Innovative Postharvest Treatment Strategy for Extending the Shelf Life of Fresh Tilapia in Africa

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Abstract

This study aims to evaluate the effectiveness of Savour Solutions™ interventions in extending the shelf life and maintaining the microbiological quality and safety of fresh Nile tilapia (*Oreochromis niloticus*). The interventions contain lactic acid and inorganic salts, with or without ethyl lauroyl arginate (E 243). Fresh tilapia weighing 100–250 g will be humanely euthanized, eviscerated, and filleted before being randomly allocated to a control group and two treatment groups (Treated 1 and Treated 2). Fish and fillets will be treated with the respective solutions at the designated processing stages prior to packaging. Packaged fillets will be stored at 4 ± 2 °C for 14 days, with independent sealed samples from each group analyzed daily throughout the storage period. Microbiological quality will be assessed by determining total viable aerobic counts (TVC), lactic acid bacteria (LAB) counts, and total coliform counts as indicators of microbial growth and spoilage. The study will assess whether the tested interventions can effectively delay microbial deterioration and extend the microbiological shelf life of fresh tilapia under refrigerated storage. The findings are expected to provide evidence on the potential application of these interventions as a postharvest strategy for reducing fish losses and improving the safety and quality of fresh tilapia in African aquaculture and fish supply chains.

Keywords: Nile tilapia; *Oreochromis niloticus*; postharvest treatment; shelf life; microbial quality; refrigerated storage; lactic acid; ethyl lauroyl arginate.

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Introduction

Fish is a lean and highly nutritious food source that provides important vitamins, proteins, minerals, with little or no saturated fat and is low in carbohydrates. However, fresh fish is highly perishable, facing rapid deterioration in freshness after harvest, resulting in loss of freshness and potentially compromising product quality and safety when appropriate preservation practices are not applied. Fish spoilage is mainly due to enzymatic activity, microbial growth and lipid oxidation which progressively contribute to undesirable changes in sensory characteristics such as odour, colour and texture. Consequently, maintaining the quality and extending the refrigerated shelf-life of fresh fish remains an important challenge throughout the post-harvest value chain.

Globally, an estimate of 10 - 12 million tons of fish are lost annually, accounting for approximately 10 % of total fish production from capture fisheries and aquaculture. Post-harvest fish losses are particularly important in Sub-Saharan African, where up to one-third of total fish production may be lost with associated financial losses estimated 2 to 5 billion annually (Abelti and Teka, 2024). These losses occur throughout the value chain with production (39 %) and handling (36 %) and are associated with factors such as prolonged transport times, inadequate handling practices, species and size discrimination, animal predation, lengthy duration of fishing cycle, insufficient use of ice, limited cold-storage facilities and disruptions in the cold chain, lack of transportation and insect infestation. Given the highly perishable nature of fresh fish, improving post-harvest preservation and refrigerated storage therefore represents an important opportunity to reduce product losses while maintaining the quality and marketability of fish destined for human consumption.

Microbial proliferation is one of the principal factors limiting the refrigerated shelf life of fresh fish. Total viable count (TVC) is commonly used as an indicator of microbial quality during chilled storage, with high aerobic bacterial loads associated with progressive spoilage and deterioration in sensory quality, although the relationship between microbial counts and sensory rejection may vary according to fish species, storage conditions and the prevailing spoilage microbiota (Gram and Huss, 1996; Cyprian *et al*., 2013). Consequently, post-harvest interventions that suppress or delay microbial growth may provide an effective means of extending the microbiological shelf life of fresh fish. Several preservation approaches have been investigated for this purpose, including temperature control, modified-atmosphere packaging, superchilling and the application of compounds. In Nile tilapia (*Oreochromis niloticus*), modified-atmosphere packaging and super chilled storage have been shown to delay microbial and sensory deterioration (Cyprian *et al.,* 2013). Organic acids and their salts have also been investigated as antimicrobial treatments for refrigerated fish; lactic acid treatments have demonstrated inhibitory effects on microbial growth in refrigerated catfish fillets (Marshall and Kim, 1996), while sodium lactate has been evaluated in refrigerated Nile tilapia together with microbial, odour and colour changes (Korel *et al*., 2001). More recently, plasma-activated lactic acid treatments have been reported to suppress microbial proliferation and delay quality deterioration in refrigerated tilapia fillets (Cai *et al*., 2024; Yang *et al*., 2026). Collectively, these studies demonstrate that organic-acid-based interventions, alone or in combination with other preservation technologies, can contribute to the control of microbial deterioration in refrigerated fish.

Although organic acids and their salts have therefore previously been investigated for the preservation of refrigerated tilapia, their use in combination with other food-grade antimicrobial compounds provides scope for further investigation. Of particular interest is ethyl lauroyl arginate (ELA; E243), a cationic antimicrobial compound with broad-spectrum activity that has been investigated for improving the microbiological quality and safety of a range of food products (Ma *et al.*, 2023). While ELA has been investigated in food preservation, including seafood applications, its application as part of a combined antimicrobial intervention for refrigerated Nile tilapia appears not to have been reported. The present study therefore evaluated two post-harvest antimicrobial interventions based on lactic acid and inorganic salts, with the more intensive intervention incorporating ELA, for their ability to suppress microbial growth in fresh Nile tilapia fillets stored under refrigerated conditions (4±2°C). It was hypothesised that these treatments would delay the increase in total viable aerobic bacterial counts relative to untreated fillets, thereby extending microbiological shelf life. Delayed microbial proliferation was further expected to contribute to the retention of desirable quality characteristics and to delay the development of visible spoilage during refrigerated storage.

Materials and methods

Fresh tilapia (21 fish of 100 – 250 g) were humanely euthanised, scaled, eviscerated, and divided into three groups: Control, Treated 1, and Treated 2 (number of fish/ fillets allocated to each group and include that it was randomly selected and allocated). Fish were dipped in their respective treatment solutions pre- and post-filleting, then packed and sealed. The control group was dipped in water collected from the holding tanks. Treated 1: Buffered Lactic Acid Intervention – pH 3.75; Treated 2: Buffered Lactic Acid Intervention + 50ppm ELA – pH 3.75. Fillets were exposed to each treatment for approximately 2 min (Fig. 1).

Samples were stored at 4±2°C for 14 days in ziplog bags. Every second day, sealed fillets from each group were tested for Total Viable Aerobic Bacterial Count (TVC). Total Viable Counts were determined in an ISO/IEC 17025-

accredited laboratory using a method included within the laboratory's scope of accreditation. Sampling was conducted on days 1, 3, 5, 7, 9, 11, 13 and 15. A new sealed fillet from each group was opened for each testing day. For each test, 25 g of sample was homogenised in 225 ml diluent (Buffered Peptone Water), serially diluted, 500 µL was spread-plated in duplicate on Plate Count Agar (PCA) and incubated for 48 hours at 36±2°C. Thereafter, the colonies on the plates were counted and recorded. Results were expressed as log10 colony forming units per gram (log10 CFU/g).

Figure 1: Preparation of tilapia samples for treatment and grouping prior to shelf-life trial.

Result and discussion

Total Viable Counts (TVCs) increased over time in all groups, with clear differences in the observed microbial growth patterns between the Control, Treated 1 and Treated 2 Groups. The Control showed the most rapid increase in TVC, while microbial growth was progressively slower in Treated 1 and Treated 2. The Control group (green) showed the most rapid increase in microbial load exceeding the 10^7 CFU/g by Day 7. In comparison, Treated 1 (purple) showed delayed microbial growth, approaching 10^7 CFU/g by Day 9, while Treated 2 (blue) maintained TVC levels well below 10^7 CFU/g throughout the 14-day storage period (Fig. 2).

From a practical quality perspective, increasing microbial loads in fresh fish are associated with progressive spoilage and the development of undesirable sensory characteristics, including changes in colour, texture and appearance (Gram and Huss, 1996, Cyprian *et al.* 2013). Thus, although sensory acceptability was not formally assessed in this present study, the delayed increase in TVC observed in the treated fillets indicates a delay in microbiological deterioration and would be expected to delay the development of spoilage-associated quality changes. This effect was most pronounced in Treated 2.

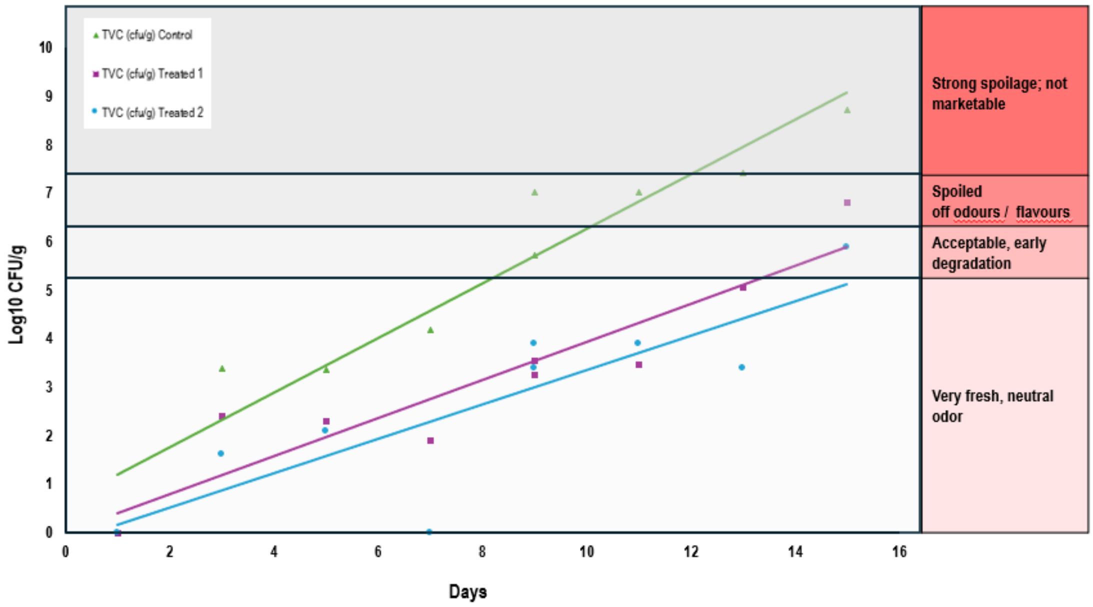

Figure 2: Changes in total viable aerobic bacterial counts (TVC) in untreated (Control) and antimicrobial-treated Nile tilapia fillets during refrigerated storage at 4±2 °C. The reference region at approximately 10^7 CFU/g is included to provide practical context for microbial deterioration and represents a microbiological indicator commonly associated with substantial quality deterioration in chilled fish; it should not be interpreted as a directly measured sensory rejection point in the present study

The delayed microbial proliferation observed in the treated fillets is consistent with previous studies demonstrating the antimicrobial effects of organic-acid-based interventions during refrigerated storage of fish. Marshall and Kim (1996) reported that lactic acid treatments suppressed aerobic microbial growth and prolonged the microbiological shelf life of refrigerated catfish fillets, although the magnitude of the effect depended on treatment concentration and exposure time. Similar preservation effects have been reported in refrigerated tilapia using lactic-acid-based technologies. More recently, Cai *et al*. (2024) demonstrated that plasma-activated lactic acid reduced total bacterial counts and other spoilage-associated bacterial groups in refrigerated tilapia fillets, resulting in an extension of microbiological shelf life relative to untreated fillets. Although the treatments and application methods used in these studies differ from those employed in the present study, their findings support the observed ability of lactic-acid-based antimicrobial interventions to retard microbial proliferation during refrigerated fish storage.

The greater inhibition of microbial proliferation observed in Treated 2 may be related to the combined antimicrobial effects of the treatment components. Previous work in refrigerated Nile tilapia has demonstrated that lactate-based treatments can influence microbial development during storage (Korel *et al*., 2001), supporting the use of organic-acid-based compounds as part of a preservation strategy. In the present study, Treated 2 additionally incorporated ethyl lauroyl arginate (ELA; E243), a broad-spectrum cationic antimicrobial that acts primarily through disruption of microbial cell membranes and has demonstrated antimicrobial activity across a range of food systems (Ma *et al*., 2023). The lower TVC observed in Treated 2 compared with Treated 1 and the Control is therefore consistent with a potential additional antimicrobial effect associated with the combined formulation. However, because the individual contribution of each treatment component was not evaluated independently, the greater inhibitory effect observed in Treated 2 cannot be attributed specifically to ELA and should instead be interpreted as the effect of the combined intervention.

Figure 3 highlights changes in colour, brightness, and overall appearance of tilapia during refrigerated storage in this trial. On Day 1, all fillets appeared similar in colour and freshness, with no visible differences between treatments.

By Day 10, the Treated 1 and Treated 2 samples retained a comparatively brighter and more uniform colour and fresher appearance, while the Control showed greater visible discolouration, deterioration and quality decline. Visual characteristics such as colour, surface appearance and lustre are also recognised as practical indicators of freshness and quality in tilapia (Stander, 2026). These observations are consistent with the slower microbial proliferation observed in the treated groups and suggest that delaying microbial deterioration may also contribute to the retention of desirable product quality characteristics during refrigerated storage. However, as colour and other sensory attributes were not assessed quantitatively or by formal sensory panel, these observations should be regarded as supportive visual evidence rather than confirmation of an extension in sensory shelf-life.

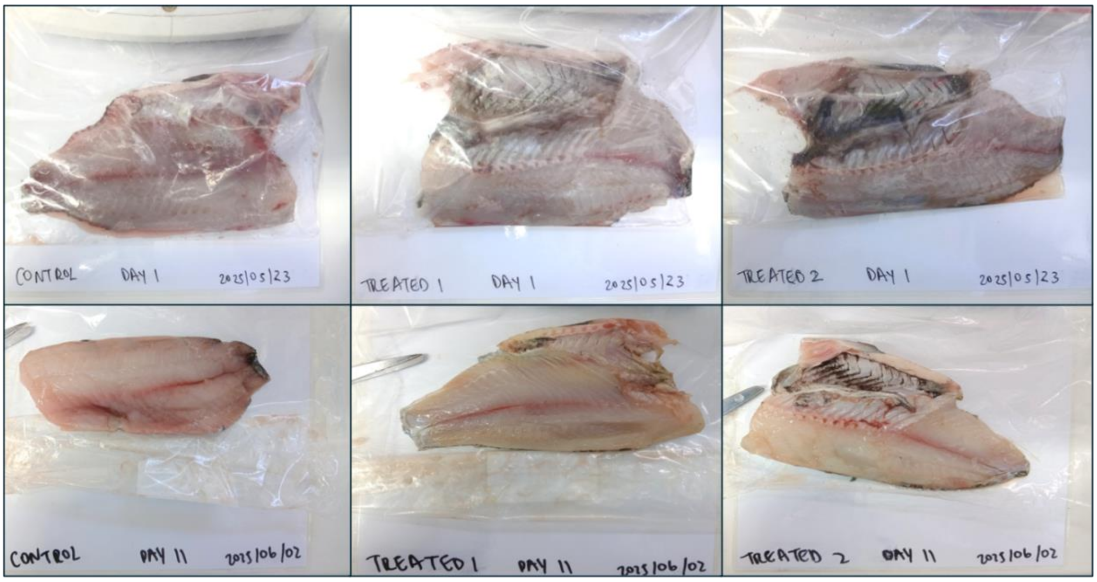

Figure 3: Visual comparison of tilapia fillets over time across treatment groups.

The findings of this study should be interpreted within the limitations of the experimental design. The trial was conducted as a preliminary evaluation of the antimicrobial interventions, and the number of biological replicates was limited. Furthermore, microbial quality was assessed primarily using total viable aerobic bacterial counts, while physicochemical and sensory quality attributes were not quantitatively evaluated. Consequently, although the observed TVC patterns and visual changes provide evidence that the treatments delayed microbial deterioration, the present findings should be regarded as preliminary evidence of microbiological shelf-life extension rather than confirmation of overall sensory shelf-life extension. Further studies incorporating greater biological replication, statistical evaluation, and complementary quality indicators such as sensory assessment, pH, instrumental colour measurements and/or established biochemical spoilage indices would provide a more comprehensive evaluation of treatment efficacy.

These findings suggest that the antimicrobial interventions (Savour Solutions™), particularly Treated 2, have potential to slow microbial deterioration and thereby extend the microbiological shelf-life of refrigerated tilapia. In practical application, such as interventions could provide an additional post-harvest preservation hurdle and, if effective under commercial production conditions, may contribute to reducing quality-related post-harvest losses. However, antimicrobial treatment should complement rather than replace established good handling practices, including hygienic processing, rapid chilling following harvest and maintenance of an uninterrupted cold chain. The integration of effective antimicrobial interventions with appropriate post-harvest management may therefore provide a practical approach to maintaining the quality of fresh tilapia during refrigerated storage.

Conclusion and recommendations

Savour Solutions™ antimicrobial interventions evaluated in this preliminary study delayed microbial proliferation in refrigerated Nile tilapia (*Oreochromis niloticus*) fillets during refrigerated storage. The Control group showed rapid bacterial growth, exceeding the spoilage threshold by Day 7, while Treated 1 delayed spoilage until approximately Day 9. Treated 2 demonstrated the strongest preservation effect, maintaining TVC levels below the microbiological reference level of 10^7 CFU/g throughout the 14-day trial. These findings indicate that the interventions, particularly Treated 2, have potential to extend the microbiological shelf-life of refrigerated tilapia. These findings are especially promising in the context of Sub-Saharan Africa's post-harvest fish losses**,** where spoilage leads to significant food waste and economic hardship.

Visual observations supported the microbial results, with Treated 1 and Treated 2 fillets retaining brighter colour and a more desirable overall appearance compared to the Control by Day 10. As sensory quality was not formally assessed, these visual observations should be considered supportive evidence of quality retention rather than confirmation of extended sensory shelf life.

The findings from this preliminary study warrant further investigation using greater biological replication and appropriate statistical analysis. A subsequent trial should also include organoleptic analysis and additional microbiological testing to confirm whether the observed delay in microbial proliferation is accompanied by extended sensory quality and overall product acceptability. Under commercial application, the Savour Solutions™ interventions should be considered complementary to appropriate hygienic handling, rapid chilling and maintenance of the cold chain.

This work lays the foundation for a practical, scalable solution **to** reduce losses and increase value across the fresh fish supply chain**.**

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