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Effects of indigenous household preservatives on fresh African catfish, *Clarias gariepinus* (Burchell, 1822)

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Abstract
Many traditional preservation methods for fish have not been able to address issues of quality, whereas the modern methods of preservation are generally expensive for the rural poor. This study investigated the effect of ginger and garlic pastes as household preservatives on African Catfish in Ghana. Fish samples were treated with the paste of garlic, ginger, and a mixture of both garlic and ginger for 72 hours under ambient laboratory conditions. Samples were subjected to physical and microbial examination on a daily basis during the storage period. The garlic, ginger, and a mixture of both pastes as treatment extended the shelf life of the fish for three days. The untreated (control) fish had deteriorated in quality by the end of the third day with confirmation of extensive aesthetic deterioration and maggot infestation of the carcass.

Keywords: Fish spoilage, ginger, garlic, fish preservation, African Catfish

1. Introduction
Fish contains vitamins A and B, and is an outstanding source of omega-3 fatty acids. Studies have shown that regular consumption of fish reduces the risk of various disorders and diseases such as asthma, prostate diseases, diabetes, eye diseases, depression, heart diseases, stroke, and premature birth [1, 2]. Fish contains high-quality protein, amino acids, and absorbable dietary minerals. Fish is a very nutritious food and it is predominantly valued for its high protein quality; highly digestible food, due to its low collagen level [3].

Fish constitutes a vital component of the diet for many people, and often supplies much-needed nutrients for healthy living; it is a cheap source of animal protein [4]. At present, about 17% of the world's edible fish catch goes directly to consumers in the raw state [5]. The spoilage of fish is easily noticed since it involves changes in flavour, colour, odour, texture, and appearance. Fish therefore requires proper post-harvest treatment and preservation to boost its shelf life and maintain its quality. Berkel *et al*. [6] defined preservation as the processing of food so that it can be stored longer.

Garlic (*Allium sativum*) is a well-known curative plant that has a lot of benefits including the reduction of food-borne ill health and food poisoning, and preservation of vitamins in foods [7]. It is famous in Central Asia and has been very stable in the Mediterranean region. It is commonly used as a seasoning in Africa, Asia, and Europe [8]. Garlic (*Allium sativum*) is one of the most used natural ingredients to improve flavor in food. It has an extensive field of dealings, including antifungal, antibacterial, and anti-oxidative properties, and in addition has an advantageous effect on the immune and cardiovascular systems of humans [9].

Ginger *(Zingiber officinale)* being a spice is geographically known and it is consumed entirely as a delicacy, used as a flavour enhancer in foods [10]. Ginger has a spectrum of biologically active compounds, like 6-shagaols, curcumin, zingiberene, 6-gingerol, bisabolene, and other types of lipids that are present in it, which gives ginger pungent and stimulant properties. The unique scent of ginger is a direct result of these blends and accounts for about 1-3% of the weight of fresh ginger [11]. Achinewhu [12] analyzed the composite assembly of thirty wild ginger flavours indigenous to Nigeria and saw that they contained high proportions of fats similar to essential oils.

The post-reap division in Ghana draws in a large workforce, including fish processors, wholesalers, and retailers. The key players in this part are women, who make up 70 percent of the workforce. Both wild and cultured fish are to a larger extent sold fresh as Ghana's wholesale product. For instance, a considerable piece of the catch is either frozen or prepared by smoke-drying, salting as well and maturation. Fish curative in Ghana is to a great extent attempted at little scale or medium-scale level, ordinarily at individual homes, and comprises strategies, for example, smoking, drying, salting, broiling, and aging [13].

Fish is a very perishable product, deteriorating not long after death, because of enzymatic and microbial activities, bringing about unbearable taste, smell, and surface; in this manner lessening customer agreeableness [14]. These previous studies have affirmed that high surrounding temperatures of the tropics are major ecological components advancing the fast deterioration of fish. Chemical weakening and microbial decay are causes of loss of 25% of gross essential fishery items consistently [15]. Preservation is therefore imperative to ensure that fishes stay fresh for quite a while, with less loss of flavor, taste, smell, nutritive esteem, and the absorbability of their tissue.

A previous study has noted that dipping fish into a concentration of ginger before smoking has positive effects on the general quality of the final products [16]. Ginger and garlic have also been reported to effectively inhibit microbial growth on fresh Nile Tilapia (*Oreochromis niloticus*) for three days [17]. Antonia da Silva *et al*. [18] noted that garlic possesses chemicals with inhibitory effects on bacterial growth and spread in some meat.

The current study sought to test the combined effect of ginger and garlic pastes as well as their singular effect on the preservation of fresh African catfish for 72 hours. Numerous homes in the rural areas of Ghana usually are not ready to bear the cost of purchasing and using refrigerators. They rather prefer to utilize the customary strategies for protection; this incorporates salting, smoking, drying, bubbling, and browning/frying. Traditional preservation methods including smoking, salting, drying, and even modern methods are generally used but they all come with their pros and cons. Therefore, exploring other ways of safeguarding fish such as using garlic and ginger as natural preservatives/ customary strategies for fresh fish is imperative. The results of this study will contribute to a healthier, cheaper, and timely preservation of fish among consumers at the household level. This will eventually help in reducing post-harvest fish losses. This study was conducted to assess the preservative impacts of garlic and ginger on the shelf life and quality of fresh African Catfish.

2. Materials and Methods

2.1 Description of the study area

Samples were obtained from the Golinga reservoir in Tamale. Golinga reservoir is found in the savannah ecological zone of Ghana between the longitude 9º 21'0" N and latitude 0º 57' 0" W. The reservoir is located at an elevation of 149 m above sea level. It serves as irrigation and fishing for people as well as a source of drinking water; Golinga has an area of 192 ha. This reservoir is recharged by Kornin River, a tributary of the White Volta.

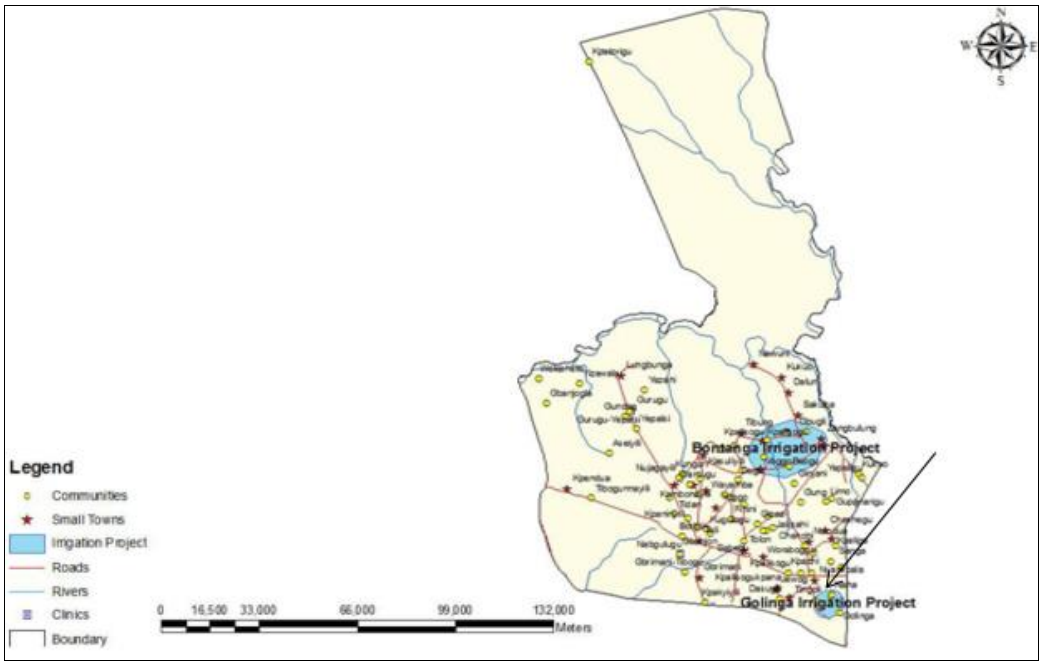

Fig 1: A map showing the Golinga reservoir and its surrounding areas

2.2 Research approach/ protocols

2.2.1 Fish sampling

African Catfish samples were purchased from fishermen at Golinga reservoir in April 2019. The average weight, standard length, and total length of African Catfish were 250.4 g, 28.4 cm, and 32.3 cm respectively. The fresh fish samples were placed in an ice chest of water to prevent the fish from struggling and transported to the Water Research Institute Laboratory, Tamale.

2.2.2 Collection of Ginger and Garlic samples

500 g each of fresh ginger and garlic samples were purchased in Tamale Aboabo market, preserved under room temperature for about 24 hours before use.

2.2.3 Laboratory Preparation Methods

Preparation of Agar

Chromucult agar, Mannitol Salt Agar, and Salmonella-Shigella agar were prepared using the manufacturer's

prescriptions and left in the biosafety cabinet to solidify.

Preparation of ginger and garlic paste

The ginger and garlic samples were first washed under running tap water and the outer coats were peeled. A sterilized blender was used to blend 200 g of ginger using 220 ml of distilled water, after the blender was washed thoroughly with distilled water, cleaned and 200 g of garlic was weighed using the electronic balance and then blended separately into a paste using 170 ml of distilled water.

Bleeding and gutting of fish samples

Aluminum foil was placed on the table and disinfected with alcohol (70%). The fish were gently removed from the ice chest of water. They were thoroughly eviscerated and washed under a running tap. Gutting was carried out by cutting open the belly and get rid of the internal organs likewise those fish body parts are most likely to decrease product quality as well as gonads.

Treatment of fish with ginger and garlic paste

Fish samples were weighed using the electronic balance of 100 g each in a bowl. The fresh fishes were treated, first batch with 100 g ginger paste, second with 100 g garlic paste, third a mixture of ginger paste (50 g) and – garlic paste (50 g), and a control. A spatula was first disinfected with ethanol and was used to gently smear the paste on the fish. Three (3) replicates each was covered with a food net and leftover under room temperature for 72 hours.

2.3 Sensory evaluation

An evaluation of difference using the sense of sight, touch and smell for the description of various organoleptic characteristics such as appearance, texture, flavour and odour was employed. Physical examination was performed on all the fresh fish samples during the 72-hour treatment period. The stored fish were examined for changes in their physical (aesthetic) characteristics. Noticeable changes in the colour, odour, appearance, and texture of the fish during the storage period were documented. These examinations and records were done at 6 pm each day during the experiment.

2.4 Experimental design

Table 1 shows the various treatments given to the fish samples within the 72-hour period, each having three replicates.

Table 1: Treatments of fresh African Catfish samples

Treatments	Garlic (A)	Ginger (B)	Garlic + Ginger (AB)	Control (C)
Replications	Rep 1	Rep 1	Rep 1	Rep 1
	Rep 2	Rep 2	Rep 2	Rep 2
	Rep 3	Rep 3	Rep 3	Rep 3

2.5 Microbial analysis

Microbial quality analysis was performed for total *Escherichia coli* (EC), *Staphylococcus* spp. (StS) and *Salmonella* spp. (SS). The target area was collected by swabbing of the targeted area of $1cm^2$ from the fish surface (skin) with sterile cotton swabs transferred into 9 ml of distilled water of the original bacteria culture (OBC) using 5 dilution banks.

Exactly 1 ml was carefully pipetted from the original bacteria culture diluted at a dilution factor of 10^3 10^2 10^1 for *Staphylococcus* spp., *E. coli*, and *Salmonella* spp. respectively. Platting was done using the filter paper method. Chromucult agar was used as a medium for *Escherichia coli* growth, Salmonella-Shigella agar for *Salmonella* spp. and Mannitol Salt Agar for *Staphylococcus* spp.

2.5 1 Incubation

Samples were incubated in triplicates at 37 °C for 24 hours, enumeration of 1 ml of each target bacterial population was done using the colony counter and recorded as colony-forming units per centimeter square (cfu/cm^2).

2.5.2 Proximate composition

Chemical analyses like moisture, crude protein, fat and ash were examined. Every fresh African Catfish sample, before and after treatment was subjected to chemical analysis in duplicates following the procedures of the Association of Official Analytical Chemists [19] for moisture, protein, fat and ash.

2.5.3 Moisture determination procedure

Moisture cans were desiccated for 30 minutes after being dried in an oven for 30 minutes at 105 °C. The cans' weights were recorded, and 3.5 g of each sample were added to each can. Sample-containing cans were dried in an oven for two hours at the same temperature (105 °C). Samples were weighed after drying and cooling in a desiccator for 30 minutes, and the weight difference was used to calculate the samples' moisture content. The percentage of moisture was computed using the expression:

$$\% \text{ Moisture} = \frac{Fresh\ weight - Dried\ weight}{Fresh\ weight} \times 100 \quad [19]$$

2.5.4 Fat extraction procedure

The temperature of a fat extractor was controlled at 125 °C to heat the device for around 30 minutes prior to usage. Thimbles were degreased with petroleum ether and placed into extraction cartridges that were set up on the support rack. Ground samples of different codes weighing 3.5 g each were weighed and placed in an extractor thimble containing cotton wool. We utilized dry, clean, fat-free aluminum beakers. Beakers were cleaned with ether, dried in an oven at 105 °C for 30 minutes, and then allowed to cool in a desiccator for 30 minutes. Before being placed on beaker racks, beakers were weighed. The front of the extraction unit's cut-out profile was filled by a rack with tubes and support thimbles. Cartridges with tubes supporting them were put on the rack. Each column's levels were positioned (rising) in the extraction unit. With the use of the transport handle, tube-supported cartridges were taken and placed into the extraction unit, being careful to ensure that each cartridge attached to the magnet on each column.

Each aluminum beaker received around 50 ml of ether. The beakers were introduced into each column using the beaker rack, and at the same time the lever was lowered, the beakers aligned so they were inserted beneath the Teflon of each column. The removal was completed. The ether cycle then started, boiling-evaporation-condensation, exposing the samples to the petroleum ether's solvent activity in both the gaseous and liquid states, removing the fat from the sample into the aluminum beaker. The extractor's levers were turned to the boiling position for approximately 30 minutes and the rinsing position for approximately 30 minutes. After roughly

10 minutes, the levers were switched to the recovery position, which prevents the ether from the condenser from flowing back into the aluminum beaker by holding it in the upper portion of the collar.
To get rid of any ether leftovers, the surface of the aluminum beakers containing the extracted fat was heated by turning on the air heater unit (attached to the fat extracting system). The fat that had accumulated in the beakers was then weighed once again. The amount of fat in samples was determined by the weight difference between fat-free beakers and beakers with fat. The percentage fat was calculated as:

$$\% \text{ Fat} = \frac{Weight\ of\ can/beaker}{Weight\ of\ sample} \times 100$$ [19]

2.5.5 Ash determination procedure
Ceramic crucibles were dried in an oven at 105 °C for 30 minutes before cooling in a desiccator for the same amount of time. Crucible weights were measured, and 3.5 g of each sample was weighed. For around 3 hours, samples were roasted in an oven at 550 °C until they were totally reduced to ash. The calculation of the ash % was done as follows:

$$\% \text{ Ash} = \frac{Weight\ of\ ash - weight\ of\ crucible}{Weight\ of\ sample} \times 100$$ [19]

2.5.6 Protein determination procedure
Crude protein was determined using the 3-step micro Kjeldahl method as follows:
Digestion - Dry fish samples weighing 1 g each were placed into 250 ml digestion tubes in groups of three. 13 ml of concentrated sulphuric acid was added to each tube after two (2) Kjeldahl tablets were placed inside. Under a fume hood, a digestion block heater with a rack of digestion tubes was inserted, and an exhaust manifold was installed and connected to a water aspirator. Samples were digested at 420 °C until the liquid became transparent, at which point the rack was withdrawn from the digester with the exhaust manifold and allowed to cool to ambient temperature in a fume hood. The distillation unit's tubes were separately moved from the exhaust manifold.
Distillation - About 65 ml of water and 35 ml of 40% sodium hydroxide solution were added to each sample treatment. Samples were then distilled and condensed liquid obtained in Erlenmeyer flask with 10 ml indicator solution (Boric acid).
Titration – The condensed liquid was titrated with 1 M hydrochloric acid (HCL) until the colour became pink. Then the titre value was noted and crude protein computed using:

$$\% \text{ N} = \frac{1.4007 \times (T - B) \times N}{W}$$

Va: Volume of acid used for sample titration (Titre)
Vb: Volume of acid used for the blank (0.5)
N: Normality of acid (0.1)
W: sample weight in grams
1.4007: Conversion factor

Therefore % Protein = % N x 6.25 [19]

2.6 Data analysis
Physical observations were recorded as narratives, statistical analyses were carried out using the Graphpad prism and the means of microbial load data were expressed to indicate differences. Analysis of variance was done to detect differences in the treatments. Differences were separated using a t-test.

3. Results and Discussion
3.1 Sensory characteristics
The fresh fish sample at the beginning of the experiment had a normal fishy smell. However, there were remarkable differences between the treated and untreated fish samples after 24 hours. The changes in physical characteristics in garlic (*Allium sativum*), ginger (*Zingiber officinale*), and ginger and garlic paste for 24 hours, 48 hours and 72 hours during ambient laboratory storage are represented in Tables 2, 3, and 4.
Samples treated with garlic, ginger and ginger plus garlic though had the scent of the paste were still intact on the 1st, 2nd, and 3rd day while there was severe spoilage accompanied with decomposing flesh, very bad odour, and the presence of maggots and houseflies on the control samples as the days increased.
The moisture content of garlic, ginger, and ginger, and garlic paste reduced as the days increased while the darkening of paste color increased with increase in days.
The stored fish were examined for changes in their physical characteristics. Observable changes in the odor, color, appearance, and texture of the fish during the storage period were recorded.

Table 2: Changes in physical characteristics of fish treated with garlic, ginger, and untreated (control) African Catfish during ambient laboratory storage conditions of fish for 24 hours

Fish treatment (24 hours)	Observed Characteristics
Ginger treated specimen	Firm flesh; ginger paste beginning to dry, ginger odor
Garlic treated specimen	Firm flesh; garlic odor
Ginger and garlic treated specimen	Firm carcass; ginger and garlic odor
Untreated specimen	Soft flesh; no ginger odor

Table 3: Changes in physical characteristics of fish treated with garlic, ginger, and untreated (control) African Catfish during ambient laboratory storage conditions of fish for 48 hours

Fish treatment (48 hours)	Observed Characteristics
Ginger treated specimen	Firm flesh; the moisture content on the ginger paste was very low; ginger odor
Garlic treated specimen	Firm flesh; garlic odor
Ginger and garlic-treated specimen	The paste began to dry up; ginger & garlic paste odor; firm flesh
Untreated specimen	Flabby flesh; grey gills; objectionable odor

Table 4: Changes in physical characteristics of fish treated with garlic, ginger, and untreated (control) African Catfish during ambient laboratory storage conditions of fish for 72 hours.

Fish treatment (72 hours)	Observed characteristics
Ginger treated specimen	Dry flesh; ginger odor; the moisture content on the ginger paste was very low with ginger dark in color.
Garlic treated specimen	Dry flesh; garlic odor; garlic paste beginning to dry
Ginger and garlic-treated specimen	Firm flesh; ginger & garlic paste becoming darker with little or no moisture content
Untreated specimen	Decomposing flesh; maggots and houseflies present with a very bad odor

There were remarkable differences between garlic, ginger, ginger and garlic-treated fish and the control (untreated) samples. This agreed with the findings of Berkel *et al*. [6] who indicated that fresh fish deterioration can be exceptionally fast after it is gotten. The decay process (rigor mortis) begins inside the fish 12 hours after their catch in the high surrounding temperatures of the tropics. The scent of the ginger as reported by Akram *et al*. [11] is a mixture of shogaols, zingerone, and gingerols volatile oils which are accountable for the distinctive odor and flavor of ginger, these components account for about 1-3% of the weight of fresh ginger.

3.2 Microbial analysis

The study identified *Escherichia coli* (E.C), *Total coliform* (T.C), *Staphylococcus* spp. (St.S), and *Salmonella* spp (S.S) on fish treated with garlic, ginger, a mixture of ginger and garlic, and the untreated fish on the 1st 24 hours after preservation, then 48 and 72 hours (Table 5). During the 72 hours of preservation, the untreated fish sample had the highest count of pathogens.

Results of the daily mean bacterial population in garlic, ginger, ginger, and garlic and the untreated fresh African Catfish under ambient laboratory storage condition is shown in Table 5. *P*-values were not significant between ginger, garlic, and ginger and garlic-treated specimens, but significant between treated and untreated ($P< 0.05$).

Table 5: Mean daily bacterial populations in the garlic, ginger, ginger, and garlic treated and untreated (control) fresh African Catfish under ambient laboratory storage conditions for 72 hours

Treatment	T.C (× 10^4 cfu/cm^2)	E.C (× 10^4 cfu/cm^2)	St.S (× 10^4 cfu/cm^2)	S.S (× 10^4 cfu/cm^2)	*P*-value ($p < 0.05$)
24 Hours					
Garlic	4.00 ± 4.00	0.002 ± 0.00	0.1 ± 0.58	2.40 ± 0.00	0.5770c 0.8746r 0.0001a
Ginger	1.67 ± 1.20	0.33 ± 0.33	3.67 ± 1.86	3.32 ± 0.64	
Garlic and ginger	1.67 ± 1.20	1.67 ± 1.20	3.67 ± 1.86	0.18 ± 0.03	
(Untreated) Control	79.00 ± 0.00	64.00 ± 0.00	70.00 ± 0.00	59.00 ± 0.00	
48 Hours					
Garlic	7.33 ± 1.8	0.24 ± 0.00	30.67 ± 24.70	3.50 ± 0.04	0.2773c 0.8683r 0.0001a
Ginger	45.00 ± 26.8	2.93 ± 2.93	6.67 ± 1.67	8.00 ± 0.00	
Garlic and ginger	12.67 ± 4.70	9.67 ± 0.00	37.67 ± 23.57	0.50 ± 0.70	
(Untreated) Control	87.00 ± 0.00	78.00 ± 0.00	77.00 ± 0.00	89.00 ± 0.00	
72 Hours					
Garlic	10.33 ± 9.84	4.00 ± 1.34	4.33 ± 1.76	4.30 ± 1.62	0.1231c 0.2119r 0.0125a
Ginger	11.00 ± 0.00	10.00 ± 0.00	36.67 ± 0.00	4.56 ± 0.00	
Garlic and ginger	34.33 ±17.52	4.80 ± 2.50	39.00 ± 2.76	4.50 ± 0.00	
(Untreated) Control	94.00 ± 00	86.00	90.00	97.00 ± 0.00	

Values in a column bearing the subscript a, are *p* – values between treated and untreated samples per day, Values in a column bearing the subscript r, are *p* – values between the different treatments per day, and Values in a column bearing the subscript c, are *p* – values between the different microbes per day. Figure 2 shows *E. coli*, *Staphylococcus* spp., *Salmonella* spp., and Total coliform bacteria population in garlic, ginger, ginger, and garlic and control (untreated) fresh African Catfish. From the chart, the mean population of the garlic sample recorded the lowest count of 1.63 × 10^4cfu/cm^2, followed by ginger, ginger, and garlic and untreated recorded the highest count 68.00 × 10^4cfu/cm^2.

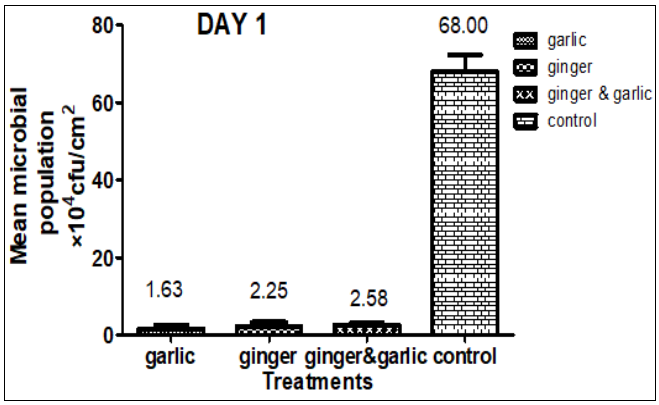

Fig 2: Day one averages of *E. coli*, *Staphylococcus* spp, *Salmonella* spp, and Total coliform bacteria population in garlic, ginger, ginger and garlic, and control (untreated) fresh African Catfish.

Figure 3 shows day two averages of *E. coli, Staphylococcus* spp, *Salmonella* spp, and Total coliform bacteria population in garlic, ginger, ginger, and garlic and control (untreated) fresh African Catfish. From the chart, the mean population of the garlic sample recorded the lowest count of 10.44 × 10^4cfu/cm^2, followed by ginger and garlic and ginger, with untreated recording the highest count 82.75 × 10^4cfu/cm^2.

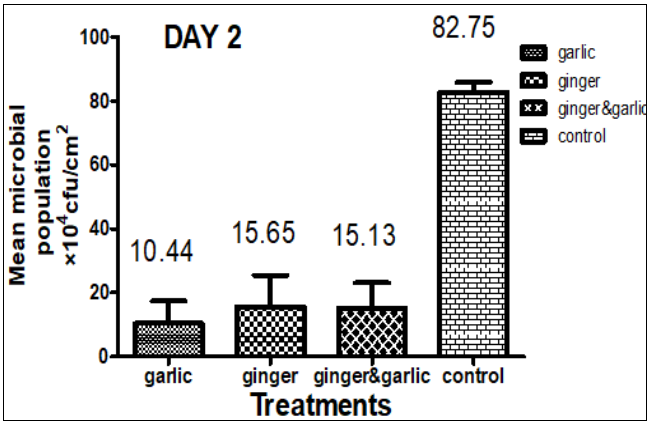

Fig 3: Day two averages of *E. coli, Staphylococcus* spp, *Salmonella* spp and Total coliform bacteria population in garlic, ginger, ginger and garlic, and control (untreated) fresh African Catfish.

Figure 4 shows day three averages of *E. coli, Staphylococcus* spp, *Salmonella* spp, and Total coliform bacteria population in garlic, ginger, ginger and garlic and control (untreated) fresh African Catfish. From the chart, the mean population of the garlic sample recorded the lowest count of 5.74 × 10^4cfu/cm^2, followed by ginger, ginger, and garlic while the untreated recorded the highest count 91.75 × 10^4cfu/cm^2. Though statistically there were no significant differences between the mean of the treated fish and the untreated, there were differences in their mean values.

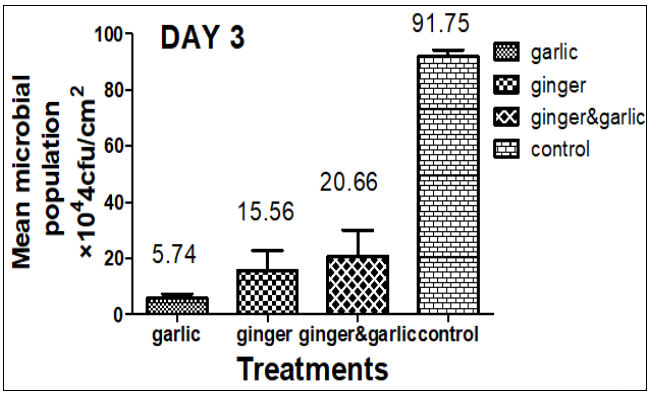

Fig 4: Day three averages of *E. coli, Staphylococcus* spp, *Salmonella* spp and Total coliform bacteria population in garlic, ginger, ginger and garlic, and control (untreated) fresh African Catfish.

In the 72-hour of preservation, the untreated fish sample had the highest count of the pathogens which were all above the recommended limits for good quality fish and fish products (5.0×10^5 cfu/cm^2) according to ICMSF [21]. Though statistically there were no significant differences between the means of the treated fish as there were in the untreated and the treated fish samples. But they are all within the recommended limits for good quality fish and fish products according to ICMSF [21]. In this research, garlic, ginger, ginger, and garlic paste were able to effectively delay the growth of *Escherichia coli, Staphylococcus* spp., *Salmonella* spp. and Total coliform bacteria; and extend the shelf-life for three days under an ambient temperature of 26-32 ºC.

From the results, garlic paste had a very high influence on microbial growth of target bacteria, on the first day (1.63 × 10^4cfu/cm^2), followed by ginger (2.25 × 10^4cfu/cm^2) and 2.58 × 10^4cfu/cm^2 for ginger and garlic paste. The untreated sample recorded the highest microbial count (68.00 × 10^4cfu/cm^2). This indicates that the treated fish samples have been progressive in inhibiting microbial growth.

In other studies, it has been proven that garlic chemicals exhibit inhibitory effects on bacterial growth and spread in some meat [18]. Ginger has a range of biologically active compounds, like, 6-shagaols, curcumin, zingiberene, 6-gingerol, bisabolene, and other types of lipids that are present in it, gives it the pungent and a stimulant property. The one-of-a-kind fragrance of ginger is because of these mixes, in addition, count for around 1-3% of the weight of new ginger [11]. Ahmed *et al*. [21] investigated that ginger has an equal antioxidant effect to that of ascorbic acid.

Results for day two indicates that the mean population of the garlic sample recorded the lowest count of 10.44 × 10^4cfu/cm^2, followed by ginger and garlic and ginger, with untreated recording the highest count 82.75 × 10^4cfu/cm^2. The results demonstrated that garlic, ginger, and a mixture of ginger and garlic paste were accountable for the decreased count in the mean microbial population of the treated samples, suggesting that the paste has been capable of impeding the growth of microbes in fresh African Catfish. Novoslavskij *et al*. [22] reasoned that, contaminated waters from which the fish is collected can have these pathogenic microbes. Breidt *et al*. [23] also argued that due to the high nutritional value of the fish, the product is readily liable to bacteria and microbial attack.

The International Commission on Microbiological Specification for food recommended the maximum bacteria count for good quality fish products is 5.0 × 10^5cfu /g [20]. The mean microbial population of *E. coli, staphylococcus* spp., *Salmonella* spp., and total coliform bacteria detected in the garlic, ginger, and ginger and garlic treated fish samples in this study were all within the maximum recommended limit. Tamakloe [24] likewise, used ginger in preserving a fresh Nile Tilapia for two days which effectively delayed microbial growth and prolonged the shelf-life of the fish.

Results for day two indicates that the mean population of the garlic sample recorded the lowest count of 10.44 × 10^4cfu/cm^2, followed by ginger and garlic and ginger, with untreated recording the highest count 82.75 × 10^4cfu/cm^2. Per the results, the garlic, ginger, ginger, and garlic paste effectively inhibited the growth of microbes and extended the shelf-life of fresh African Catfish. Hughes and Lawson [25] explained that thiosulfinates are essentially responsible for garlic's antibiotic activity since extracts free of thiosulfinates usually lose their antimicrobial capacity whilst Bhatwalkar *et al*. [26] identified that it is medicinally effective because of its oil and water-soluble organosulphur compounds. Notwithstanding, both the quality and quantity of the biologically active components of the rhizome are dependent on the cultivation activities and post-harvest treatment [27].

Similar research revealed ginger extract is effective in retarding rancidity in

results for day 3 indicate that the mean population of the garlic sample recorded the lowest count of 5.74 × 10^4cfu/cm^2, followed by ginger 15.56 × 10^4cfu/cm^2, ginger and garlic 20.66 × 10^4cfu/cm^2 while the untreated recorded the highest count 91.75 × 10^4cfu/cm^2. The mean microbial loads of all the treated fishes after the three days were within the recommended maximum bacteria count for good quality fish products, 5.0 × 10^5cfu /g [20] while the untreated fishes were not. This can best be explained as the results of the pastes the fresh fishes were treated with. From the bar chart, garlic has the lowest mean bacteria population count proofing that it has been very efficient in the preservation. This attests to the findings by (Bhatwalkar [28] that garlic (*Allium sativum*) has an extensive field of dealings, including antifungal, antibacterial, and anti-oxidative. This agrees with a similar study which demonstrated that garlic can efficiently delay microbial growth and prolong the shelf-life of fresh fish (Nile tilapia) under ambient storage conditions for three days [17].

In addition to this ability of garlic, it is also known to help prevent cardiovascular diseases such as atherosclerosis, high cholesterol, and hypertension; and certain types of cancer including stomach and colon cancers [29, 8].

3.3 Chemical analysis

Table 6 shows the summary of the chemical composition of African Catfish samples before and after treatment with garlic paste. The protein and ash composition were reduced but was not significant as compared to the moisture and fat.

Table 6: Chemical composition of African Catfish fish samples before and after treatment with garlic paste

Composition	Untreated fish Mean ± S.D.	Fish treated with garlic Mean ± S.D.	*P*- value ($p < 0.05$)
Protein (%)	58.83 ± 0.12	58.48 ± 0.50	> 0.05
Moisture (%)	74.06 ± 1.25	58.30 ± 0.99	< 0.001
Ash (%)	4.47 ± 0.19	4.94 ± 1.43	0.6881
Fat (%)	7.74 ± 0.04	21.65 ± 2.42	0.0148

The fat, ash, and moisture content of the fish had highly significant deference amongst their mean values after the treatment with the change in protein composition being insignificant (Table 7).

Table 7: Chemical composition of African Catfish fish samples before and after treatment with ginger paste

Composition	Untreated fish Mean ± S.D.	Fish treated with ginger Mean ± S.D.	*P*- value ($p < 0.05$)
Protein (%)	58.09 ± 0.06	58.11 ± 0.06	>0.05
Moisture (%)	75.13 ± 0.09	60.87 ± 0.23	<0.001
Ash (%)	4.50 ± 0.29	9.31 ± 0.31	0.0038
Fat (%)	7.69 ± 0.05	11.18 ± 0.33	0.0045

Table 8 shows the chemical composition of African Catfish fish samples before and after treatment with ginger and garlic paste. The moisture, ash, and fat content of the fish had highly significant deference amongst their mean values after the treatment with the change in protein composition being insignificant.

Table 8: Chemical composition of African Catfish fish samples before and after treatment with ginger and garlic paste

Composition	Fish before treatment with ginger & garlic Mean ± SD	Fish after treated with ginger & garlic Mean ± S.D.	*P*- value ($p < 0.05$)
Protein (%)	56.33 ± 0.06	56.42 ± 0.43	> 0.05
Moisture (%)	72.95 ± 0.71	53.39 ± 0.54	< 0.001
Ash (%)	4.36 ± 0.10	7.28 ± 0.37	0.0084
Fat (%)	6.85 ± 1.25	26.28 ± 0.09	0.0021

Table 9 shows the chemical composition of the African Catfish fish sample untreated. The composition of protein, moisture, ash, and fat-reduced after 72 hours but the significance in their differences only occurred among the protein and moisture composition.

Table 9: Chemical composition of African Catfish fish sample untreated

Composition	Control before Mean ± S.D.	Control After Mean ± S.D.	*P*- value ($p < 0.05$)
Protein (%)	56.33 ± 0.06	44.56 ± 1.02	0.0022
Moisture (%)	74.96 ± 1.39	38.17 ± 0.20	0.032
Ash (%)	4.17 ± 0.24	3.44 ± 1.33	0.5235
Fat (%)	7.90 ± 0.04	6.66 ± 0.12	0.143

From the results, it can be noticed that there was no significant difference between the proximate composition of protein on the treated fishes before and after each treatment. There was a decrease in the protein composition of the fishes after the treatments as well as the untreated (control). That is garlic, ginger, ginger and garlic, and control, all had a *P*-value of 0.40 while the untreated had 0.0022.

Comparing the moisture composition of untreated fishes before and after the experiment, there was a significant difference ($P = 0.032$) while that of the treated fishes before and after treatment ($P = 0.1143$) was not significant. Nevertheless, the moisture content in all the fishes at the beginning of the experiment was higher but reduced after the preservation.

Comparing the proximate composition of ash before and after the treatment indicated that, the content of ash in the ginger treated fish increased from 4.50 to 9.31 which was highly significant (0.0038) as compared to the ginger and garlic treated which increased from 4.36 to 7.28 also being significant, 0.0084. Garlic treated fish sample had a statistically insignificant difference (0.6881) between the ash values before and after treatment, though it increased from 4.47 to 4.494. While the untreated was statistically insignificant (0.5235) decreasing from 7.90 to 6.66.

Fish samples used in this research could be classified as fatty fish based on the report of Taşbozan and Gökçe [30] who stated that fish samples with more than 5% fat are generally regarded as fatty. The fat in the garlic-treated fish was highly significant (0.0148), increasing from 7.74 to 21.65 before and after treatment, as well as the ginger and garlic-treated fish samples whose fat before and after treatment was 6.85 and 26.28 respectively with P value 0.0021. The fish sample treated with ginger recorded a significant difference of 0.0045, between the fat compositions before after treatment being 7.69 to 11.18. Similarly, Achinehwu [12] examined the compound creation of thirty wild flavours indigenous to Nigeria and saw that they contained high measures of fats just as basic oils. The control (untreated) sample also reduced from 7.90 to 6.6.

In other studies, it has been revealed that protein, fat, and ash compositions significantly increased while the moisture content of smoked mackerel significantly decreased, when treated with ginger extract. Despite this, the ginger extract was active in retarding the oxidation of lipid [4].

4. Conclusion

This study demonstrated that garlic, ginger, and a mixture of both can effectively delay microbial growth and extend the shelf-life of treated fresh fish (African catfish) for three days, though garlic performed best. Garlic, ginger and ginger, and garlic paste also inhibited the development and emergence of maggots in the fish carcass. These pastes and extracts may therefore be used in place of refrigeration for short duration preservation of perishable foods in underprivileged households, or during power shortages.

There was a decrease in the protein and moisture composition of the treated samples after 72 hours, but the untreated had the highest difference. The fat and ash of all treated samples increased while the untreated decreased.

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