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Bactericidal Potentials of Garlic (*Allium sativum*) and Onion (*Allium cepa*) Paste on Microbial Quality and Shelf Life of Nile Tilapia (*Oreochromis niloticus*)

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ABSTRACT
Fish remains a critical protein source globally, particularly in developing countries where it contributes significantly to food security and livelihoods. Nile tilapia (*Oreochromis niloticus*) is one of the most widely cultured fish species due to its adaptability, rapid growth, and high nutritional value. However, its high perishability poses significant challenges, especially in regions with limited cold storage infrastructure. This study evaluated the bactericidal potentials of garlic (*Allium sativum*) and onion (*Allium cepa*) paste on the microbial quality and shelf life of fresh Nile tilapia. Fish samples were treated with graded amounts of garlic paste and onion paste (15%, 30%, and 45%) while untreated samples served as control. Microbial analyses were conducted to determine total viable count and the presence of spoilage organisms over a defined storage period. Results indicated that treated samples exhibited significantly reduced microbial loads compared to control, with garlic showing the highest inhibitory effect. The 45% (9.00 ± 0.66^{c}) garlic treatment showed the strongest antibacterial effect, indicating potent bacteriocidal activity as compared to onion paste (14.70 ± 1.33^{c}) at the same application rate. These findings suggest that garlic and onion paste can serve as effective, low-cost natural preservatives, offering a sustainable solution to reduce post-harvest losses and enhance food safety in fish processing systems.

Keywords: Nile Tilapia, Natural Preservatives, Garlic, Onion, Antimicrobial Activity, Fish Spoilage

INTRODUCTION

Fish constitutes a critical component of global food systems, providing high-quality animal protein, essential fatty acids, vitamins, and micronutrients that support human health and nutrition. In recent years, the importance of fish in addressing food security has intensified, particularly in developing countries where it contributes significantly to dietary protein intake and livelihoods (Varzakas & Smaoui, 2024). According to the Food and Agriculture Organization, global fish consumption has continued to rise, driven by population growth, urbanization, and increasing awareness of the nutritional benefits of aquatic foods (FAO, 2022). Among farmed species, *Oreochromis niloticus* occupies a prominent position due to its rapid growth rate, adaptability to diverse environmental conditions, and high market acceptance (Geletu & Zhao, 2022). This species has become one of the most widely cultured fish globally, particularly in Africa and Asia, where aquaculture expansion is viewed as a strategic pathway to enhance food security and economic development (Tran *et al*., 2022).

Despite its nutritional and economic importance, fish is one of the most perishable food commodities. The high water activity, neutral pH, and rich nutrient composition of fish muscle create an ideal environment for microbial proliferation and enzymatic degradation immediately after harvest. These factors accelerate spoilage processes, leading to rapid quality deterioration if appropriate preservation measures are not implemented. Contemporary studies have shown that microbial activity is the primary driver of spoilage in fresh fish, with bacteria such as *Pseudomonas*, *Shewanella*, and *Aeromonas* contributing to the production of off-odours, slime formation, and structural breakdown of tissues (Basdeki *et al*., 2025; Tavares *et al*., 2021). In addition to microbial spoilage, endogenous enzymatic reactions and lipid oxidation further compromise fish quality, resulting in reduced shelf life and economic losses.

In many developing regions, including Nigeria, the challenge of fish preservation is compounded by inadequate infrastructure, particularly unreliable electricity supply and limited access to cold storage facilities. These constraints significantly reduce the effectiveness of conventional preservation methods such as refrigeration and freezing, thereby increasing post-harvest losses. Recent global assessments indicate that a substantial proportion of fish produced in low- and middle-income countries is lost due to inadequate handling, storage, and processing techniques (FAO, 2022). Addressing these losses requires the development of alternative preservation strategies that are cost-effective, accessible, and adaptable to local conditions.

Natural plant-based preservatives have emerged as promising alternatives to synthetic chemical additives in food preservation systems. These bioactive substances, derived from herbs, spices, and other plant materials, possess antimicrobial and antioxidant properties that can inhibit spoilage processes and extend shelf life (Osinubi *et al*., 2026). Among these, garlic (*Allium sativum*) and onion (*Allium cepa*) have received considerable attention due to their widespread availability, low cost, and established safety for human consumption. Both plants contain a range of bioactive compounds, including organosulfur compounds and phenolic substances, which exhibit strong antimicrobial activity against a broad spectrum of microorganisms (Borlinghaus *et al*., 2021; Upadhyay *et al*., 2014). These compounds act through multiple mechanisms, including disruption of microbial cell membranes, inhibition of enzyme activity, and interference with genetic material, thereby reducing microbial growth and metabolic activity.

Garlic, in particular, is known for its high content of allicin, a reactive sulfur compound formed when garlic cloves are

crushed or chopped. Allicin has been widely documented for its potent antimicrobial properties, demonstrating effectiveness against both Gram-positive and Gram-negative bacteria, as well as fungi and viruses (Borlinghaus *et al*., 2021). Onion, on the other hand, contains flavonoids such as quercetin and various sulfur-containing compounds that also contribute to its antimicrobial and antioxidant effects. Although generally considered less potent than garlic, onion extracts have been shown to inhibit the growth of several foodborne pathogens and spoilage organisms (Fredotović *et al*., 2021). The combined antimicrobial and antioxidant properties of these plants make them suitable candidates for use in fish preservation.

Recent research has increasingly focused on the application of plant-derived antimicrobials in extending the shelf life of perishable foods, including fish. Studies have demonstrated that natural extracts can effectively reduce microbial load, delay lipid oxidation, and maintain sensory quality during storage (Nunes *et al*., 2023; Hauzoukim *et al*., 2020). In fish products, the use of plant-based preservatives has been associated with reduced formation of total volatile basic nitrogen (TVB-N), lower microbial counts, and improved organoleptic properties. These findings highlight the potential of natural preservatives to serve as sustainable alternatives to synthetic chemicals, which are often associated with safety concerns and regulatory restrictions.

The use of garlic and onion in fish preservation is particularly relevant in the context of small-scale fisheries and aquaculture systems, where access to advanced preservation technologies is limited. In such settings, locally available plant materials offer a practical and affordable means of reducing spoilage and improving product quality. Furthermore, the adoption of natural preservation methods aligns with current consumer preferences for minimally processed foods and the growing demand for clean-label products. This shift in consumer behavior has further stimulated research into natural alternatives that can ensure food safety while maintaining nutritional and sensory quality.

In addition to their antimicrobial properties, garlic and onion also possess antioxidant activities that can inhibit lipid oxidation, a major cause of quality deterioration in fish. Lipid oxidation leads to the formation of rancid flavours, discoloration, and loss of nutritional value, particularly in fatty fish species. The presence of phenolic compounds and sulfur-containing molecules in garlic and onion contributes to their ability to scavenge free radicals and stabilize lipid structures, thereby preserving product quality during storage (Nunes *et al*., 2023). This dual functionality enhances their effectiveness as natural preservatives.

Although the potential of garlic and onion as preservatives has been widely recognized, there remains a need for systematic evaluation of their effectiveness under different conditions, including varying concentrations and storage durations. Understanding the relationship between treatment concentration, storage time, and preservation efficacy is essential for optimizing their application in real-world settings. Moreover, integrating sensory evaluation with microbiological assessment provides a comprehensive understanding of both product quality and safety, which is critical for consumer acceptance and regulatory compliance.

The present study is therefore designed to evaluate the effects of garlic and onion paste treatments on the microbial quality and sensory attributes of *Oreochromis niloticus* during storage. By examining the influence of different concentrations over time, the study aims to provide empirical evidence on the effectiveness of these natural preservatives in extending the shelf life of fish. The findings are expected to contribute to the development of sustainable preservation strategies that can reduce post-harvest losses, improve food quality, and enhance food security, particularly in resource-limited environments.

MATERIALS AND METHODS

Study Area and Sample Collection

Fresh Nile tilapia samples were obtained from Cable market Asaba Delta State Nigeria after proper identification using Fish base pictorial keys (Latitude 6.18845 and longitude 6.75434) Asaba, Delta State, Nigeria. Samples were transported under hygienic conditions to the laboratory.

Preparation of Garlic and Onion Paste

Fresh garlic (*Allium sativum*) and onion (*Allium cepa*) bulbs were peeled, washed, and grounded into paste using a sterile blender. The pastes were stored under refrigerated conditions prior to use.

Experimental Design

24 fish samples weighing between 150-300kg each were used for this experiment. Each set up was composed of 3 treatments and 1 control. The first treatment was administered 15g of Garlic paste, the second treatment 30g, while the third treatment 45g of the paste. The control fish was devoid of paste application. Also a similar set up was done using Onion paste as treatment on the fish that is 15g Onion paste on the first treatment fish, 30g on the second and 45g on the third treatment fish with a control fish devoid of Onion paste treatment. Each of these treated fish and the control were neatly placed in individual containers. The experimental set up was replicated thrice and was left to stand for three (3) days at ambient temperature. Observations of organoleptic characteristics were done at 2pm daily throughout this experimental period.

Microbiological Analysis

Microbial load was assessed using standard plate count methods:

i. Total Viable Count (TVC)
ii. Isolation and identification of bacteria

Serial dilution and plating were carried out on appropriate media, followed by incubation at 37°C for 24–48 hours.

Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) to determine significant differences between treatments at $p < 0.05$.

RESULTS AND DISCUSSION

Effect of Garlic and Onion Pastes on the Bacterial Load of Treated Fish Samples

These bacteria (*Escherichia coli*, *Staphylococcus aureus*, *Salmonella spp*., *Pseudomonas aeruginosa streptococcus pneumoniae*, *bacillus* and *lactobacillus cereus*) were identified via microscopy techniques on both control and treated fish, *Oreochromis niloticus*. The effects of varying concentrations (15%, 30%, and 45%) of garlic and onion pastes on the bacterial load on treated fish samples stored for 24, 48, and 72 hours is presented in **Table 1**. The control (0%) sample consistently recorded higher mean values throughout the duration of exposure, indicating more bacterial activity or deterioration compared to the treated fish samples. In contrast, all treated fish samples showed significantly lower bacterial counts ($p<0.05$), suggesting strong antimicrobial activity of both garlic and onion pastes even though garlic proved to be more effective as compared to onion paste with time.

Table 1: Effect of Garlic and Onion Paste Treatments on the Microbial Quality of Samples Stored for 24, 48, and 72 Hours

Treatment%	Onion paste 24hrs	Garlic paste 24hrs	Onion paste 48hrs	Garlic paste 48hrs	Onion paste 72hrs	Garlic paste 72hrs
0(Control)	44.70±0.88^{a}	44.70±0.88^{a}	80.30±0.88^{a}	80.30±0.88^{a}	95.00±1.00^{a}	95.00±1.00^{a}
15%	32.00±3.46^{b}	14.00±3.06^{b}	30.00±1.15^{b}	20.00±2.00^{b}	26.00±2.00^{b}	13.00±1.00^{b}
30%	25.70±2.60^{bc}	11.00±2.08^{b}	20.70±1.76^{c}	18.70±0.66^{b}	15.70±0.33^{c}	12.30±0.33^{b}
45%	21.70±2.73^{c}	10.00±1.15^{b}	20.30±1.45^{c}	13.70±0.88^{c}	14.70±1.33^{c}	9.00±0.66^{c}

Means with different superscript letters (^{a}, ^{b}, ^{c}) within the same column differ significantly ($p<0.05$).

The reduction in bacterial load increased with higher treatment concentration in both onion and garlic treated fish. 30% paste treated fish outperformed that of 15% (Figure 1-4) from 24 to 48 hours exposure period for both onion and garlic. The 45% garlic and onion paste treatments recorded the lowest mean values at 72 hours (9.00±0.66^{c} and 14.70±1.33^{c} respectively), signifying the highest inhibitory effect. The observed reduction can be attributed to the possible presence of antimicrobial properties in garlic and onion, This outcome is similar to the report of Azuamah *et al* (2026) who studied the antibacterial effect of Aqueous extracts of onion and garlic on some ethical bacterial isolates concluding that aqueous extracts of both garlic and onion have anti-bacterial activities against the tested bacterial pathogens with garlic exhibiting greater anti-microbial potential compared with onion extracts, and their anti-bacterial activities is concentration dependent. Merati and Boudra (2024) also reported that fresh *Allium santium* (Garlic) juice exhibited a significant antibacterial effect on the resistant *E. coli* strains. However, fresh *Allium cepa* (onion) juice appeared to be ineffective **against the tested bacterial strain.** FAO & WHO (2023), current study also align with the view of Griffit *et al* (2002) who reported that a quercetin, a flavonol, is the primary compound responsible for inhibition of bacterial growth via bacterial membrane disruption.

The microbial quality data presented in Table 1 demonstrate a clear and consistent influence of garlic (*Allium sativum*) and onion (*Allium cepa*) paste treatments on the microbial load of *Oreochromis niloticus* during storage. The results reveal two dominant patterns: a progressive increase in microbial counts with storage time in untreated samples, and a concentration-dependent reduction in microbial load in treated samples. These findings collectively indicate that both garlic and onion possess significant antimicrobial properties capable of inhibiting spoilage microorganisms and extending the microbiological shelf life of fish.

The control samples exhibited a marked increase in microbial counts from 44.70 at 24 hours to 95.00 at 72 hours, reflecting rapid microbial proliferation under ambient storage conditions. This trend is consistent with the well-established understanding that fresh fish provides a favourable substrate for microbial growth due to its high moisture content, neutral pH, and abundance of nitrogenous compounds. Recent studies have emphasized that microbial spoilage in fish is primarily driven by psychrotrophic and mesophilic bacteria such as *Pseudomonas*, *Shewanella*, and *Aeromonas*, which proliferate rapidly in the absence of preservation interventions (Basdeki *et al*., 2025; Tavares *et al*., 2021). The sharp increase observed in the control group therefore confirms the susceptibility of untreated fish to rapid microbial deterioration.

In contrast, all treated samples showed significantly lower microbial counts across all storage periods, with the degree of reduction increasing as treatment concentration increased. At 24 hours, the reduction in microbial load was already evident, particularly in garlic-treated samples, where counts decreased to as low as 10.00 at 45% concentration. This early inhibition suggests that the antimicrobial compounds in garlic and onion act rapidly upon application. Garlic, in particular, demonstrated stronger antimicrobial activity than onion across all concentrations and time intervals. This observation is consistent with the known potency of allicin, a sulfur-containing compound in garlic that exhibits broad-spectrum antimicrobial activity by disrupting microbial cell membranes and inhibiting essential metabolic enzymes (Borlinghaus *et al*., 2021; Upadhyay *et al*., 2014).

The concentration-dependent effect observed in this study highlights the importance of dosage in determining antimicrobial efficacy. At 15% concentration, both treatments significantly reduced microbial counts compared to the control, but the effect was more pronounced at 30% and 45% concentrations. This suggests that higher concentrations provide greater quantities of active compounds, thereby enhancing the inhibitory effect on microbial growth. Similar findings have been reported in recent studies where increasing concentrations of plant extracts resulted in stronger antimicrobial effects against foodborne and spoilage microorganisms (Nunes *et al*., 2023; Vijayan *et al*., 2021). The progressive decline in microbial counts with increasing concentration therefore reflects a direct relationship between bioactive compound availability and antimicrobial activity.

Temporal analysis further reveals that while microbial counts increased over time in all treatments, the rate of increase was significantly lower in treated samples compared to the control. For instance, garlic-treated samples at 45% concentration maintained relatively low microbial counts even at 72 hours, indicating sustained antimicrobial activity throughout the storage period. This suggests that the bioactive compounds in garlic and onion not only act immediately but also retain their effectiveness over time. The persistence of antimicrobial activity is particularly important in practical applications, as it ensures continued protection against microbial proliferation during storage. Recent research has shown that natural preservatives can provide prolonged antimicrobial effects by forming inhibitory environments that limit bacterial growth and metabolic activity (Hauzoukim *et al*., 2020).

The superior performance of garlic over onion observed in this study can be attributed to differences in their chemical composition and mechanisms of action. Garlic contains highly reactive organosulfur compounds such as allicin, diallyl sulfide, and ajoene, which exhibit strong antimicrobial activity against a wide range of bacteria, including both Gram-positive and Gram-negative species. These compounds act by penetrating microbial cells and interfering with thiol-containing enzymes essential for cellular metabolism (Borlinghaus *et al*., 2021). In contrast, onion contains flavonoids such as quercetin and sulfur compounds that also possess antimicrobial properties but may act through less direct or slower mechanisms (Fredotović *et al*., 2021). This difference in potency likely explains the consistently lower microbial counts observed in garlic-treated samples.

The statistical grouping indicated by superscripts in the table further supports the significance of these findings. Treatments with different superscripts differ significantly, indicating that the reductions in microbial load observed at higher concentrations are not due to random variation but represent true treatment effects. The clear separation between control, moderate, and high concentration treatments underscores the reliability of the observed trends and reinforces the conclusion that garlic and onion pastes are effective antimicrobial agents.
From a food safety perspective, the reduction in microbial load achieved through these treatments has important implications. High microbial counts in fish are associated not only with spoilage but also with potential health risks due to the presence of pathogenic bacteria. By significantly reducing microbial populations, garlic and onion treatments contribute to both improved shelf life and enhanced safety of fish products. This aligns with recent global efforts to promote the use of natural preservatives as safer alternatives to synthetic chemicals in food systems (Nunes *et al*., 2023).
The findings also have practical relevance for fish handling and preservation in resource-limited settings. In many developing regions, inadequate access to refrigeration leads to rapid spoilage and significant post-harvest losses. The use of locally available plant materials such as garlic and onion provides a low-cost and accessible method for controlling microbial growth and extending shelf life. According to recent reports, reducing post-harvest losses through improved preservation techniques is critical for enhancing food security and economic sustainability in the fisheries sector (FAO, 2022). The application of garlic and onion pastes therefore represents a viable strategy for addressing these challenges.
Despite the promising results, it is important to acknowledge that the study focuses on total microbial counts without identifying specific microbial species. Different microorganisms exhibit varying levels of susceptibility to antimicrobial agents, and the effectiveness of garlic and onion may differ depending on the microbial composition of the fish. Future studies should therefore include microbiological characterization to identify dominant spoilage organisms and assess the spectrum of antimicrobial activity more precisely. Additionally, integrating physicochemical analyses such as pH, lipid oxidation, and total volatile basic nitrogen would provide a more comprehensive understanding of spoilage dynamics.
The microbial quality data clearly demonstrate that garlic and onion paste treatments significantly inhibit microbial growth in *Oreochromis niloticus* during storage. The effectiveness of these treatments is strongly influenced by concentration, with higher levels providing greater antimicrobial protection. Garlic exhibited superior performance compared to onion, likely due to its more potent bioactive compounds. The results highlight the potential of natural plant-based preservatives as effective, sustainable, and accessible tools for improving fish quality and reducing post-harvest losses. These findings contribute to the growing body of evidence supporting the integration of natural antimicrobial agents into food preservation systems.

Sensory Evaluation of Treated Fish Samples

The sensory attributes (appearance, odor, texture, and overall acceptability) of samples treated with different concentrations of garlic and onion pastes were evaluated to assess the impact of treatment on consumer quality characteristics.
Appearance scores (Figure 1) show that both garlic and onion treated fish samples maintained high visual quality (appearance) throughout storage. The 45% treatments for both pastes recorded the highest and most stable scores (9.00 ± 0.00^{a}). Awad *et al.* (2022) on physicochemical methods of food preservation highlighted that increasing concentrations of certain preservatives or antioxidants effectively inhibit microbial growth and oxidation, thereby maintaining the appearance and safety of food products.

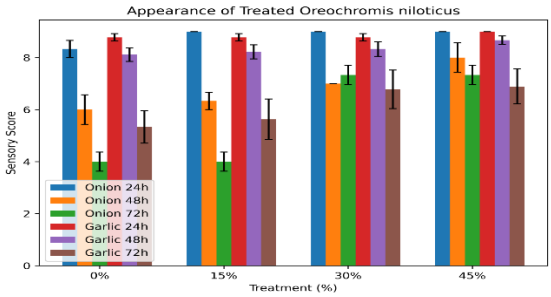

Figure 1: Appearance/Facial Appeal of Treated Fresh *Oreochromis niloticus*

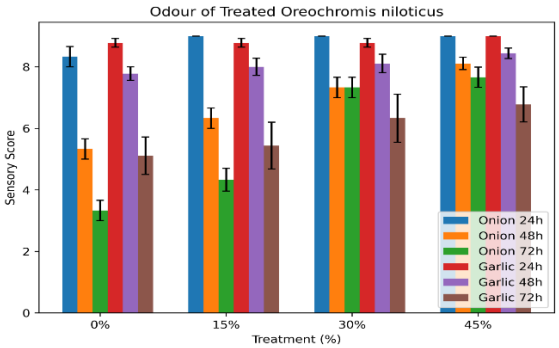

Figure 2: Comparative odour of garlic and onion-treated fresh *Oreochromis niloticus*

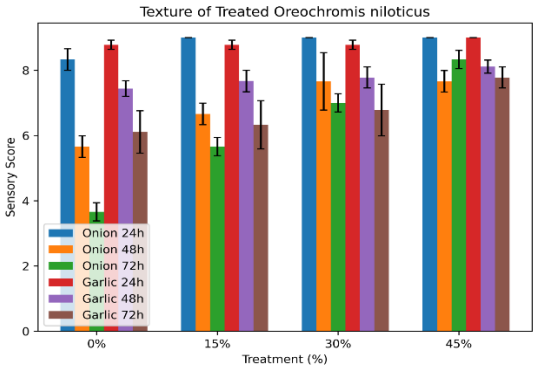

Figure 3: Textural Quality of Treated Fresh *Oreochromis niloticus*

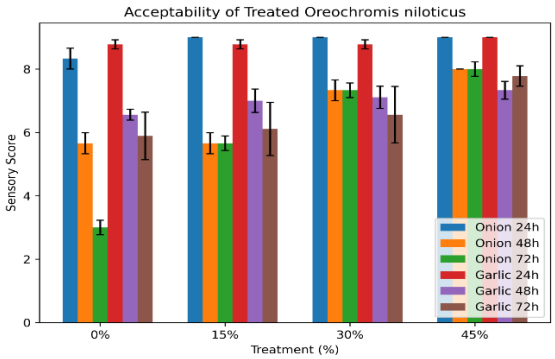

Figure 4: Overall Acceptance of Treated Fresh *Oreochromis niloticus*

This indicates that increasing concentration helped preserve the visual appeal of the fish (Figure 1), possibly by inhibiting discoloration caused by microbial activity or oxidation. The control samples exhibited a faster decline in odour compared to the treated samples (Figure 2). Odour acceptability also improved with increasing treatment concentration (Figure 4). The 45% garlic paste treatment had the highest odour score (8.44 ± 0.17^{a}), followed closely by 45% onion paste (8.11 ± 0.20^{a}). This implies that both pastes effectively masked undesirable odour and prevented spoilage. This agrees with the view of Adaka *et al*. (2021) that *clarias gariepinus* treated with extracts of garlic and ginger retained nutritional quality compared to the control fish.

The texture and overall acceptability scores of the control samples had lower scores (Figure 3), while samples treated with higher concentrations (30–45%) recorded significantly higher $p<0.05$. The 45% garlic and onion paste treatments received the best evaluations for texture (7.78 ± 0.32^{a}; 8.33 ± 0.28^{a}) and overall acceptability (7.78 ± 0.32^{a}; 8.00 ± 0.23^{a}). This indicates that both paste preserved the sensory attributes effectively during storage. This concur with the report of Akpotu *et al*. (2025) who concluded that garlic amd onion paste effectively reduced microbial load and preserved the sensory attributes of smoke-dried *Oreochromis niloticus* with higher concentration exhibiting the most significant quality preservative effect and garlic also outperforming onion in fish quality preservation.

The present study demonstrates that the application of onion (*Allium cepa*) and garlic (*Allium sativum*) pastes significantly influences the sensory stability of *Oreochromis niloticus* during short-term storage. Across all evaluated parameters, namely appearance, odour, texture, and overall acceptability, higher treatment concentrations (30% and 45%) consistently delayed the onset of spoilage compared to untreated samples. These findings align with contemporary understanding that fish spoilage is primarily driven by microbial proliferation, enzymatic degradation, and oxidative reactions, processes that can be effectively mitigated by natural bioactive compounds (Tahiluddin *et al*. 2022; Ghaly *et al*., 2010).

The improved preservation observed at higher concentrations of garlic and onion treatments can be attributed to the antimicrobial activity of their bioactive constituents. Garlic contains allicin and related organosulfur compounds, while onion is rich in flavonoids such as quercetin and sulfur-containing metabolites. These compounds exert antimicrobial effects by disrupting bacterial cell membranes, inhibiting enzymatic systems, and interfering with nucleic acid synthesis (Borlinghaus *et al*., 2021; Upadhyay *et al*., 2014). The sustained sensory quality observed in treated samples at 48 and 72 hours suggests that these compounds effectively suppressed spoilage microorganisms, thereby slowing quality deterioration. This observation is consistent with recent studies indicating that plant-derived antimicrobials can significantly extend the shelf life of fish products by reducing microbial load and oxidative damage (Hauzoukim *et al*., 2020).

Temporal declines in sensory attributes across all treatments reflect the progressive nature of spoilage processes, although the rate of deterioration varied markedly among treatments. The rapid decline in odour and texture observed in the control samples after 48 hours is indicative of accelerated microbial metabolism and enzymatic breakdown. Spoilage-associated bacteria produce volatile compounds such as amines, aldehydes, and sulfur-containing metabolites, which contribute to off-odours and reduced acceptability (Basdeki *et al*., 2025). The slower rate of decline in treated samples suggests inhibition of these microbial pathways, reinforcing the role of onion and garlic as effective natural preservatives.

Recent research has shown that bioactive plant extracts can reduce the formation of total volatile basic nitrogen (TVB-N) and other spoilage indicators in fish during storage (Vijayan *et al*., 2021).

Differences between garlic and onion treatments observed in this study further highlight variation in antimicrobial potency. Garlic-treated samples generally maintained slightly higher sensory scores, particularly in odour and texture, suggesting a stronger preservative effect. This may be attributed to the high reactivity of allicin, which exhibits rapid bactericidal activity by targeting thiol-containing enzymes essential for microbial metabolism (Borlinghaus *et al*., 2021). In contrast, onion-derived compounds such as quercetin exert antimicrobial effects that are often less immediate and more dependent on concentration and environmental conditions (Fredotović *et al*., 2021). This distinction may explain the relatively enhanced performance of garlic treatments at extended storage durations.

Texture preservation is a critical quality parameter in fish, as it reflects the structural integrity of muscle tissues. Post-mortem softening is primarily associated with endogenous enzymatic activity and microbial proteolysis. The higher texture scores observed in treated samples indicate that these degradative processes were effectively slowed. Antimicrobial compounds in garlic and onion likely inhibited proteolytic bacteria, thereby preserving muscle structure. Recent studies have demonstrated that natural plant extracts can significantly reduce protease activity and maintain textural quality in fish during storage (Awad *et al*., 2022). This supports the assertion that bioactive plant treatments can serve as dual-function agents, controlling microbial growth while preserving structural properties.

The pattern of overall acceptability observed in this study reflects the combined influence of all sensory attributes and provides a practical indicator of consumer perception. The retention of acceptable sensory quality in samples treated with higher concentrations of garlic and onion beyond 48 hours is particularly relevant for small-scale fish processors and vendors. In many developing regions, including Nigeria, limited access to refrigeration necessitates alternative preservation methods. The use of locally available plant materials such as garlic and onion offers a cost-effective and sustainable solution. This aligns with current global trends promoting the use of natural preservatives as safer alternatives to synthetic additives in food systems (Nunes *et al*., 2023).

From a food security perspective, the findings of this study have important implications. Fish is a highly nutritious but perishable commodity, and post-harvest losses remain a significant challenge in many parts of the world. Recent estimates suggest that a substantial proportion of fish produced in developing countries is lost due to inadequate preservation and storage infrastructure (FAO, 2022). The application of natural preservatives such as garlic and onion could play a critical role in reducing these losses, thereby improving food availability and economic returns for fish producers and marketers.

It is important to acknowledge that sensory evaluation, while valuable, is inherently subjective and may be influenced by individual panelist perceptions. Although the use of trained panelists helps to minimize variability, future studies should incorporate complementary analytical methods, including microbiological assays and chemical indicators such as pH, lipid oxidation, and microbial counts, to provide a more comprehensive assessment of preservation efficacy. Additionally, further research exploring synergistic effects between garlic and onion extracts, as well as optimization of treatment concentrations and application methods, would enhance the practical applicability of these findings.

The study provides strong evidence that garlic and onion pastes significantly improve the sensory quality and shelf life of *Oreochromis niloticus* during short-term storage. The effectiveness of these treatments is closely linked to their antimicrobial and antioxidant properties, which inhibit spoilage processes and preserve organoleptic characteristics. The findings underscore the potential of natural plant-based preservatives as sustainable and accessible tools for fish preservation, particularly in resource-limited settings. By integrating traditional knowledge with modern scientific validation, such approaches can contribute to improved food quality, reduced post-harvest losses, and enhanced food security.

The results demonstrate the effectiveness of garlic and onion paste as natural antimicrobial agents in fish preservation. The strong inhibitory effect observed in garlic-treated samples is consistent with previous studies attributing antimicrobial activity to allicin, which disrupts bacterial cell functions. Onion's flavonoids, particularly quercetin, enhanced the overall bactericidal efficiency. The reduction in microbial load directly translates to extended shelf life, which is critical in regions lacking reliable refrigeration. These findings align with global efforts to promote sustainable and low-cost food preservation methods.

CONCLUSION

The present study provides a comprehensive evaluation of the preservative efficacy of garlic (*Allium sativum*) and onion (*Allium cepa*) pastes on the microbial quality and sensory attributes of *Oreochromis niloticus* during short-term storage. The findings demonstrate that both plant-based treatments exert measurable inhibitory effects on microbial proliferation, with efficacy increasing proportionally to concentration and duration of exposure. Garlic paste consistently exhibited stronger antimicrobial activity compared to onion paste, reflecting the higher potency of its bioactive sulfur compounds, particularly allicin. This enhanced bacteriostatic effect was evident across all storage intervals, where treated samples recorded significantly lower microbial loads than the untreated control. The progressive increase in microbial counts observed in control samples underscores the inherent perishability of fresh fish and highlights the importance of timely preservation interventions.

Beyond microbial control, the treatments also influenced organoleptic properties, which are critical determinants of consumer acceptance. Samples treated with higher concentrations of garlic and onion paste maintained better scores for appearance, odour, texture, and overall acceptability over the storage period. While slight declines in sensory quality were observed with increasing storage time, treated samples retained acceptable characteristics compared to the rapid deterioration recorded in untreated fish. The integration of microbiological and sensory data therefore provides a coherent indication that garlic and onion pastes not only suppress spoilage organisms but also contribute to the preservation of desirable quality attributes.

The study further establishes that natural preservatives derived from locally available plant materials can serve as effective alternatives to conventional preservation methods, particularly in environments where cold storage infrastructure is limited or unreliable. The application of garlic and onion paste offers a low-cost, accessible, and environmentally sustainable approach to reducing post-harvest losses in fish. These findings align with current global emphasis on the use of natural additives in food systems, driven by increasing

concerns over synthetic preservatives and the demand for safer, minimally processed foods.

In light of these findings, it is recommended that small-scale fish processors and vendors adopt the use of garlic and onion paste as part of post-harvest handling practices to extend the shelf life of fresh fish. Optimization of treatment concentrations should be encouraged, with higher concentrations demonstrating greater preservative efficacy without compromising sensory quality. Further research is necessary to evaluate the long-term effects of these treatments under varying environmental conditions, including temperature fluctuations typical of tropical storage systems. Additionally, studies integrating combined preservation techniques, such as the use of plant extracts with modified atmosphere packaging or mild refrigeration, could provide synergistic effects that further enhance shelf life and product safety.

Policy support and extension services should also promote awareness and training on the application of natural preservatives among fish farmers, processors, and marketers. Such interventions will facilitate the adoption of sustainable preservation strategies, improve product quality, and ultimately contribute to enhanced food security and reduced economic losses within the fisheries sector.

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