exhibited the lowest moisture content (6.18%) and the highest protein content (61.74%). In contrast, *Ocimum gratissimum* treated fish showed the highest ash content (10.53%) and the highest fiber content when combined with ginger (1.83%). Fat content showed minimal variation, with ginger-treated fish showing the lowest fat content (10.50%). Quality deterioration parameters revealed that the combination treatment of *Ocimum gratissimum* and ginger had the lowest peroxide value (8.45 meq/kg) and total volatile base nitrogen (14.67 mg N/100g), indicating superior preservation of lipid quality. Thiobarbituric acid reactive substances (TBARS) values were also lowest in the combination treatment (5.27 mg malondialdehyde/kg). For spoilage indicators, ginger-treated fish exhibited the lowest total trimethylamine nitrogen (5.58 mg N/100g) and total viable count (1.81 x 10^5 CFU/g), while yeast and mould counts were minimal in ginger-treated fish (1.14 x 10^3 CFU/g). Sensory evaluation revealed that ginger-treated smoked catfish scored highest in aroma (7.05), taste (7.20), texture (7.95), appearance (7.73), and overall acceptance (7.83). These results indicate that ginger treatment significantly enhances the sensory quality of smoked catfish compared to others. This study highlights ginger as a particularly effective bio-preservative for improving the nutritional quality and sensory attributes of smoked catfish.

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INTRODUCTION

Fish are usually reared in ponds or different types of tanks at different stocking densities (FAO, 2012). For the extensive culture of this fish, the larvae are fed with cow brain and egg yolk after 4-6 days prior to stocking in fenced nursery ponds. The post-larvae are then fed with single ingredient or compounded feeds. Fingerlings are graded and harvested after 24-48 days and are transferred to the production pond or being sold by the farmers. Different systems are currently being used in growing the catfish including the traditional flooded ponds, pits or ditches, earthen ponds, tanks, raceways and even in cages. Fish has been regarded as means of getting income, food and employment (FAO, 2014; Amponsah et al., 2016). Fish is rich in protein and amino acids (Pasqualino et al., 2016), vitamins and minerals (FAO, 2012). It also provides polyunsaturated fatty acids for human health (Allison, 2011). Fish provides an important component of diet for many people, and often provides the required nutrients for a healthy living. Processing of fish is a way of preserving fish. The traditional ways of preserving fish by drying, salting, pickling and smoking is still widely practiced by locals in developed and developing countries. Modern ways of processing and preservation have led to the consumption of many species of fish (Okorie-Humphrey et al., 2022).

The African catfish (*Clarias gariepinus)* is a large eellike fish usually of dark gray or black coloration on the back, with white belly and is locally known as "hito" and "pantat" belonging to family Clariidae (FAO, 2012). It is hardy with an accessory air-breathing organ (labyrinth organ) and it is found to be suitable for both small-scale and commercial aquaculture since it does not require extreme efforts and costs and has faster growth rate (FAO, 2012). *Clarias gariepinus* commands high price when sold in the market and its production greatly increases (FAO, 2012). The demand for catfish in the world continued to increase with production volume ranging between 3,729.29 metric tons in 2016 and 5,420.77 metric tons in 2020 (PSA, 2021). It also contributed an annual value of PHP 5.77 million in 2020 (PSA, 2021).

Catfish are among one of the most surprising fish groups in the world. Catfish are characterized based on their cylindrical body with a flattened ventral and prominent barbell(s), mostly scale-less compared to other teleost fishes. Catfish are energetic bottom dwelling movement fish and opportunistic feeders who actively search for food, especially at night. They are distributed worldwide, except in the Antarctic. They are also one of the most diverse groups of ray-finned fish globally, containing both highly endangered and the world's worst invasive alien species (Armbruster, 2011). Historically, the number of catfish species was reported as 3093 in 2005 (Armbruster, 2011). In year 2011, this count increased to 3407 species (Armbruster, 2011), indicating a notable growth in the understanding and discovery of catfish biodiversity. With an increasing number of catfish species found in the world (Mejia et al., 2022; Jokar et al.,

2023), it is expected that it can reach up to 5000 species by the end of 2030. This is also because catfish can be found in marine and freshwater environments and are also exceptionally important as an aquatic product. Due to their diversity, distribution, and ecological importance, catfish have become one of the potential model organisms for scientific research and publication, in various fields of study such as toxicology, evolutionary biology, fisheries, parasitology, neurology, immunology, and economics. For example, catfish are hardy species, and they are a suitable candidate for toxicology related experiments since they are high tolerance to low dissolved oxygen which was potentially induced by the heavy metals' contaminants (Rejab et al., 2020).

Despite the nutritional benefits derived from fish and its products, they are vulnerable to spoilage if not properly preserved. Spoilage in fish occurs because it is susceptible to microbial and enzymatic deterioration which results in quality reduction, especially in the absence of proper processing and storage techniques. Generally, during post-harvest period large amounts of fish spoil and waste due to the fact that they are not properly handled and transported (FAO, 2016). Also, in order to meet the complex and long chain of distribution as well as fish food security, it is important to ensure proper fish preservation using natural preservatives that can improve organoleptic properties of fish and also extend its shelf-life. So, using preservatives like ginger, pepper and sodium chloride can hinder the growth of microbes during storage (Amuneke et al., 2020).

Spices are food adjuncts that are used as flavouring agents and as preservatives in food products (Okorie-Humphrey et al., 2022). There have been reported mixed feelings from consumers over health challenges such as hypertension, cancer and obesity resulting from excessive use of artificial food additives. *Ocimum gratissimum* and *Zingiber officinale* parts are used as spices in the preparation of local dishes which are better used to replace these artificial spices (Edeoga et al., 2005).

Both ginger (*Zingiber officinale*) and scent leaf (*Ocimum gratissimum*) are well-known for their medicinal properties and potential benefits for animal health. According to Owen (2021), the well-known anti-inflammatory, antioxidant, and antibacterial qualities of ginger, can enhance the health and feed efficiency of chickens. Similarly, antibacterial properties of scent leaf have been documented; these properties may help regulate the quantity of microbes in the stomach, enhancing nutrient absorption and growth efficiency (Agholor et al., 2018).

Ginger is inexpensive, and it is also "Generally Recognized as Safe" (GRAS). Secondary metabolites found in the rhizome include phenolic compounds (gingerol, paradol, and shogaoal), volatile sesquiterpenes (zingiberene and bisabolene), and monoterpenoids (curcumene and citral) (Ali et al., 2018). Previous research has shown that Z. officinale plant extracts have strong antioxidant and free radical scavenging properties (Erkmen and Bozoglu, 2016; Bakhouche et al., 2021), as well as antibacterial, antifungal,

anticancer, and anti-inflammatory effects (Ali et al., 2018; Islam et al., 2019). As a result, there is a great deal of interest in using ginger extract to improve the safety and quality of fish after harvest.

There is scanty of information regarding the impact of natural preservatives and different storage period at room temperature on the nutrient quality, microbial quality and shelf-life of smoked *Clarias gariepinus*. This study was on the effect of *Ocimum gratissimum* and *Zingiber officinale* as natural preservatives on the changes in microbial population and quality of smoked *C. gariepinus* during 12-weeks ambient storage.

MATERIAL AND METHOD

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 September, 2024.

Source of Materials

A 12 weeks completely randomized design (CRD) feeding trial was conducted at the site of Fisheries Technology Department and a total of 8000 g of fresh African catfish (*Clarias gariepinus*) was procured from reputable farm. The ginger used in the experiment was purchased at the Ado local market.

Sample Preparation

One kilogram of ginger was obtained and immediately transported to the laboratory in a clean polythene bag. Green's field identification guide (UNESCO, 2006) was used to confirm the identity of the ginger samples. It was then washed, blended with an Akai blender, and stored for future use. The scent leaves were washed, separated from their stems, and oven-dried at 55°C until they became crispy in order to preserve their greenish-brown colour (Figure 1). The dried leaves were pulverized using a laboratory blender. Twenty (20 g) of the powdered *Ocimum gratissimum* (Figure 2) and ginger root were added to 1 liter of water to form 2% of *Occimum gratissum* aqueous and ginger aqueous solution respectively (Samira et al., 2022). The fish were randomly assigned to four experimental treatments (Figure 3). All the treatments were replicated thrice. The first treatment (T1) was control, without extract. The second treatment (T2) was *Ocimum gratissimum* powder (O); the third treatment (T3), ginger root powder (G); the fourth treatment (T4), mixture of two powders (OG), each with a concentration of 2%. Table 1 indicates the experimental treatments adopted by Abdurrazzaq et al. (2024).

The fish was later soaked in the respective solutions (O, G and mixture of OG) for 30 minutes.

Table 1. Experimental design

Treatments	Ingredients	Concentration (%)
T1 (Control)	Without extract	-
T2	*Ocimum gratissimum* powder extract	2.0
T3	Ginger root powder extract	2.0
T4	Mixture of *Ocimum gratissimum* powder and ginger root powder	2.0

Figure 1. Scent leaf (*Ocimum gratissimum)*

Figure 2. Ginger root (*Zingiber officinale)*

Figure 3. BrendaN77: iStock African Catfish (*Clarias gariepinus*)

METHODS

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 alkaloid, flavonoids, glycosides, saponins and tannin. The fish samples were processed using Kainji Improved Drum Kiln. The drying rate or moisture loss was measured at the end of the dying process, there was frequent checking of the fish in other to take precaution against charring of the fish product until the fish was completely oven dried. The fish were then allowed to cool at an ambient temperature before they were packaged using a polyethylene leather for preservation. The fresh oven-dried fish sample were stored for twelve weeks at room temperature (28°C) and tested for proximate analysis according to AOAC (2015).

Figure 1, the scent leaves, Figure 2, the ginger root and Figure 3, the catfish are the materials used for this experiments. Fresh and oven-dried fish were also examined for quality deterioration 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). Total viable count was done using the pour plate method of (AOAC, 2000). One milliliter of the serially diluted samples was taken in duplicates and plate count agar was poured at 40 on the plates. The samples and the medium were properly mixed, allowed to set and incubated at 35 and 37 for 24h. The number of colonies on the plates was counted. The colonies were sub cultured to get pure cultures which were further screen for the presence of indicator organisms.

Proximate Analysis

This was done for fresh and oven dried samples in accordance to the method of Association of Official Analytical Chemists (AOAC) (2015). The chemical components determined were moisture content, crude protein, ash, fibre, fat and carbohydrate.

Sensory Analysis

Organoleptic attributes of taste, texture, colour, rancidity and general acceptability of the fish samples were evaluated by 10 trained panelists, selected from the department of Fisheries Department, Modibbo Adama University, Yola using a 9- point hedonic scale (Peryam and Pilgrim, 1957).

Microbiological Analysis

The following procedures were used for the specific microbes: One gram (1g) representative sample was obtained aseptically from the muscle of the smoked catfish samples. The samples were grounded and serial dilutions of the homogenized samples were made using sterile distilled water. All chemicals used were of analytical grade and supplied by Sigma Co. (St Louis, USA). Each analysis was carried out in triplicates. All microbial analysis was done following the methods prescribed by (AOAC, 2000).

Statistical Analysis

The statistical analysis was carried out using Statistical package for social sciences version 20 (SPSS, 2014). The data were expressed as mean ± standard deviation and multivariate analysis of variance were used to show significant variations at $p<0.05$.

RESULTS AND DISCUSSION

The mean proximate composition of smoked catfish treated with *Occimum gratissum* showed significant variations across different treatments (Table 2). The analysis of the proximate composition of smoked catfish treated with different bio-preservatives yielded varied results. The moisture content was lowest in the fish treated with Ginger, measuring 6.18%. Regarding protein content, the fish treated with ginger exhibited the highest level at 61.74%, Ash content, reflecting mineral levels, was highest in the *Ocimum gratissum* treated fish at 10.53%. Fat content varied minimally among treatments, with the ginger-treated fish showing 10.50% and the combination treatment at 12.01%. The control had a fat content of 10.92%, while the *Ocimum gratissum* treated fish had 11.44%.

Table 2. Proximate composition of the smoked catfish treated with scent leaves (O*ccimum gratissum) and Zingiber officinale*

Parameters (%)	**$T_{1(Control)}$**	**T_{2} (Ocimum)**	**$T_{3(Ginger)}$**	**$T_{4(Ocimum\ \&\ Ginger)}$**
Moisture	7.90 ±1.21^{b}	8.04 ±0.90 ^{a}	6.18 ±0.28^{c}	8.80 ±3.87^{a}
Protein	59.59 ±1.58^{b}	52.85 ±7.16^{bc}	61.74 ±0.38^{a}	53.71 ±9.74^{b}
Ash	8.55 ±0.10^{c}	10.53 ±1.50^{a}	8.32 ±0.24^{c}	9.83 ±0.42^{b}
Fibre	1.21 ±0.01^{b}	1.16 ±0.13^{b}	1.36 ±0.12^{b}	1.83 ±0.37^{a}
Fat	10.92 ±0.13^{c}	11.44 ±1.61^{b}	10.50 ±0.05^{c}	12.01 ±2.11^{a}
Carbohydrate	11.64 ±0.32^{c}	15.88 ±2.92^{a}	11.87 ±0.79^{c}	13.79 ±2.97^{b}

$^{a-c}$ means with different superscript along row are significantly different ($p<0.05$).

Quality Deterioration and Microbiological Parameters

The mean quality deterioration and microbiological parameters of smoked catfish treated with *Ocimum gratissimum*, ginger and their combination were analyzed and presented in Table 3. The peroxide value (PV), which indicated the extent of lipid oxidation, was lowest in the combination treatment of *Ocimum gratissum* and ginger (T4) with a value of 8.45 meq/kg. This was significantly lower than the control (T1) at 11.68 meq/kg, the *Ocimum gratissum* treated fish (T2) at 12.44 meq/kg, and the ginger-treated fish (T3) at 10.14 meq/kg. For thiobarbituric acid reactive substances (TBARS), which measure secondary products of lipid oxidation, the combination treatment (T_4) also showed a lower value of 5.27 mg malondialdehyde/kg compared to the *Ocimum gratissum* treated fish (T_2) at 8.29 mg malondialdehyde/kg, the control (T_1) at 5.03 mg malondialdehyde/kg, and the ginger-treated fish (T_3) at 4.28 mgMDA/kg.

Total volatile base nitrogen (TVB-N), which reflects the overall quality and spoilage of fish, was lowest in the combination treatment (T_4) with a value of 14.67 mg N/100g. This was significantly lower than the control (T_1) at 24.17 mg N/100g, the *Ocimum gratissum* treated fish (T2) at 20.17 mg N/100g, and the ginger treated fish (T_3) at 20.05 mg N/100g. Total trimethylamine nitrogen (TMA-N), another spoilage indicator, was lowest in the ginger treated fish (T_3) at 5.58 mg N/100g, compared to the control (T_1) at 6.39 mg N/100g, the Ocimum-treated fish (T2) at 7.22 mg N/100g, and the combination treatment (T_4) at 5.77 mg N/100g.

In terms of total viable count (TVC), which reflects the overall microbial load, the control (T1) had the highest count at 4.42 x 10^5 CFU/g, while the *Ocimum gratissum* treated fish (T_2) had the lowest count at 1.49 x 10^5 CFU/g. The ginger-treated fish (T_3) had a count of 1.81 x 10^5 CFU/g, and the combination treatment (T4) had a count of 2.91 x 10^5 CFU/g. Yeast and mould counts, indicating fungal contamination, were lowest in the ginger-treated fish (T_3) at 1.14 x 10^3 CFU/g, compared to the control (T_1) at 2.43 x 10^3 CFU/g, the combination treatment (T_4) at 1.92 x 10^3 CFU/g, and the *Ocimum gratissum* treated fish (T_2) at 2.29 x 10^3 CFU/g.

Table 3. Quality deterioration and microbiological parameters of the smoked catfish treated with scent leaves (O*ccimum gratissum) and Zingiber officinale)*

Parameters	T1(Control)	T2 (Ocimum)	T3(Ginger)	T4(Ocimum & Ginger)
PV (meq /kg)	11.68 ±4.13b	12.44 ±4.38a	10.14 ±3.45c	8.45 ±2.05d
TBARS (mg malondialdehyde/kg)	5.03 ±2.08b	8.29 ±3.07a	4.28 ±2.36c	5.27 ±1.87b
TVB-N (mgN /100g)	24.17 ±0.42a	20.17 ±11.54b	20.05 ±9.36b	14.67 ±6.40c
TMA-N (mg N/100g	6.39 ±4.11b	7.22 ±3.41a	5.58 ±3.99c	5.77 ±4.06c
TVC (x 105 CFU/g)	4.42 ±0.42a	1.49 ±0.60c	1.81 ±0.01c	2.91 ±0.18b
Yeast and Mould (x 103Cfu/g)	2.43 ±0.89a	2.29 ±0.94b	1.14 ±0.66c	1.92 ±0.79c

[a-d] means with different superscript along row are significantly different ($p<0.05$)

Sensory Evaluation

The mean of sensory evaluation of smoked catfish treated with *Ocimum gratissimum,* ginger, and their combination are presented in Table 4. The aroma score was highest for the ginger treated fish (T_3) at 7.05, which was significantly better than the control (T_1) at 6.50, the *Ocimum gratissum* treated fish (T_2) at 6.15, and the combination of *Ocimum gratissum* and ginger (T_4) at 6.20. In terms of taste, the ginger treatment (T_3) again provided the highest score of 7.20, compared to the control (T_1) at 6.68, *Ocimum gratissum* treated fish (T_2) at 5.68, and the combination treatment (T_4) at 6.65. Texture evaluation revealed that the Ginger-treated fish (T_3) had the highest score of 7.95, significantly better than the control (T_1) at 7.03, the *Ocimum gratissum* treated fish (T_2) at 6.25, and the combination treatment (T_4) at 6.08. For appearance, the ginger-treated fish (T_3) also scored highest at 7.73, compared to the control (T_1) at 7.13, the *Ocimum gratissum* treated fish (T_2) at 6.05, and the combination treatment (T_4) at 5.88. Overall acceptance was highest for the ginger-treated fish (T_3) at 7.83, significantly higher than the control (T_1) at 7.23, the combination treatment (T_4) at 6.78, and the *Ocimum gratissum* treated fish (T2) at 6.40. This suggests that ginger treatment provided the most favorable overall sensory quality of the smoked catfish.

Table 4. Mean sensory evaluation of the smoked catfish treated with scent leaves (O*cimum gratissum) and Zingiber officinale*

Parameters	T1(Control)	T2 (Ocimum)	T3(Ginger)	T4(Ocimum & Ginger)
Aroma	6.50 ±0.99b	6.15 ±0.72b	7.05 ±0.81a	6.20 ±0.43b
Taste	6.68 ±1.65b	5.68 ±0.70c	7.20 ±0.98a	6.65 ±0.75b
Texture	7.03 ±0.84b	6.25 ±1.28c	7.95 ±0.47a	6.08 ±0.34c
Appearance	7.13 ±0.67b	6.05 ±0.98c	7.73 ±0.55a	5.88 ±0.48d
Overall Acceptance	7.23 ±1.07a	6.40 ±1.00b	7.83 ±0.61a	6.78 ±0.90b

a-d means with different superscript along row are significantly different ($p<0.05$)

DISCUSSION

Table 2 shows the mean percentage proximate composition of catfish treated with scent leaves (*Ocimum gratissum*) at twelve weeks storage condition. A slight decrease in moisture content was observed in the *Occimum gratissum* treated fish sample (T_2) while the ginger treated fish sample shows the least value of moisture content during the period of storage. This could be attributed to the anti - oxidative properties present in ginger. This study is in accordance with the findings of Adaka, 2021, who reported low moisture content in oven-dried ginger-spiced fish at twenty-eight (28) days storage condition. It was observed that differences in moisture content could be due to different smoking methods adopted which could influence the shelf life of the fish. Salami et al. (2024) reported that using oven drying method could remove moisture content and thereby reducing the microbial activity and elongates the shelf of the fish. The result of this study indicates that the ginger treated fish sample formed the largest quantity of crude protein. Also, there is a significant difference ($p<0.05$) in the percentage crude protein content of differently treated smoked catfish with the crude protein of the control (T_1) and ginger treated smoked (T_3) catfish being the largest with mean value 61.74±0.38% which reduce significantly when compared with other treated smoked catfish.

The highest crude protein detected in ginger treated smoked catfish in this study correspond with the study of Adaka (2021), who found highest crude protein in fish treated with ginger (71.68%) within 28 days storage condition. Likewise, Mohammed et al. (2010) found out that fish treated with ginger had highest crude protein at 28 days storage period. The reduction in percentage crude protein *Occimum gratissum* treated catfish could be as a result of increase in the ash content of the fish product which is a function of the ash content of treatment (T_2) applied to the fish. Similar trend was also applied to fibre content and lipid content of the fish. However, the result of the percentage ash content indicates that the ginger treated fish has the lowest ash content with a mean value of 8.32%. This study corresponds with Ayeloja et al. (2013) who reported the lowest fat and ash content in ginger treated smoked catfish. There was significant different ($p<0.05$) in the carbohydrate content of all the fish products.

The results of Quality deterioration and microbiological parameters of the smoked catfish treated with scent leaves (*Occimum gratissum)* and ginger are presented in Table 3. Peroxide value (PV) was highest (12.44 meq/kg) in *Occimum gratissum* treated sample and lowest in combination sample (T_4) (8.45 meq/kg). Adindu et al. (2022) reported 10-15 meq of O_2/kg for rancidity. The peroxide values recorded in this study were within the acceptable limit indicating that the products will keep well during storage. The high Thiobarbituric acid value obtained for the *Occimum gratissum* treated sample (T_2) could be as a result of combined effect of temperature and exposure time;

and the formation of secondary oxidation compounds has proved to be an interesting tool to assess the chemical changes produced as a result of the drying process.

It was observed that exposure time during drying of fish can influence the formation of secondary lipid oxidation compound from 40-60^{0}C (Ortiz et al., 2013). Cakli et al. (2006) reported that TBARS values more than 3 -4 mg MDA/kg represent loss of product quality. The values obtained for TBARS for pretreated smoked-dried fishes in this study were above the limit (3-4 mg MDA/kg) acceptability, while ginger treated sample falls within acceptable limit (4.28 mg MDA/kg). TVB-N values decreased in all treatment sample compared to control from initial storage period to end of storage period. The mean TVB-N values of combination treatment (T4) shows lowest value 14.67 mgN /100g and shows significantly difference ($p>0.05$) to other treatments (T_1, T_2 and T_3). The TVB-N values of all treatments recorded in this study were lower than 25mg/100 g which was considered as the threshold for a good-quality fish product; high TVB-N values are unacceptable and are associated with unpleasant smell in the fish.

Likewise, it was observed that TVB-N values range between 9.20mgN/100g-17.81mgN/100g could be found in pre-treated smoked catfish muscle after 28 days storage condition. TMAN has been found to be a useful index of spoilage and parameter for freshness assessment of sea-food. Renitta et al. (2021) reported that TMA-N is produced from the bacterial reduction of TMAO. The increase of TMA – N values in detected in *Occimum gratissum* (7.22 mg N/100) treated fish sample may be due to the increase in moisture content during the storage. The value of TMA-N recorded in this study was lower than the findings of Remitta et al. (2021), who reported TMA-N value between 2.00 mg N/100 to 14.00 mg N/100 of smoked *C. ramosus* and *V. cochlidium* at 180 days storage period. For the Total Viable Bacteria Count (TVC), the control sample (T_1) had the highest bacteria count (4.42 x 10^5 cfu/g) while lowest bacteria count was observed in the treatment group. The microbial populations for the entire treated smoked-dried fish samples observed in this study are within the recommended safe limits (5 x10^5 cfu/g) for good quality fish product as reported by (Adindu et al., 2022).

Adindu et al. (2022) reported that molds caused fish spoilage due to production mycotoxins and they can grow in salt concentration within 5-26%. Total fungal count ranged from 1.14 X 10^3cfu/g to 2.43 X 10^3cfu/g. Ginger treated sample recorded lowest value of fungal count. From the result of the microbiological examination, it is evident that the different pre-treatment of smoked-dried fish seems sufficient to have destroyed microbes and the absence of viable mold mass indicates the effectiveness of the applied pretreatments as anti-fungal agents. This agrees with the findings of Amuneke et al., 2020), who reported that natural preservatives extract was effective in microbial load reduction in stored fish. Moreover, Klin-Kabari et al. (2011) reported that *Piper guineensis and Xylophia aethiopicum* had antioxidant and chemical

preservatives which could preserve smoked dried fish for longer period without the microorganism growth and also improve the shelf life of the fish. Furthermore, Oluborode et al. (2015) corroborates the result of this study by reporting that microbial analysis of fish Samples treated with 3 spices showed the total viable counts as well as bacteria species were not detected in the fish samples after smoking.

The results of sensory evaluation of the smoked catfish treated with scent leaves (*Occimum gratissum)* and ginger rhizome under twelve weeks storage duration are shown in Table 4. The best rates in terms of aroma and taste was ginger treated sample (T_3) with a sensory score of 7.05 and 7.20 for taste and aroma respectively which translates to 'like moderately' on the sensory Hedonic scale". The O*ccimum gratissum* (T_2) was the least preferred by the panelists with a sensory score of 6.14 and 5.68 for aroma and taste respectively. Adindu et al. (2022) reported that Aroma is a perceived odours which diffuse from the food which is taken up by the nose and detected by the olfactory receptors.

The texture attribute of the smoke-dried catfish ranged from 6.08 to 7.95 The texture of the *Occimum gratissum* treated sample (T_2) and combination sample (T_4) were the least preferred by the panelists with mean scores of 6.25 and 6.08 respectively which translates to 'Like slightly' on sensory Hedonic scale', and are not significantly difference ($P>0.05$). However, Ginger treated sample (T_3) with a mean score of 7.95 recorded better texture attribute and translates to Like very much on sensory 'Hedonic scale' compared to T_1, T_2 and T_4 sample. The appearance attributes of smoked fish ranged from 5.88 (combination treated sample T_4) to 7.73 (ginger treated sample T_3). The appearance of the combination sample and the *Occimum gratissum* treated sample were the least preferred by the panelists with mean scores of 5.88 and 6.05 respectively which translates to "Like slightly" on the Hedonic scale. Treatment three (T3) recorded better sensory scores compared to T1, T2 and T4.

Iwe et al. (2017) reported that physical appearance is an important feature in evaluating food samples. From this result in Table 4, the best smoked-dried fish sample with respect to general acceptability was ginger treated sample with recorded mean sensory score of 7.83. This was closely followed by control sample and combination treated sample while the least preferred is *Occimum gratissum* sample with a sensory score of 6.40. However, all the smoke-dried products were liked very much and slightly by the panelists in terms of general acceptability, except for the T_2 sample which was liked slightly with sensory mean score of 6.40 and this in agreement with Kefas et al. (2022).

CONCLUSION

This study shows that the two indigenous spices used in this study scent leaves (*Occimum gratissum*) and ginger (*Zingiber officinal*) had chemical preservative and anti-

oxidant properties. The study revealed that scent leaves and ginger juice has more anti - oxidative and anti - fungal effects which can retard oxidative rancidity, inhibit microbial growth impart, give acceptable flavour and thus, extend the keeping quality of fish like *Clarias gariepinus*. The results from the sensory evaluation is of socio - economic importance to the general consumers because the result of the analysis showed that the sample treated with ginger (T_3) improved the general acceptability. The combination of both spices i.e. gingers and scent leaves (T_4) contain chemicals which have anti - oxidative, and anti - fungal factors which preserved and prolong the shelf - life and keeping quality of the smoked fish. They also have seasoning effects which do not only improve the nutritional quality but also imparted flavour and improved general acceptability.

RECOMMENDATION

This study recommends the utilization of ginger rhizome as a natural preservative for smoked catfish, enhancing quality, shelf life and sensory attributes. The combination treatment was particularly effective in minimizing lipid oxidation and improving fiber content. Fish processors aiming for extended shelf-life and quality stability should consider this combination. Fish processors in artisanal and commercial settings should be encouraged to adopt ginger and *Ocimum gratissimum* as natural preservatives, offering a sustainable alternative to chemical preservatives for improved fish quality and safety. Future research should investigate the efficacy of this combination on various species of fish and consumer acceptance. Training programs and regulatory guidelines are also recommended.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' Contributions

COR and BAT 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.

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