

THE IMPACT OF ELECTROLYZED WATER ON THE CHEMICAL PARAMETERS OF SALTED FISH (MOLOHA) AND ITS APPLICATION AS AN ANTIBACTERIAL AGENT AGAINST STAPH. AUREUS

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ABSTRACT

This study examined the antibacterial effectiveness and sensory effects of electrolyzed water (EW) treatments on *Staphylococcus aureus*, experimentally inoculated in a traditionally salted fish (Moloha) in Egypt. A reference strain (ATCC 6538) was used to inoculate samples at 1.0×10^4 CFU/mL. Three groups were evaluated, G1 (rinsing with tap water), G2 (washing with EW), and G3 (dipping in EW for 15 minutes). EW was prepared through electrolysis of 0.2% NaCl solution, producing slightly acidic and alkaline types. Physicochemical properties (salt %, pH, and histamine levels) and microbiological counts were measured throughout a 30-day storage period. Initial *S. aureus* levels were considerably decreased by 95% (1.30 log) with G2 and G3 treatments. Throughout storage, G3 continuously kept bacterial levels lower than G2, reducing them by 97.35% on day 1 and 91.82% on day 4. Physicochemical analysis revealed stable salt levels (average 15.2%) and safe pH (average 5.9), while EW-treated samples had slightly lower histamine levels. Using a 10-point hedonic scale for sensory evaluation, it was found that EW treatments, particularly G3, significantly enhanced color, texture, and odour at all times. G3 samples maintained high sensory scores (>7), indicating excellent quality, while G1 and G2 showed declines after 15 days. Overall, EW showed greater antibacterial and sensory preservation effects, especially when dipping. According to the study, EW is a successful non-chemical method for improving the quality and safety of salted fish (Moloha).

Key words: *Staphylococcus aureus*, Electrolyzed water, Histamine

INTRODUCTION

Staphylococcus aureus is a common foodborne pathogen known for its ability to produce heat-stable enterotoxins, posing a significant threat to food safety and public health, especially in protein-rich foods like fish (Kadariya *et al.*, 2014 & Parada Fabián

et al., 2025). Its persistence in food processing environments is attributed to its resilience under salt stress and its ability to survive desiccation, making it a critical concern in salted and fermented fish products (Argudín *et al.*, 2010 & Serrano *et al.*, 2025).

Moloha is a traditional Egyptian fermented and salted fish product, commonly prepared from freshwater fish species such as *Hydrocynus forskalii* (African tigerfish) (Farag *et al.*, 2022). It is popular in areas

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with inadequate cold-chain infrastructure because of its high salt content and low water activity, which allows it to be preserved for several months without refrigeration (Onaheid *et al.*, 2012; Ahmedou *et al.*, 2025). But because conventional preparation techniques frequently lack standardized sanitary controls, dangerous bacteria like *S. aureus* may be able to survive or become contaminated during or after fermentation (Niyigaba *et al.*, 2025).

Electrolyzed water (EW), which is generated through the electrolysis of a dilute saline solution, has emerged as a promising antimicrobial agent due to its high oxidative potential and non-toxic by-products (Tolba *et al.*, 2023). Depending on the pH and available chlorine concentration, it is typically divided into two categories: slightly acidic electrolyzed water (SAcEW) and slightly alkaline electrolyzed water (SAIEW) (Al-Haq *et al.*, 2002; Hricova *et al.*, 2008 & Shi *et al.*, 2024).

EW has demonstrated broad-spectrum antimicrobial activity against various foodborne pathogens, including *S. aureus*, by causing oxidative damage to microbial membranes and interfering with cellular metabolism (Issa-Zacharia *et al.*, 2010). Additionally, its use in seafood preservation has demonstrated encouraging outcomes in terms of increasing shelf life without degrading chemical or sensory quality (Adal *et al.*, 2024 & Rabiepour *et al.*, 2024).

Few studies have examined the effectiveness of EW in traditionally fermented salted fish like Moloha, despite its expanding use in the food industry. Furthermore, little is understood about how it affects important chemical quality indicators, such as pH, histamine production, and salt concentration, all of which are crucial in assessing the end product's acceptability and safety (Aliyu-A *et al.*, 2019; Mahmoud *et al.*, 2023). In addition to determining how well electrolyzed water works as an antibacterial

agent against *S. aureus* in lab-prepared Moloha, this study also sought to determine how it affected physicochemical metrics and sensory quality.

MATERIALS AND METHODS

1. Bacterial Strain

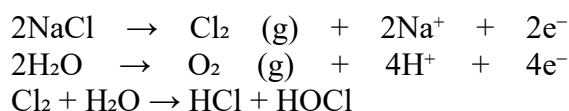
For this investigation, the reference bacterial strain, *Staphylococcus aureus* (NCTC 7447 / ATCC 6538), was acquired from the Animal Health Research Institute in Giza. Using the techniques outlined by the Clinical and Laboratory Standards Institute (CLSI, 2020), the strain was verified by morphological and biochemical traits.

2. Preparation of Electrolyzed Water (EW)

Electrolyzed water (EW), including slightly alkaline electrolyzed water (SAIEW, pH ~8.5) and slightly acidic electrolyzed water (SAcEW, pH ~6), was prepared following the method described by Al-Haq *et al.* (2002), Hricova *et al.* (2008), and Adal *et al.* (2024). Briefly, a 0.2% sodium chloride (NaCl) solution was prepared by dissolving 2 g of NaCl per liter of tap water. This solution underwent electrolysis in a chamber equipped with two electrodes—an anode (+) and a cathode (—) —at a voltage of 9–10 V and a current of 8–10 A for 10 minutes. Ion exchange between the compartments occurred via a salt bridge.

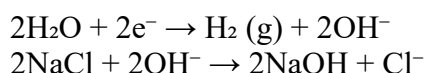
At the anode compartment, SAcEW was generated as a result of the formation of hypochlorous acid (HOCl), hypochlorite ions (OCl⁻), and chlorine gas (Cl₂) through the following reactions:

Anode reactions:



Meanwhile, at the cathode side, SAIEW was formed due to the generation of sodium hydroxide (NaOH):

Cathode reactions:



The pH of the generated EW solutions was measured using a calibrated digital pH meter (FSSAI, 2015). Each type of EW was subsequently used to produce crushed ice (EW-ice), which was applied in sample preservation throughout the experimental period (Tolba *et al.*, 2023).

3. Sample Preparation and Experimental Grouping

Moloha is a traditional Egyptian fermented-salted fish product, commonly prepared from freshwater species such as *Hydrocynus forskalii* (commonly known as African tigerfish). It is widely consumed, especially during festive seasons, due to its distinctive flavor and long shelf-life at ambient temperatures without refrigeration. In this study, Moloha was prepared under controlled laboratory conditions, mimicking conventional techniques. Thirty samples of Moloha were processed using whole fish (*Hydrocynus forskalii*), which were gutted, cleaned, and dry salted using coarse sodium chloride at a 1:1 weight ratio. The fish were then packed in sterilized containers and allowed to ferment and mature at $25 \pm 2^\circ\text{C}$ for a period of 21–30 days.

Following processing, the samples' physicochemical characteristics were examined. Effective preservation was confirmed by the salt level, which ranged from 10.8% to 19.6% with an average of 15.2%. The microbiological stability and safety for prolonged storage without refrigeration were shown by the mean pH value of 5.9 and the average water activity (a_w) of 0.900. These findings are consistent with other studies on fermented fish products that demonstrated that microbial growth is greatly inhibited by high salt concentrations and decreased water activity (Onaheid *et al.*, 2012; FAO, 1992; Ali *et al.*, 2019; Ahmedou *et al.*, 2025).

Laboratory-prepared salted fish samples were utilized as the experimental model. Samples were divided into three groups:

- **Negative control group (NC):** The samples had no bacterial inoculum and were cleaned with drinkable tap water.
- **Positive control group (G1):** Following a *S. aureus* inoculation at a concentration of 104 CFU/mL, the samples were rinsed with tap water.
- **Treatment group (G2):** Samples were inoculated with *S. aureus* at the same concentration (10^4 CFU/mL) and washed with freshly prepared electrolyzed water (EW), which was generated using a standard electrolysis system as described by Hricova *et al.* (2008) and Adal *et al.* (2024).
- **Treatment group (G3):** Samples were inoculated with *S. aureus* at the same concentration (10^4 CFU/mL) and dipped in freshly prepared electrolyzed water (EW) for 15 min., which was generated using a standard electrolysis system as described by Al-Haq *et al.* (2002)

All samples were stored under refrigerated conditions in their original packaging until visible spoilage indicators appeared.

4. Microbiological Analysis

Isolation and enumeration of *S. aureus* from all experimental groups were conducted weekly using Baird-Parker agar, following ISO 6888-1 (ISO, 2021). Colonies were counted and expressed as log CFU/g of fish tissue.

5. Physicochemical Analyses

All groups underwent the following analyses to determine how electrolyzed water affected the product's chemical characteristics:

- **Salt content** in tissues was determined by the Mohr titration method (AOAC, 2019).
- **pH value** was measured using a calibrated digital pH meter (FSSAI, 2015).

- **Histamine concentration** was quantified by high-performance liquid chromatography (HPLC) based on the methods described by Mahmoud *et al.* (2023).

6. Sensory Evaluation

Sensory assessment was carried out by a trained panel of 10 members using a 10-point hedonic scale to evaluate the following attributes: odor, texture, and color. Evaluations were conducted under controlled lighting and temperature conditions, according to the guidelines of Codex Alimentarius (CXG 31-1999) and Meilgaard *et al.* (2016). Sensory evaluations were conducted by a trained sensory panel composed of specialists from the Reference Laboratory, Animal Health Research Institute. The panel members possessed the required expertise to perform objective assessments in accordance with a standardized sensory evaluation protocol and the designated evaluation sheet criteria. In terms of overall acceptability, samples receiving a quality score between 7 and 10 were classified as having excellent quality. Scores ranging from 5 to 6 indicated good quality, while a score of 4 was considered borderline. Samples that received a score below 4 were deemed unacceptable, reflecting poor or very poor quality.

7. Statistical Analysis

All experimental data were analyzed in triplicate and expressed as mean $\pm$ standard deviation (Mean $\pm$ SD). Statistical analysis was performed using SPSS software, version 20. One-way analysis of variance (ANOVA) was employed to assess significant differences among treatment groups. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

Physicochemical analysis of the laboratory-prepared salted fish samples treated with

electrolyzed water (EW) revealed notable variations among the experimental groups in terms of salt content, pH, and histamine concentration. The negative control (NC), which was not inoculated with *S. aureus*, showed a salt concentration of 16.96%, a pH of 0.067, and a histamine content of 3.2 mg/100g. In the positive control group (G1), which was inoculated with *S. aureus* and washed with tap water, the salt content increased to 18.38%, with a corresponding rise in pH to 0.187 and a notable decrease in histamine levels to 2.18 mg/100g (**Table 1**).

Table 1: Physicochemical analyses of Laboratory-prepared salted fish samples were treated with EW

experimental group	Salt %	pH %	Histamine content
NC	16.96	0.067	3.2
G1	18.38	0.187	2.18
G2	16.18	0.08	8.7
G3	18.54	0.29	3.94

In contrast, Group 2 (G2), treated with EW by surface washing, exhibited a lower salt concentration (16.18%) and a slight increase in pH (0.08); however, this group showed the highest histamine content at 8.7 mg/100g, which could suggest insufficient microbial inhibition. Group 3 (G3), where samples were dipped in EW for 15 minutes, showed the highest salt content (18.54%) and the highest pH value (0.29), yet the histamine concentration was moderate at 3.94 mg/100g. These findings suggest that while EW dipping (G3) effectively maintained both salt levels and microbial safety as reflected by moderate histamine accumulation, simple washing with EW (G2) might be less effective in controlling histamine production despite maintaining near-baseline salt and pH levels (**Figure 1**).

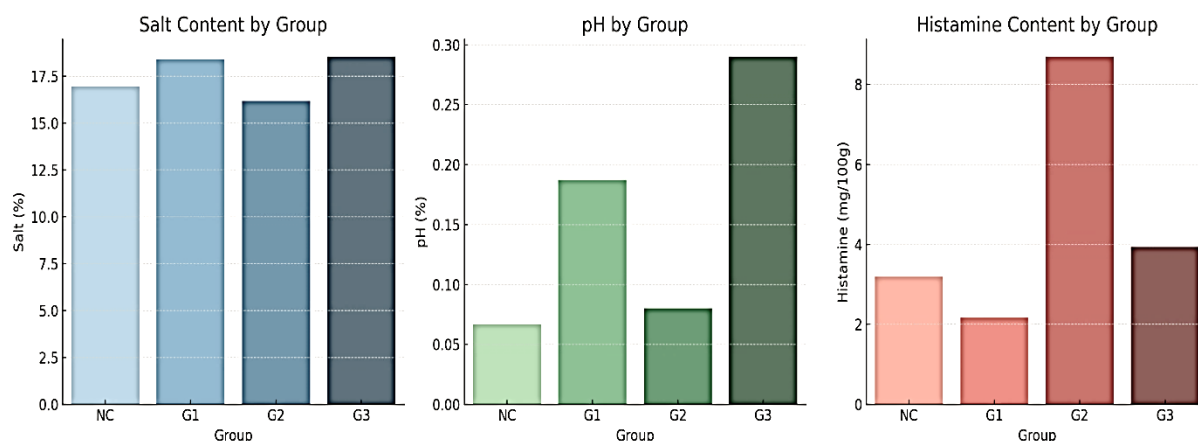


Figure 1: Physicochemical analyses of Laboratory-prepared salted fish samples were treated with EW

The artificially inoculated Moloha samples had an initial *Staphylococcus aureus* bacterial load of 1.0×10^4 CFU/mL. Following prompt treatment, the bacterial count was considerably decreased to 5.0×10^2 CFU/mL by both the electrolyzed water (EW) washing (G2) and the EW dipping for 15 minutes (G3), which represented a 1.30 log reduction (95% reduction) in comparison to the untreated group (G1).

Throughout the storage period, bacterial counts in the control group (G1), which was washed only with tap water, declined gradually from 6.8×10^3 CFU/mL on day 11 to 3.5×10^2 CFU/mL by day 7/8 (**Table 2**). This decline may be attributed to the high salt content and reduced water activity of the Moloha samples, which created an unfavorable environment for microbial growth.

On the other hand, at every time point, G2 and G3 continuously showed lower bacterial numbers than G1. Day 11 showed a 97.35% (1.58 log) drop for G3 and a 96.32% (1.43 log) reduction for G2.

It's interesting to note that on day 30, G3 had maintained a 30.43% decrease in bacterial counts, however G2 had slightly increased them in comparison to G1, indicating a -13.04% shift. This could indicate that the bacteria had regrown or had become resistant to exposure to EW.

Overall, EW treatment, especially prolonged dipping (G3), proved more effective than simple washing (G2) in reducing and sustaining lower levels of *S. aureus* on Moloha samples. The extended contact time with EW likely contributed to its superior antimicrobial efficacy over time.

Table 2: Initial and Post-Treatment Counts of *S. aureus* (CFU/mL) in Moloha Samples Immediately After Inoculation and Treatment with Tap Water (G1), Electrolyzed Water Washing (G2), and Electrolyzed Water Dipping for 15 Minutes (G3).

Time of storage	G1 (Tap Water)	G2 (EW Wash)	G3 (EW Dip 15 min)
2h	1.0×10^4	5.0×10^2	5.0×10^2
After 24h	6.8×10^3	2.5×10^2	1.8×10^2
4 th day	3.3×10^3	3.0×10^2	2.7×10^2
9 th day	4.0×10^2	2.7×10^2	1.9×10^2
14 th day	2.3×10^2	2.6×10^2	1.6×10^2
19 th day	3.5×10^2	—	—

G3 samples achieved the highest hedonic scores across all evaluated attributes, indicating superior sensory quality. The sensory evaluation of Moloha samples treated with electrolyzed water (EW)

reveals that prolonged dipping (G3) significantly enhances sensory attributes—odor, texture, and color—compared to tap water washing (G1) and brief EW washing (G2) (Figure 2).

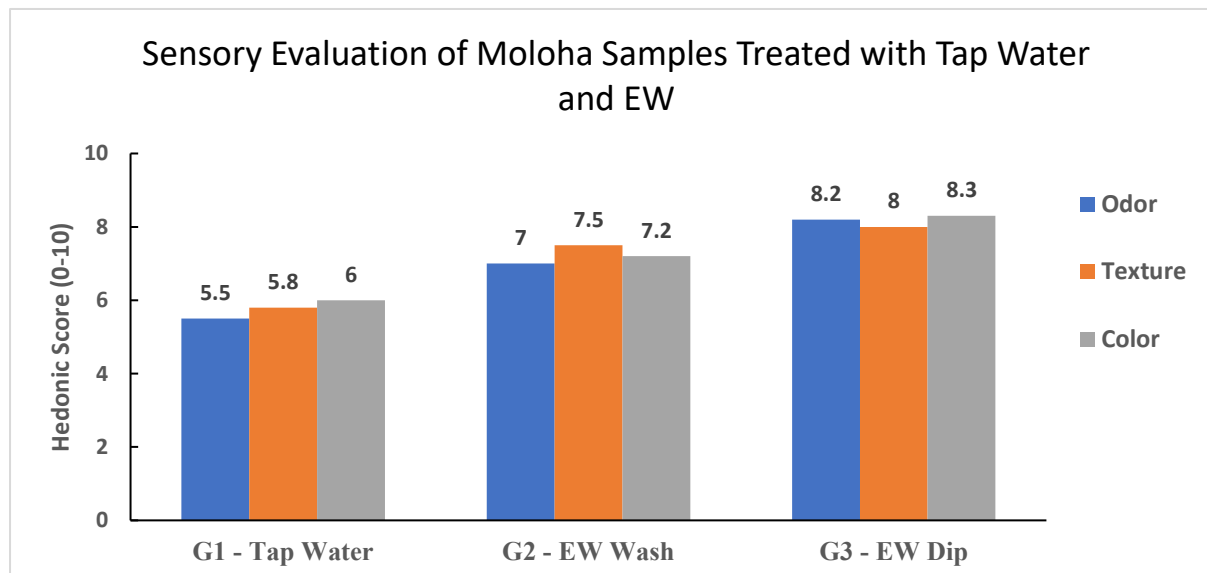


Figure 2: The average scores for odor, texture, and color of Moloha samples treated with tap water (G1), electrolyzed water washing (G2), and electrolyzed water dipping for 15 minutes (G3). G3 (EW dip) received the highest scores across all attributes, indicating superior sensory quality and overall acceptability.

Immediately after inoculation (Fresh), both G2 and G3 achieved a 95% reduction in bacterial load. After 24hs, G3 (dipping) achieved the highest reduction (97.35%, log 1.58), indicating enhanced efficacy of dipping compared to simple washing (G2). As storage progressed, antibacterial efficacy decreased, especially on 9th and

14th day, when G2 started showing minimal or negative impact, possibly due to bacterial regrowth or environmental adaptation. G3 consistently outperformed G2, especially in the first few weeks, showing that dipping in EW for 15 minutes is more effective than surface washing in reducing *S. aureus* (Table 3).

Table 3: Log Reductions & Percentage Reductions in *S. aureus* Count in Moloha Samples Treated with EW Washing (G2) and EW Dipping (G3) Relative to Tap Water Control (G1) Across the Storage Period.

Time of storage	G2 Log Reduction	G2 % Reduction	G3 Log Reduction	G3 % Reduction
2h	1.30	95.00%	1.30	95.00%
After 24h	1.43	96.32%	1.58	97.35%
4 th day	1.04	90.91%	1.09	91.82%
9 th day	0.17	32.50%	0.32	52.50%
14 th day	-0.05	-13.04%	0.16	30.43%
19 th day	—	—	—	—

DISCUSSION

Significant differences in salt content, pH, and histamine levels across treatment groups are revealed by physicochemical examination of laboratory-prepared salted fish samples treated with electrolyzed water (EW). Remarkably, Group 3 (G3) had the highest pH value (0.29) and salt content (18.54%) after dipping samples in EW for 15 minutes. They also had a moderate histamine concentration (3.94 mg/100g). However, Group 2 (G2), whose samples were cleaned with EW, had the lowest salt content (16.18%), the highest histamine concentration (8.7 mg/100g), and a slightly higher pH (0.08). The negative control (NC) and positive control (G1) groups both showed intermediate values; G1 had the lowest salt content (18.38%), pH (0.187), and histamine level (2.18 mg/100g). These results imply that the physicochemical characteristics of salted fish are strongly influenced by the EW application technique.

The extended exposure to EW may have contributed to the greater pH and salt content in G3, as it may have facilitated the absorption of alkaline and salt components into the fish tissue. Because EW has antibacterial qualities that prevent histamine-producing bacteria, the moderate histamine level in G3 suggests that prolonged EW treatment may aid in regulating histamine generation. On the other hand, G2's higher histamine concentration raises the possibility that washing with EW alone won't be enough to prevent histamine buildup, underscoring the significance of treatment time and technique.

The antimicrobial efficacy of EW is primarily due to the presence of hypochlorous acid (HOCl), which has been shown to effectively inactivate a broad spectrum of microorganisms by penetrating cell membranes and oxidizing vital cellular components (Phuvasate *et al.*, 2010;

Boecker *et al.*, 2023). The effectiveness of EW is influenced by factors such as pH, oxidation-reduction potential (ORP), and available chlorine concentration. Slightly acidic EW (pH 5.0–6.5) with high ORP and appropriate chlorine levels has demonstrated superior antimicrobial activity while maintaining the sensory qualities of food products (Zhang *et al.*, 2024; Luevanos-Aguilera, 2025).

In the context of fish preservation, the application of EW, particularly through dipping methods, has shown promise in reducing histamine-producing bacteria and controlling histamine levels, thereby enhancing the safety and shelf-life of fish products. However, the method and duration of EW treatment are critical factors that determine its effectiveness. Further research with replicated trials is necessary to statistically validate these observations and optimize EW treatment protocols for different fish products.

The antibacterial efficacy of electrolyzed water (EW) against *S. aureus* in Moloha samples was evaluated across different treatment methods and storage periods. The initial bacterial load (1.0×10^4 CFU/mL) was significantly reduced in both treatment groups—EW washing (G2) and EW dipping (G3)—to 5.0×10^2 CFU/mL immediately post-treatment. This corresponds to a 1.30 log reduction (95% reduction), indicating that EW exhibits strong immediate bactericidal action. Hricova *et al.* (2008) and Al-Haq *et al.* (2002) reported similar initial reductions (1–3 log) in *S. aureus* and *E. coli* using electrolyzed water on fresh produce and meat, emphasizing the immediate effectiveness of free chlorine species like hypochlorous acid (HOCl) in penetrating and disrupting bacterial cell membranes. These results are consistent with previous studies showing that electrolyzed oxidizing water (EOW), particularly in its slightly acidic form, disrupts bacterial membranes

and oxidizes intracellular components (Len *et al.*, 2002; Zhang *et al.*, 2024).

During storage, the bacterial count in the control group (G1) gradually declined, likely due to the high salt concentration and low water activity inherent to Moloha, which are known inhibitory factors for microbial growth (FAO, 1992; Ahmedou *et al.*, 2025). However, this reduction was slower and less consistent compared to the EW-treated groups. On the 24th hour, G3 demonstrated superior efficacy (1.58 log reduction, 97.35%), compared to G2 (1.43 log, 96.32%). This difference, though slight, underscores the impact of prolonged contact time on EW's antimicrobial action, as HOCl in EW requires sufficient time to penetrate and inactivate bacterial cells (Hricova *et al.*, 2008; Poçan, & Karakaya, 2025).

By day 4, reductions in bacterial counts persisted, with G3 showing a 1.09 log (91.82%) reduction versus G2's 1.04 log (90.91%). However, by the 9th and 14th days, the efficacy of both treatments declined. G3 still maintained a notable advantage (52.5% reduction on day 9 and 30.43% on day 14), while G2's reduction was minimal or even reversed by day 14 (–13.04%), suggesting possible bacterial regrowth or the development of resistance due to sublethal stress from insufficient EW exposure time (Rahman and Lamsal, 2023).

These findings reinforce the importance of treatment duration when using EW for bacterial decontamination. Dipping allows more extensive exposure to active chlorine species like HOCl, enhancing microbial inactivation. This is particularly significant for fermented or salted products like Moloha, where surface contamination with pathogens such as *S. aureus* poses a food safety risk. While EW washing is convenient, its transient contact may not sustain bactericidal effects over prolonged storage (Zhang *et al.*, 2024; Rahman and Lamsal, 2023). Few studies specifically address fermented or salted fish. However,

Ahmedou *et al.*, (2025) and Onaheid *et al.* (2012) found that high salt levels in traditional fish products inhibited microbial growth, much like what you observed in G1 over time.

In conclusion, prolonged EW dipping (G3) was more effective than washing (G2) in reducing and maintaining low levels of *S. aureus* in Moloha. This suggests that EW, particularly when used with extended exposure, could be a viable non-thermal decontamination method for traditional salted fish, enhancing safety without compromising product integrity.

The sensory analysis of electrolyzed water (EW)-treated Moloha samples shows that, in contrast to tap water washing (G1) and short EW washing (G2), extended dipping (G3) dramatically improves sensory qualities—odor, texture, and color. This is consistent with the results of earlier research on the use of EW in seafood preservation.

In the current study, G3 samples achieved the highest hedonic scores across all evaluated attributes, indicating superior sensory quality. The extended contact time with EW likely contributed to the improved preservation of sensory characteristics.

Similar outcomes have been reported in studies involving EW treatments on various seafood products. For instance, Li *et al.* (2020) observed that SAEW treatments effectively maintained the sensory quality of farmed puffer fish during cold storage, preserving attributes such as odor and texture over time. Additionally, research on sea bass fillets demonstrated that SAEW treatments, especially when combined with ultrasound, significantly slowed the decline in sensory scores during refrigerated storage.

These studies support the notion that EW treatments, particularly with extended exposure times, can effectively preserve the

sensory qualities of seafood products, aligning with the findings observed in the Moloha samples.

The enhanced sensory attributes observed in G3 samples underscore the efficacy of prolonged EW dipping in preserving the quality of Moloha. These findings are consistent with previous research, suggesting that EW treatments can be a valuable method for maintaining the sensory integrity of seafood products during storage.

CONCLUSION

In order to control *S. aureus* contamination in Moloha salted fish, this study showed the antibacterial effectiveness and preservation potential of EW, especially slightly acidic and slightly alkaline EW. The application of EW significantly reduced the initial bacterial load, with both washing (G2) and dipping (G3) treatments achieving a 95% (1.30 log) reduction immediately following inoculation. Throughout the 30-day storage period, the dipping treatment (G3) consistently outperformed the washing technique (G2), maintaining higher levels of bacterial inhibition, particularly in the early and mid-storage phases.

Physicochemical analyses confirmed that EW treatment preserved the quality of Moloha, with treated groups showing slightly lower pH and histamine levels, alongside higher salt percentages. These parameters contribute to creating unfavorable environments for bacterial survival and growth, enhancing food safety and shelf life.

Moreover, sensory evaluation revealed that EW treatments had a positive effect on the organoleptic properties of Moloha. G3, the EW dipping group, scored highest in odor, texture, and color across all evaluation time points, maintaining better overall acceptability than the other groups. This indicates that prolonged exposure to EW

not only reduces microbial risk but also preserves product quality, aligning with consumer preferences.

The use of EW, especially via dipping, offers an effective, eco-friendly, and safe method to enhance the microbial safety and sensory quality of traditional foods like Moloha, and may be recommended for broader application in food processing and preservation systems.

CONFLICT OF INTEREST:

No

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تأثير الماء المحلل كهربائياً على المعايير الكيميائية للأسماك المملحة (الملوحة) واستخدامه كمضاد للبكتيريا ضد المكورات العنقودية الذهبية

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هدفت هذه الدراسة إلى تقييم الفعالية المضادة للبكتيريا والمظهر الحسي لمعاملة أسماك الملوحة المصرية التقليدية (Moloha) بماء الإلكتروليت/ المحلل الكهربائي (Electrolyzed Water – EW) بعد تلويثها تجريبياً ببكتيريا المكورات العنقودية الذهبية المرجع (ATCC 6538) بتركيز ابتدائي 1.0×10^4 CFU/mL. تم تقسيم العينات إلى ثلاث مجموعات: G1 (غُسلت بماء الصنبور)، G2 (غُسلت بماء الإلكتروليت)، و G3 (ثُقت في ماء الإلكتروليت لمدة 15 دقيقة). تم تحضير ماء الإلكتروليت عن طريق تحليل محلول كلوريد الصوديوم (0.2%) باستخدام خلية تحليل كهربائي، لإنتاج نوعين: ماء إلكتروليتي حمضي قليلاً وآخر قلوي قليلاً.

أظهرت النتائج أن المعالجة بماء الإلكتروليت قللت عدد البكتيريا فوراً بنسبة 95% (1.30 لوغ). واحتفظت مجموعة G3 (النقع) بتقليل أكبر في الحمل البكتيري خلال فترة التخزين مقارنةً بـ G2، حيث حققت تقليلاً بنسبة 97.35% في اليوم الأول و 91.82% في اليوم الرابع. في اليوم 30، استمرت G3 في تقليل العدوى بنسبة 30.43%، بينما أظهرت G2 زيادة طفيفة في العدوى (13.04%). فيما يخص الخواص الفيزيائية والكيميائية، أظهرت العينات مستويات ملح مستقرة (متوسط 15.2%)، ودرجة حموضة آمنة (متوسط 5.9)، ومستويات منخفضة نسبياً من الهستامين في العينات المعالجة. أظهرت التقييمات الحسية (الرائحة، الملمس، اللون) أن G3 حافظت على جودة عالية (>7 درجات)، بينما تراجعت G1 و G2 بعد الأسبوع الثاني.

تستخلص النتائج إلى أن ماء الإلكتروليت، خصوصاً عند استخدامه بطريقة النقع، يُعد وسيلة فعالة وأمنة لتحسين جودة وسلامة المنتجات السمكية المخمرة مثل الملوحة، دون اللجوء إلى مواد كيميائية.