Turmeric and ginger extracts affects the proximate composition, oxidative stability, shelf life and the microbial biota of smoked *Clarias gariepinus* fillets

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ABSTRACT

African catfish, *Clarias gariepinus* of average weight 1.5 kg were filleted and pretreated with extracts of turmeric (TU) and ginger (GI) before hot smoking at 80 °C. The combination levels of TU and GI per treatment were as follows: Treatment 1, T1 (100TU:50GI), T2 (50TU:100GI), T3 (0TU:150GI), T4 (0TU:0GI), and T5 (75TU:75GI). The fillets were immersed into the treatment solution for 20 min and then hot smoked for 36 hours at 80°C. The smoked and dried fillets were stored for 30 days and analyzed for proximate composition, thiobarbituric acid essential substances (TBASR), peroxide value (PV), free fatty acid content, total volatile nitrogen base, and fungal and microbial biota. Protein content increased in the post-treated sample while moisture was reduced and lipid varied with smoking. Thiobarbituric acid reactive substances of the fillets were highest among those subjected to treatment T4, 0.75±0.11mg/100g but lowest for those of T1, 0.38±0.01mg/100g. The free fatty acids of the fillets after treatment, ranged from 1.23±0.07 % oleic acid in fillets treated with T1, to 3.06±0.08% oleic acid in fillet treated with T4. The fillets TVB-N treated with treatment 4 (T4), had the highest 1 TVB-N 19.81±0.04 mg/100g. Fillet treated with T4 had the highest FFA of 3.06±0.08% oleic acid while those treated to T1 had, 1.23±0.07 % oleic acid. Peroxide value was highest for T4, 20.07±0.22 and lowest for those subjected to T1, 10.30±0.03. Treatment 1 was toxic to both bacterial and fungal infestation with no visible growth of *Rhizopus* spp growth after 3 days of incubation. However, there was high vegetative fungal growth in the T4 experimental group.

Keywords: Fish preservation, Microbial load, Oxidation of fish, Phytogenics, Shelf life


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INTRODUCTION

Fish is a major source of fatty acids like the n-3 LC PUFA, EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) (Tacon and Metian, 2013; Mohanty et al., 2019; Erkan et al., 2023). Fish meat also contains well-balanced amino acid containing high quantities of choline and taurine, vitamins D3 and B12, phosphorus, iodine, and selenium (Lund, 2013). Although fish productivity is high in Nigeria, there is also heavy post-harvest loses (Nukpezah et al., 2020; Enyidi and Joseph, 2020). Post-harvest loss involve those types of aquaculture and fisheries products originally intended for human consumption but subsequently rejected by people, or have serious quality degeneration (FAO, 2020). Post-harvest loses could results from poor preservation and poor packaging and lack of refrigeration (FAO, 2020). Fish spoilage starts as soon as the fish dies after harvest or after being caught (Solanki et al., 2016; Dehghani et al., 2018). Smoking of fish products after harvest or capture, comes with highly minimized incidences of spoilage and activities of the autochthonous pathogenic bacterial (Horner, 1992, Begum et al., 2012; Hagos 2021). There are two types of smoking; cold smoking carried out without thermal breakdown at <30 °C (Goulas and Kontaminas, 2005) and hot smoking with thermal break down carried out at 70-80 °C. Hot smoking of fish reduces water activity of the fish meat and generates deposits of polyphenolic constituents on fish to ensure the quality and safety as well as extend shelf life of fish. Enyidi and Joseph (2020), noted that preservation by smoking and drying reduces water activity, bacterial action and deterioration rate. When fish is smoked there is an extension of their shelf life because, the pH and other physicochemical parameters of the fish like volatile basic nitrogen level, thiobarbituric acid and the nutrient values are kept normal (Hicks 2016). The quality of smoked fish is affected mainly by the quality of the fresh fish used (Solanki et al., 2016), and by season, (Puke and Galoburda 2020). Spices are known to be very effective in controlling bacterial growth and fish preservation (Shokri et al., 2015; Raphe et al., 2019; Mei et al., 2019). The quality of smoked fish can be affected by pretreatment with special spices and sauces before smoking (Saed et al., 2020; Ekelemu et al., 2021; Mugahi et al., 2022). Catching or killing fish in a stressful way increases the lactic acid value of the muscle, in combination with high temperature muscle color would be changed to dullness and the meat would have acidic or metallic aftertaste (Borderías and Sánchez-Alonso, 2011). Pretreatment of raw fish with garlic and onions or with ginger, had been noted to improve taste and extend shelf life in smoked African catfish Clarias gariepinus (Adaka et al., 2020; Ekelemu et al., 2021). Pretreatment of African catfish fillets with turmeric Curcuma longa extract has not been reported before. Turmeric is a medicinal plant widely used in Nigeria with enormous health benefits. The African catfish is high prize fish in Nigeria and Nigeria is the World’s largest producer but there are much post-harvest loses. There is a serious need for long period storage of catfish fillets to meet demand at all seasons. There had not been a research on pretreatment of catfish and long storage period. In a recent research it was noted that pretreatment of hake with pitaya extract enhanced inhibition of peroxides, fluorescent compound and free fatty acids in gelatin hake (Castro-Enríquez et al., 2023). Synthetic antioxidant like butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) used in the prevention of lipid oxidation (Blundel et al., 2022), but their implication to human health is in doubt (Hyldgaard et al., 2012). Some spices that can be used as fish shelf life extenders and antioxidants are turmeric and pepper, nutmeg, ginger and cinnamon (Prasad et al., 2011;
Enyidi and Joseph, 2020). This research is designed to examine the effects of pre-treating fillets of African catfish, *C. gariepinus* with graded combination levels of turmeric and ginger extracts before smoking, on the microbial load, lipid oxidation, and shelf life and freshness of the fillets.

**MATERIALS and METHODS**

**Extraction of turmeric and ginger**
The extraction of the turmeric and the ginger followed the methods stipulated in Sujata *et al.*, (2019) and Mugahi *et al.*, (2022). Turmeric rhizome were procured from National Root Crop Research Institute (NRCRI) Umudike Nigeria. The roots were thoroughly and dried and then grounded to powdered. The use of alcohol extraction was adopted in this research using 90% ethanol and soxhlet extraction methods. Using electronic balance, (Phillips Electronic balance BV), 250g of powdery turmeric was measured and placed in a 500ml beaker. The turmeric was poured into filter thimble of soxhlet extractor. Then 120ml of 90% ethanol was poured into the balloon. The mixture was heated slowly and the turmeric was mixed with alcohol and returned to the balloon. Extraction was done resulting in the extract settling at the bottom of the flask. The solvent was removed from the solute. The extract was spread on five Whatman filter papers and placed on preheated oven, and dried at 45°C. Dried extracts were placed in a black nylon foil and stored at 4°C in a fridge freezer till used.

**Experimental fish**
The catfish used in this experiment were procured from fish farm of Michael Okpara University of Agriculture Umudike FISHARM fish farm. One year and six months old adult African catfish, *C. gariepinus* (n=10) that were weighing on an average of 1.5kg were used for this experiment. The fish were washed, degutted, filleted, trimmed and skinned, exposing the beautiful musculature of the catfish muscles. The fillets were divided into 3 per replicates treatment making 9 fillets per treatment solution. Each replicate sample of fillet was weighed and kept under ice till used.

**Experimental Treatments solution**
The treatment was made from the dried turmeric and ginger alcoholic extracts. The inclusion levels (g) of turmeric and ginger extract were as follows; turmeric (TU) and ginger (GI). Treatment 1, T1 (100TU:50GI), 100g of turmeric extract plus 50g of ginger extract. Treatment 2, T2 (50TU:100GI), 50g of turmeric plus 100g of ginger. Treatment 3, T3 (0TU:150GI), 0g of turmeric plus 150g of ginger. Treatment 4, T4 (0TU:0GI), 0g of turmeric plus 0g of ginger. Treatment 5, T5 (75TU:75GI), 75g of turmeric plus 75g of ginger. The sum total of extracts was 150g, and for all treatment, 150g mixture were mixed with 500mls of water to produce 300g/dm³ of the turmeric and ginger (Table 1). The treatment solution of turmeric and ginger were mixed with 50g of food grade table salt (NaCl). Triplicate sample of the treatment solution was made per treatment and stored for about an hour to cure in a refrigerator at 4°C before usage.
Table 1: The compositions of the treatments solution, T1 to T5, varying in the inclusions turmeric and ginger extracts made into solutions

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Turmeric (g)</th>
<th>Ginger (g)</th>
<th>Concentration /dm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>100</td>
<td>50</td>
<td>300</td>
</tr>
<tr>
<td>T2</td>
<td>50</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>T3</td>
<td>0</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>T4</td>
<td>0</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>T5</td>
<td>75</td>
<td>75</td>
<td>300</td>
</tr>
</tbody>
</table>

**Treatment of fillets**

The fillets were placed in plastic trays of about 40 cm diameter and the fish fillets were placed on it as a single layer. The treatment solution was poured into the tray containing the fish till the fillets were completely immersed. Fillets were left inside the treatment solution for 20 min. After 20 min. the fish fillets were removed and placed in inverted plastic racks for three minutes to drain.

**Smoking of fish**

Locally manufactured four steps smoking kiln equipped with a thermostat was used for this smoking experiment. The smoking kiln was cleaned and the grills were washed and dried. The oven was heated for 20 min. at 80°C and the fish fillets were loaded and smoked for 10 h. Mahogany wood charcoal were used in generating smoke for the smoking. The fish fillets were overturned thrice in the grill within this period to ensure uniform smoking and drying of the fish. After 10 h smoking temperature was reduced to 50 °C and fillets were further smoked for another 4 h. The fillets became dry and the color changed to golden brown with attractive architecture of the catfish musculature and sweet titivating smoky aroma. The smoked fillets were cooled in a desiccator for 30 min. to enhance muscle integrity prevent breakages of the fillets.

**Storage of fish**

The fillets were dried and then stored in a glass shelf that is cool and dry. The shelf is similar to the shelf used in storing smoked fish is supermarkets. The storage was within plastic glass chamber that has space of air space. The fillets were stored there for 30 days during which period inspections were done weekly. After 30 days the fish were examined for microbial load, lipid oxidation, peroxide value, thiobarbituric acid reactive substances and pH and proximate analysis.

**Proximate composition**

Final muscle water content was measured from muscle samples taken from three fish per tank. Muscle samples were taken from below the dorsal fin and between the pectoral and caudal fins, excluding the skin. Crude protein was analyzed by the Kjeldahl method from the muscle samples, both pretreated and smoked treated fish. Analyses were made using a
Tecator kjeltec model 1002 system using block digestion and steam distillation (Tecator kjeltec Hogänäs, Sweden) and crude protein was calculated as % N x 6.25. The total lipids of fish muscles were analyzed using chloroform-methanol extraction at a ratio of 2:1, according to methods stipulated by Enyidi (2012). Total lipid was calculated as the weight difference in non-extracted and extracted muscle samples (Kainz et al., 2004). Ash content was estimated by burning a known amount of freeze-dried muscle sample from the catfish in a muffle furnace for 24 h at 550°C.

**Measurement of Thiobarbituric acid reactive substances (TBARS)**
The thiobarbituric acid reactive substance level of the fillets were measured after methods of Siripatrawan and Noipha, (2012). The preserved filleted fish were used in this experiment.
Thiobarbituric acid =Absorption no at 538 nm x 7.8
TBARS value were expressed in milligram of malonaldehyde per 1000 g (1 kg),

**Measurement of Peroxide Value (PV)**
The peroxide value of the fillets was measured after the methods stipulated in AOAC (2005). The value was calculated from the titrant volume.
Peroxide value =S x M x 1000/W
Where S = titre of sample (ml), B = titre of blank (ml); M = molarity of the thiosulfate solution; W = weight of sample (g).

**Measurement of Free Fatty Acid Content (FFA)**
This analysis followed the methods of Lowry and Tinsley (1976). To measure the free fatty acids, 25 ml ethyl alcohol neutralized with normal NaOH was added to the oil sample (resulting from the solvent evaporation and remaining in the lower phase of the decanter).

**Measurement of Total Volatile Nitrogen Bases (TVB-N)**
In analyzing for the total volatile base nitrogen (TVB-N) contents of the C. gariepinus fillets, we used Conway’s dish method (Cobb al. 1973). The extract was absorbed by boric acid and then titrated against 0.02 N hydrochloric acid (HCL). The values were expressed as (mgN/100 g)

**Microbial load analysis**
The microbial analysis was done after methods stipulated in Enyidi and Onyenakazi (2019). The isolates were passed through biochemical and morphological tests.

**RESULTS**

**Effects on the proximate composition of fish fillets**
The processing techniques using hot smoking and treatment with turmeric and garlic supplements had effects on the proximate composition and quality of the catfish fillets. The values of the proximate composition of the untreated fillets (Table 2) was noted to be higher than those of treated and smoked fillets (Table 3).
There was generally very high moisture content of the pretreated and pre-smoked fresh catfish fillets. The moisture content of the fresh catfish fillet ranged from 77.73±0.02% of those to be treated with T2 to 77.84±0.02% of those to be treated with T3. There were no significant (P>0.05) differences in the moisture content of the pretreated catfish fillets (Table 2). After treatment and smoking the moisture content of the fillets were very reduced at least 10% dryness. The catfish fillet treated with T1 had moisture content of 10.11±0.01%. The moisture content of T1 treated fillets was significantly lower than that of all other treatments (P<0.05). There were no significant differences (P>0.05) in the moisture content of catfish fillets treated with either T2:11.24±0.05% and T3:11.3±0.02% (P>0.05). Moisture content of the smoked and treated fillets were very much lower than the fresh to minimize the water activity of the fillets. The fillets treated with treatment T1 had an initial protein content of 19.35±0.04% but post treatment protein value of 22.00±0.04%. The protein value of post treatment smoked catfish fillets treated with T1 was higher than the protein value of other treated fillets (P<0.05). The fillets treated with T2 had protein content of 21.87±0.06% (P<0.05). The protein content of the fillet treated with T2 was similar to those of T5:21.64±0.04% (P>0.05). The lowest post treatment fillet protein content was from those subjected to treatment T4:20.13±0.07% (Table 3). In this experiment, we noted that the lipid content of the fillets was reduced after hot smoking of the fish. Fish fillets were losing oil and moisture as hot smoking was going on. There was an inverse relationship between the treated and smoked fillets lipids and moisture content. The lipid content of the catfish fillets pre-treatment and smoking were as follows, T1:16.25±0.03% T2:16.25±0.03%, T3:16.25±0.03%, T4:16.25±0.03% and T5:16.25±0.03% (Table 2). Evidently, after hot smoking, the lipid content of fillets was reduced. The post treated smoked catfish lipid contents were as follows; T1:13.25±0.03%, T2:9.34±0.03% and T3:8.07±0.11%, T4:6.88±0.04% and those treated with T5:5.89±0.01% (Table 3). There were no significant differences in the pH of the

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>19.35±0.04</td>
<td>19.35±0.04</td>
<td>19.35±0.04</td>
<td>19.35±0.04</td>
<td>19.35±0.04</td>
</tr>
<tr>
<td>Lipids</td>
<td>16.25±0.03</td>
<td>16.25±0.03</td>
<td>16.25±0.03</td>
<td>16.25±0.03</td>
<td>16.25±0.03</td>
</tr>
<tr>
<td>Ash</td>
<td>1.41±0.06</td>
<td>1.41±0.06</td>
<td>1.41±0.06</td>
<td>1.41±0.06</td>
<td>1.41±0.06</td>
</tr>
<tr>
<td>pH</td>
<td>6.98±0.09</td>
<td>6.98±0.09</td>
<td>6.98±0.09</td>
<td>6.98±0.09</td>
<td>6.98±0.09</td>
</tr>
<tr>
<td>Moisture</td>
<td>77.83±0.02</td>
<td>77.73±0.02</td>
<td>77.84±0.02</td>
<td>77.75±0.02</td>
<td>77.76±0.02</td>
</tr>
</tbody>
</table>
pretreated catfish fillet (Table 2). There was however significant difference ($P<0.05$) after treating the fillets TU and GI extracts and smoking. The pH was lower for fillets treated with T1:6.04±0.04; T2:6.03±0.01 and T3:6.02±0.01, respectively (Table 3). There were no significant differences ($P>0.05$) between the pH of fillets pretreated with T1, T2, and T3 (Table 3). There were however significant differences ($P<0.05$) between the pH of smoked catfish fillets pretreated with T1, T2, T3 and those of T4 (Table 3). Ash content of the pretreated catfish fillets were not significantly different ($P>0.05$) (Table 2). There were however some few significant differences in the ash content of the pretreated and smoked catfish fillets. The ash content was highest for fillets treated with T2:1.60±0.04g (Table 3). The ash content of fillet treated with T4:1.20±0.07g was the least among all treated fillets (Table 3). There were no significant differences ($P>0.05$) between the ash content of smoked fillets treated with T3:1.39±0.08g and those on T5:1.40±0.01g (Table 3).

**EFFECTS ON BIOCHEMICAL PARAMETERS**

The fillets treated with T4 had the highest TVB-N 19.81±0.04 mg/100g and this was significantly higher than that of all other treatments ($P<0.05$). The TVB-N of fillets treated with T5 and T3 were next with TVB-N value of 17.91±0.09 mg/100g and 16.01±0.07 mg/100g, respectively (Table 3). There was significant difference ($P<0.05$) between the TVB-N of fillets treated with T5:16.51±0.09mg/100g and T3:17.01±0.07mg/100g ($P<0.05$). The fillets treated with T1 had the lowest TVB-N 13.70±0 mg/100g followed by those treated with T2:15.90±0.06 mg/100g ($P<0.01$) (Table 3). The thiobarbituric acid (TBARS) content of the fillets were highest among those fillets subjected to treatment T4:0.75±0.11mg/100g. The lowest TBARS was measured from the fillet subjected to treatment T1:0.38±0.01mg/100g. The fillets treated with T2 had TBARS value of 0.43±0.03mg/100g which was next to those treated with treatment T1. There was significant difference between the TBARS values of fillets treated with T1 and T2 ($P<0.05$). TBARS of fillets treated with T3:0.57±0.02mg/100g was significantly higher than that of those fillets treated with treatment T5:0.51±0.03mg/100g ($P<0.05$) (Table 3). Free fatty acids value of fillets treated with T2 (1.32±0.01% oleic acid) was smaller than that of all other treatment fillets except those treated with T1 ($P<0.05$). The fillet treated with T4 had the highest FFA of 3.06±0.08% oleic acid, and this was significantly higher than the FFA of all other treatment fillets (Table 3). The FFA value of fillet treated with T3:1.76±0.12% oleic acid was significantly higher than the FFA of fillets treated with treatment T5:1.39±0.04% oleic acid ($P<0.05$). Peroxide value (PV) of the catfish fillet treated with T4:20.07±0.22 was
higher than all other treatments \((P<0.05)\). Conversely the lowest PV was in the fillet treated with T1:10.30±0.03 followed by PV of those fed T2:13.34±0.07 (Table 3). The fillet treated with T3 had higher PV 17.08±0.04 than those treated with T5:15.05±0.11 (Table 3). There was significant difference between the TBARS of T3:0.38±0.02mg/100g, and those of fillets treated with T4:0.31±0.11 \((P>0.05)\) (Table 3).

**Table 3: Effects of turmeric and ginger on the protein content, lipid content, ash, pH, moisture content, total volatile Nitrogen base and, thiobarbituric Acid resistance substance (TBARS), peroxide value (PV) and free fatty acids of hot smoked fillets of *C. gariepinus* stored for 2 month**

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>21.10±0.04a</td>
<td>21.87±0.06ab</td>
<td>20.66±0.01c</td>
<td>20.13±0.07d</td>
<td>21.64±0.04b</td>
</tr>
<tr>
<td>Lipids</td>
<td>13.25±0.03a</td>
<td>9.34±0.03b</td>
<td>8.07±0.11c</td>
<td>6.88±0.04d</td>
<td>5.89±0.01d</td>
</tr>
<tr>
<td>Ash</td>
<td>1.31±0.04b</td>
<td>1.60±0.04a</td>
<td>1.39±0.08c</td>
<td>1.20±0.07d</td>
<td>1.40±0.01c</td>
</tr>
<tr>
<td>pH</td>
<td>6.04±0.04a</td>
<td>6.03±0.01a</td>
<td>6.02±0.01a</td>
<td>6.34±0.09b</td>
<td>6.10±0.03ab</td>
</tr>
<tr>
<td>Moisture</td>
<td>10.11±0.01a</td>
<td>11.24±0.05b</td>
<td>11.30±0.02b</td>
<td>12.27±0.01c</td>
<td>11.32±0.07b</td>
</tr>
<tr>
<td>TVB-N</td>
<td>13.70±0.01a</td>
<td>15.90±0.06b</td>
<td>17.01±0.07c</td>
<td>19.81±0.04e</td>
<td>16.51±0.09d</td>
</tr>
<tr>
<td>TBARS</td>
<td>0.38±0.01a</td>
<td>0.43±0.03b</td>
<td>0.57±0.02d</td>
<td>0.75±0.11c</td>
<td>0.51±0.03c</td>
</tr>
<tr>
<td>FFA</td>
<td>1.23±0.07a</td>
<td>1.32±0.01b</td>
<td>1.76±0.12d</td>
<td>3.06±0.08e</td>
<td>1.39±0.04c</td>
</tr>
<tr>
<td>PV</td>
<td>10.30±0.03a</td>
<td>13.34±0.07b</td>
<td>17.08±0.04d</td>
<td>20.07±0.22e</td>
<td>15.05±0.11c</td>
</tr>
</tbody>
</table>

**FUNGAL MICROBIAL ANALYSIS AFTER 30 DAYS STORAGE**

The stored fillets did not show any sign of spoilage after 30 days storage at room temperature. Moreover, after 48 hours incubation of streaked samples of the stored fillets, there were no traces of bacterial nor fungal growth found in all the samples therefore they were marked Nil, except for those treated with T4 (Table 4). Nevertheless, when the incubation period under laboratory condition was extended for further 72 hours. After 72 hours under laboratory condition some fungal growth were noted. The fillets treated with T1 had no visible growths or colonies of *Rhizopus* spp or any other fungi. The smoked catfish fillet treated with treatment T2 had very mild and moderate growth of 3 colonies of *Rhizopus* spp at 4.0x10^8 CFU/ml. Similarly, the fillets that were treated with T3 (0TU:150GI), had profuse growth of *Rhizopus* spp at approx.1.20x10^8 CFU/ml. The fillets treated with treatment T4 had very vegetative and profuse fungal growth at 1.28x10^8 CFU/ml (Table 4). Fillets that was treated with T5 had growth of *Rhizopus* sp at 1.3x10^8 CFU/ml (Table 4).
Table 4: Effects of graded inclusion of garlic and turmeric spices supplement on the shelf life and bacterial and fungal load of African catfish fillets

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Volume</th>
<th>Dilution Factor</th>
<th>No colonies</th>
<th>Total no of organism</th>
<th>78 h Organisms (Fungi)</th>
<th>Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0.1</td>
<td>0</td>
<td>0.0 x 10^8</td>
<td>Fungi</td>
<td>Bacteria</td>
</tr>
<tr>
<td>T1 (100 TU:50 GI)</td>
<td>1</td>
<td>0.3</td>
<td>0</td>
<td>0.0 x 10^8 Nil</td>
<td>No growth after 3 days incubation</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>0.0 x 10^8</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>T2 (100 GI:50 TU)</td>
<td>1</td>
<td>0.1</td>
<td>3</td>
<td>4.0x10^8 CFU</td>
<td>Rhizopus spp</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.3</td>
<td>3</td>
<td>4.0x10^8 CFU</td>
<td>very little moderate growth after 3 days incubation</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
<td>3</td>
<td>4.0x10^8 CFU</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>T3 (0TU:150GI)</td>
<td>1</td>
<td>0.1</td>
<td>12</td>
<td>1.2x10^8 CFU</td>
<td>Rhizopus spp</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.3</td>
<td>12</td>
<td>1.2x10^8 CFU</td>
<td>profuse growth after 3 days incubation</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
<td>12</td>
<td>1.2x10^8 CFU</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>T4 (0TU:0GI)</td>
<td>1</td>
<td>0.1</td>
<td>12</td>
<td>1.28x10^8 CFU</td>
<td>Rhizopus spp</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.3</td>
<td>12</td>
<td>1.28x10^8 CFU</td>
<td>very profound and excessive profuse growth after 3 days incubation</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
<td>12</td>
<td>1.28x10^8 CFU</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>T5 (75TU:75GI)</td>
<td>1</td>
<td>0.1</td>
<td>13</td>
<td>1.3x10^8 CFU</td>
<td>Rhizopus spp</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.3</td>
<td>13</td>
<td>1.3x10^8 CFU</td>
<td>growth</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
<td>13</td>
<td>1.3x10^8 CFU</td>
<td>after 3 days incubation</td>
<td>NIL</td>
</tr>
</tbody>
</table>

DISCUSSIONS
The results suggest that turmeric and ginger both have bactericidal and antioxidant effects on the fillets. The effects of pretreatment with T1 (100TU:50GI), shows that turmeric has more profound antibiotic effect than ginger. Turmeric (Curcuma longa L.), is known to possess Curcumin, a principal bioactive substance which is anti-fungal, strong antioxidant, anti-inflammatory and antibacterial (Adamczak et al., 2020), antifungal, and antiviral agent. Consequently, catfish fillet treated with treatment T1 had no visible fungal or sign of microbial spoilage for 30 days storage period. Our result is in consonance with Moghadamtousi et al., (2014); Praditya et al., 2019, and Ebrahimi et al., (2023), who noted that antimicrobial activities of turmeric was higher than that of ginger and clove.
Based on results, the application of turmeric and ginger extracts on the fillets of African catfish affected its shelf life and nutritional quality. Our results show that hot smoking reduces the protein content of fillets. This supports the position of Abraha et al., (2018), Belichovska et al., (2019) who both noted that hot smoking of fish and processing with high temperature reduces the protein content. Smoking also reduced the total lipid content of the fillets, this could be because at hot smoking fish meat loses oil that drips off. This is in line with Idah and Nwankwo (2013), who noted reduced lipid content of fish when wood was used for smoking. We experienced a similar scenario in this experiment. The TVB-N (Total Volatile Basic Nitrogen) of the fillets in this experiment increased with increasing inclusion of ginger supplement compared to turmeric. This could be because turmeric is more of an antioxidant than ginger. The relationship between the fillets TVB-N and the inclusion of turmeric is polynomial with \( R^2 = 0.86 \) (Fig.1). The TVB-N is a method of analysis that quantifies the presence of nitrogenous compounds (ammonia and dimethyl and trimethyl amine) in fish, indicating spoilage (Parlapani et al., 2015). The catfish fillets that was not treated with turmeric and ginger had elevated TVB-N which suggest that the treatment impeded oxidation of the fillets. The catfish fillets TVB-N increased more with storage for those fillets not treated previously with Turmeric or ginger. This is in line with Salako et al., (2014), and Asensio et al., (2019), who noted increase in the TVBN of fish stored close to a period of one month. Nevertheless, the catfish fillets TVB-N values were all within acceptable value <20-30 mg/100g. This is in line with previous researches of Laly et al., (2019), who noted that TVB-N values of 30 were still acceptable. The values of the thiobabyturic acid (TBARS) suggest that fillets maintained freshness with increasing inclusion of turmeric supplement than ginger. There was inverse relationship between the quantity of lipids and the moisture content of the catfish fillet \( R^2 = 0.97 \) (Fig 2). Besides the fish fillets were still fresh after 30 days storage based on sensory evaluation. The results are in line with Enyidi and Joseph (2020), who noted that smoking produced fish that had long shelf life. The treated and smoked fillets peroxide value jointly increased with free fatty values of the fillet (Fig 3), \( R^2 = 0.93 \). The absence of observable fungi and bacteria infection on the treated and smoked fillets for 30 days indicates that the treatment solution supplements were both bactericidal and fungicidal. This is in line with Adamczak et al., (2020) and Hussain et al., (2022), who stated that turmeric contains curcumin which is a strong antioxidant, antibacterial and antifungal agent. Evidently the inclusion of turmeric and the ginger prevented vegetative progress of the fungi and bacteria on the stored fillets for 30 days. Similarly, smoking deposits polyphenolic compounds that inhibits bacteria growth (Belichovska et al., 2019; Hago, 2021). The presence of the Rhizopus spp after 30 days storage could be due to air quality in the laboratory and the handling of the samples in the laboratory environment. The samples that had no turmeric had profound vegetation of fungal growth.
**CONCLUSION**

Turmeric and ginger supplements are good in the preservation and storage of African catfish, *C. gariepinus*. The supplements prevented the growth of bacteria and fungi over 30 days and under incubation for 48h. Turmeric is medicinal and same for ginger. The best combination was with 100 g turmeric and 50 g ginger (T1). Turmeric and ginger can be used in the processing and preservation of catfish fillets since they have the potential of enhancing shelf life and preventing microbial spoilage post-harvest loss of fish.

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