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Effect of Garlic and Coriander Essential Oils on Quality Parameters of *Oreochromis niloticus* Fillets

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Abstract

The study was assumed to verify the effect of garlic and coriander essential oils on quality parameters of fish. Deteriorative changes of fish could be occurred directly after catching, thus Seventy-five *Oreochromis niloticus* (*O. niloticus*) (150 fillet samples) were divided into five groups, with the control group being dipped in sterile distilled water, the second and third groups being dipped in garlic essential oil (GEO) 1% (w/v) and 2%, and the fourth and fifth groups being dipped in coriander essential oil (CEO) 1% (w/v) and 2%, respectively. On the sixth day of storage, the sensory analysis revealed that all treated groups were considerably ($P < 0.05$) greater than the control. The initial pH value for all group were 6.02±0.01 while on the 6th day of chilling was 6.48±0.02, 6.24±0.04, 6.13±0.03, 6.31±0.01, and 6.19±0.04 in control, GEO 1%, GEO 2%, CEO 1% and CEO 2%, respectively. The Trimethylamine (TMA-N) mean values on the 6th day were 10.16± 0.21 , 6.11±0.14, 3.91±0.10, 7.12±0.12, and 4.26±0.14 mg N/100 g in control GEO 1%, GEO 2%, CEO 1% and CEO 2%, respectively. On the third and sixth days of storage, thiobarbituric acid (TBA) in the control group was substantially greater than in the treatment groups ($p < 0.05$). The initial counts of *Staphylococcus* were 5.24±0.32 $\log_{10}$ CFU/g in the control and were reduced to 4.02±0.18, 3.22±0.13, 4.13±0.16 and 3.35±0.18 $\log_{10}$ CFU/g in GEO 1%, GEO 2%, CEO 1% and CEO 2%, respectively on the 6th day of chilling. The *Pseudomonas* counts significantly reduced ($p < 0.05$) on the 3rd and 6th day of chilling in all treated groups in comparison with the control group. Therefore, Garlic and coriander essential oils have the ability to enhance sensory, delay spoilage parameters, reduce bacterial load in cold stored *O. niloticus* fillet in addition to prolong the shelf life.

KEYWORDS
Oreochromis niloticus, Garlic essential oil, Coriander essential oil, Thiobarbituric acid, *Pseudomonas*, *Staphylococcus*

INTRODUCTION

Fish is regarded as one of the most valuable foods since it gives Egyptians access to animal protein with a high biological value while simultaneously addressing the issue of a lack of animal flesh (Hussein *et al*., 2022). However, the availability of these vital nutrients is determined by the storage methods used (Verbeke *et al*., 2005). Fish is a perishable food, and losses after harvest can occur for a variety of reasons, including bacterial and autolytic degradation. These causes lead fish to lose their organoleptic qualities, rendering them unfit for human eating (Hussein *et al*., 2019). Furthermore, contamination with various types of food poisoning bacteria affects consumer health (Ahmed *et al*., 2013). Chemical preservatives have proven to be quite effective in preventing rancidity and microbiological development. However, synthetic antioxidants and chemical preservatives have repeatedly been linked to specific health issues. Due to this, the management of fish rotting parameters in storage has required the use of natural antimicrobials and antioxidants, such as the essential oils of specific spices. Garlic, coriander, onion, rosemary, and thyme are examples of spices that are bacteriostatic, antiseptic and antioxidant plant elements. They are used as spices and flavor enhancers, and they are also added to meals to prevent the beginning of degradation, such as rancidity (Abdel-Hamied *et al*., 2009). One of the common spices used to enhance the flavor of fish is garlic (*Allium sativum*), a popular medicinal herb that has some health advantages, including lowering the risk of contracting food-borne illnesses (Sherman and Billing, 1999). Garlic (*Allium sativum*), a popular medicinal herb with several health benefits, including lessening the risk of developing food-borne illnesses, is one of the primary spices used to improve the flavor of fish (Gafar *et al*., 2012). Coriander (*Coriandrum sativum*) contains a group of bioactive aliphatic polyacetylenes and has been demonstrated to be particularly harmful to bacterial and fungal cells. These synthetic compounds of coriander are utilized as antioxidants and used in a variety of pharmaceutical formulations for the treatment of a variety of illnesses, particularly in the digestive system (Claudiu-Nicolae and Maria-Mihaela, 2009). The study was planned to evaluate the effect of dip treatments by two essential oils on the quality of *O. niloticus* fillets during refrigerated storage at 3±1°C.

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MATERIALS AND METHODS

Samples collection

Seventy-five *O. niloticus* fish (400-500 g) were caught recently and split longitudinally into two halves by cutting from the head to the tail region, then eviscerated and washed. There were five groups created from the fillets.: sterilized distilled water was used to dip the control group, the second and third groups were dipped in garlic essential oil (GEO) 1% (w/v) and 2%, respectively, and the fourth and fifth groups were dipped in coriander essential oil (CEO) 1% (w/v) and 2%, respectively. After dipping, the groups were sieved for 30 minutes at 3±1oC before being individually packed in Ziplock bags and stored at 3±1oC for subsequent analysis.

Sensory evaluation

Ten-person internal consumer panel to evaluate the organoleptic qualities of the fish samples, including appearance, juiciness, saltiness, rancidity, flavor, and general acceptability. A hedonic scale of nine points was used, with nine denoting extreme like and one denoting extreme dislike (Carbonell *et al*., 2002). The samples were cleaned with water for one minute, covered in aluminum foil, baked for 30 minutes at 80°C, and then allowed to cool at room temperature before being shown to the panelists.

Physicochemical analysis

Estimation of pH values in fish fillets was carried out by using the Hanna pH meter model 8014 (Pearson, 1976). According to Özer *et al*. (2012) and Nielsen (2003), the trimethylamine (TMA-N) and TBA were determined.

Bacteriological parameters

Fish fillet samples weighed 25 g and homogenized for 1 min in a laboratory blender (type Moulinex made in France) containing 225 ml of 0.1% sterile peptone water (Oxoid Canada CM0009) and serial was made up to 107 according to APHA (2001). According to ISO 6888-1 (1999), the *Staphylococcus* count method was used simply put, 0.1 mL of each of the produced dilutions was applied to duplicate plates of Baird Parker (BP) agar (Oxoid Canada CM 275), supplemented with egg yolk tellurite emulsion (50 mL/L, Oxoid SR54), and then incubated at 37°C for 24-48 h. On the *Pseudomonas* agar basis (Oxoid Canada CM 559; supplemented with cetrimide, fucidin, and cephaloridine supplements), *Pseudomonas* counts were performed following ISO 13720:(2010). (SR 103; Oxoid, Basingstoke, Hampshire, United Kingdom). After 48 hours of incubation at 25°C, *Pseudomonas* colonies were counted.

Statistical analysis

One-way analysis of variance was used to analyze the data on sensory evaluation, pH, TMA-N, TBA, and bacterial counts. The post hoc Duncan's test was then used to compare bacterial counts and values of chemical parameters between various fish species. (IBM SPSS Statistics, version 22). At ($P<0.05$), the test was significant. *Pseudomonas* count and *Staphylococcus* count data were represented as an average of log-standard deviation. (SD).

RESULTS

The results of sensory analysis for the *O. niloticus* fillets were presented in Table 1. In the fresh fillet samples (day 0), the application of post hoc Duncan's sensory evaluation gave a significantly lower score ($P \leq 0.05$) for GEO 2% in comparison with control and CEO-treated samples. By the 3rd and 6th day, the general acceptability was 6.24±0.21 and 4.27±0.23, respectively. On the sixth day of storage, all treatment groups had significantly greater levels ($P < 0.05$) than the control group. The results in Table 2 show that there were no differences between all examined groups at zero time with initial values of 6.02±0.01. Meanwhile, significant differences were obtained ($P \leq 0.05$) on the 3rd and 6th days of chilling. A gradual increase in pH values was observed in all groups as the storage time increased with a sig-

Table 1. Effect of garlic and coriander essential oils on overall acceptability during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n.=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	8.22±0.24^{a}	7.14±0.22^{b}	6.94±0.25^{b}	8.26±0.26^{a}	8.14±0.26^{a}
3rd day	6.24±0.21^{b}	7.15±0.21^{ab}	7.10±0.22^{ab}	7.99±0.26^{a}	7.74±0.24^{ab}
6th day	4.27±0.23^{b}	7.13±0.22^{a}	7.15±0.21^{a}	7.16±0.22^{a}	7.16±0.21^{a}
9th day	Unacceptable	5.95±0.15	6.52±0.18	6.63±0.15	6.87±0.14
12th day	Unacceptable	4.26±0.16^{b}	5.67±0.14^{a}	4.37±0.12^{b}	6.64±0.13^{a}
15th day	Unacceptable	Unacceptable	4.92±0.14	Unacceptable	5.13±0.16

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

Table 2. Effect of garlic and coriander essential oils on pH during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	6.02±0.01^{a}	6.02±0.01^{a}	6.02±0.01^{a}	6.02±0.01^{a}	6.02±0.01^{a}
3rd day	6.36±0.05^{a}	6.13±0.05^{c}	6.08±0.04^{c}	6.22±0.05^{b}	6.15±0.05^{c}
6th day	6.48±0.02^{a}	6.24±0.04^{b}	6.13±0.03^{c}	6.31±0.01^{b}	6.19±0.04^{bc}
9th day	Unacceptable	6.36±0.05^{a}	6.28±0.04^{c}	6.39±0.04^{a}	6.38±0.05^{b}
12th day	Unacceptable	6.49±0.01^{a}	6.33±0.02^{c}	6.48±0.03^{a}	6.41±0.03^{b}
15th day	Unacceptable	Unacceptable	6.52±0.10	Unacceptable	6.55±0.10

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

nificant ($p < 0.05$) decrease in pH values of high-concentration treated samples (GEO 2% and CEO 2%) compared to the control group on the 6th day of the storage period. The CEO 2% treated group achieved the lowest pH value of 6.72±0.10 on the 15th day of storage. The mean value TMA-N at zero days ranged from 0.86±0.01 to 0.90±0.01mg N/100 g. This indicates the high quality of the *O. niloticus* fillet used in the experiment. At zero-day, there were no differences between the control and treated samples that were significant ($P<0.05$) Table 3. A gradual increase in TMA-N values with increasing storage time. On the 3rd and 6th day, the control group 6.18±0.45 and 10.16±0.21 significantly higher ($p < 0.05$) than 3.74±0.13 and 6.11±0.14, 2.20±0.10 and 3.91±0.10, 3.82±0.11 and 7.12±0.12, 2.54±0.10 and 4.26±0.14 mg N/100 g in GEO 1%, GEO 2%, CEO 1% and CEO 2%, respectively. According to the data in Table 4, the initial mean value of TBA. TBA in *O. niloticus* fillet was 0.54±0.01 mg MAD/kg at zero time. On the 3rd and 6th days of storage, gradual increases were observed in control and all treated groups as storage time increased. Furthermore, the control group achieved 2.70±0.20 and 4.29±0.01mg MAD/kg which differed significantly higher ($p < 0.05$) than 1.98±0.12 and 2.76±0.12, 1.80±0.10 and 2.14±0.09, 2.11±0.12 and 2.94±0.13, 1.95±0.10 and 2.64±0.12 for GEO 1%, GEO 2%, CEO 1% and CEO 2% on the 3rd and 6th day of storage, respectively. The recorded results in Table 5 declared that *Staphylococcus* count at zero time had no significant differences ($P< 0.05$) between the examined groups at zero days. Gradual increases in *Staphylococcus* count in all examined groups as the storage time increased with a significant ($p<0.05$) increase in the control group than all treated groups on the 3rd and 6th day of storage. The obtained results in Table 6 declared that *Pseudomo-*

Table 3. Effect of garlic and coriander essential oils on trimethylamine TMA-N mg N/100g during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	0.90±0.01^{a}	0.89±0.01^{a}	0.87±0.01^{a}	0.88±0.01^{a}	0.86±0.01^{a}
3rd day	6.18±0.45^{a}	3.74±0.13^{b}	2.20±0.10^{b}	3.82±0.11^{b}	2.54±0.10^{bc}
6th day	10.16±0.21^{a}	6.11±0.14^{b}	3.91±0.10^{c}	7.12±0.12^{b}	4.26±0.14^{c}
9th day	Unacceptable	8.36±0.16^{a}	5.60±0.10^{b}	8.72±0.20^{a}	5.91±0.12^{b}
12th day	Unacceptable	9.87±0.14^{a}	7.12±0.13^{b}	10.38±0.16^{a}	8.23±0.13^{b}
15th day	Unacceptable	Unacceptable	9.52±0.20	Unacceptable	10.28±0.19

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

Table 4. Effect of garlic and coriander essential oils on thiobarbituric acid TBA mg MAD/kg during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	0.54±0.01	0.54±0.01	0.54±0.01	0.54±0.01	0.54±0.01
3rd day	2.70±0.20^{a}	1.98±0.12^{b}	1.80±0.10^{b}	2.11±0.12^{ab}	1.95±0.10^{b}
6th day	4.29±0.01^{a}	2.76±0.12^{b}	2.14±0.09^{c}	2.94 ±0.13^{b}	2.64±0.12^{b}
9th day	Unacceptable	3.88±0.13^{a}	3.06±0.11^{b}	4.08±0.15^{a}	3.17±0.18^{b}
12th day	Unacceptable	4.36±0.17^{a}	3.96±0.12^{b}	4.68±0.14^{a}	3.98±0.17^{b}
15th day	Unacceptable	Unacceptable	4.10±0.10	Unacceptable	4.25±0.16

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

Table 5. Effect of garlic and coriander essential oils on *Staphylococcus* count $\log_{10}$ CFU/g during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	2.89±0.12	2.82±0.11	2.75±0.19	2.85±0.16	2.79±0.11
3rd day	4.10±0.18^{a}	3.11±0.15^{b}	2.94±0.17^{b}	3.32±0.17^{ab}	3.08±0.13^{b}
6th day	5.24±0.32^{a}	4.02±0.18^{b}	3.22±0.13^{c}	4.13 ±0.16^{b}	3.35±0.18^{bc}
9th day	Unacceptable	4.28±0.26	3.92±0.21	4.42±0.23	4.03±0.21
12th day	Unacceptable	5.04±0.27^{a}	4.11±0.26^{b}	5.22±0.27^{a}	4.26±0.23^{ab}
15th day	Unacceptable	Unacceptable	4.82 ±0.28	Unacceptable	4.92±0.27

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

Table 6. Effect of garlic and coriander essential oils on *Pseudomonas* count $\log_{10}$ CFU/g during chilled storage of *Oreochromis niloticus* fillets at 3±1ºC (n=5).

Chilling days	Control group	GEO 1%	GEO 2%	CEO 1%	CEO 2%
Zero day	2.66±0.12	2.10±0.11	<2	2.26±0.11	2.08±0.10
3rd day	3.98±0.17^{a}	2.88±0.12^{b}	2.24±0.11^{b}	3.12±0.13^{ab}	2.49±0.12^{b}
6th day	4.87±0.32^{a}	3.79±0.16^{b}	3.04±0.14^{c}	3.92 ±0.15^{b}	3.32±0.14^{bc}
9th day	Unacceptable	4.18±0.21^{a}	3.67±0.19^{b}	4.31±0.18^{a}	3.82±0.21^{ab}
12th day	Unacceptable	4.95±0.23^{a}	3.99±0.21^{b}	5.06±0.18^{a}	4.14±0.22^{ab}
15th day	Unacceptable	Unacceptable	4.84 ±0.24	Unacceptable	5.11±0.23

Means carrying different superscript letter on the same row (^{a,b,c}) are significantly different ($P < 0.05$). Results presented as means± standard error.

nas count ranged from < 2 in CEO 2% to 2.66±0.12 log_{10}CFU/g in control

DISCUSSION

The sensory assessment of food products before any food processing technology is crucial in assessing their acceptability to consumers. Any food's flavor and taste can be dramatically enhanced by using essential oils. Additionally, these materials have antioxidant and antibacterial properties ((ÖZKAN *et al*., 2004). The *O. niloticus* fillet's flavor and general acceptability were impacted as the storage times rose in all samples, particularly the control group. This may be attributable to an increase in lipid oxidation. Different compounds are created by lipid oxidation, some of which have disagreeable flavors and odors. Cold-water fish were found to benefit from the organoleptic enhancement of garlic essential oils (Nahid *et al*., 2014). Furthermore, coriander essential oil may have reduced the changes in the sensory score of stored fish (Kuzgun *et al*., 2020). The unacceptable sensory character was recorded from the 9th day in the control groups but for GEO 1% and CEO, 1% unacceptability was recorded on the 15th day of storage. The acceptable groups on the 15th day of storage were GEO 2% and CEO 2% with general acceptability scores of 4.92±0.14 and 5.13±0.16, respectively.

Fish have an average pH of about 7.3 when they are alive, but this value sharply decreases after death as a result of rigor mortis and the conversion of glycogen to lactic acid (Kelly *et al*., 1966). The postmortem pH is typically between 6.0 and 6.8, rising again with deterioration in the majority of species (Khalafalla *et al*., 2015). The pH levels at day 0 of cold storage yielded similar results of Sallam *et al*. (2007), while Hernández *et al*. (2009), Gandotra *et al*. (2012), Asik and Candogan (2014) obtained higher pH values. Lower results were obtained by Dergal *et al*. (2013) on tilapia fish fillets. The species, nutrition, season, level of stress experienced during the catch, and type of muscle may all be contributing factors to the initial pH readings being different from those reported in other research (Khalafalla *et al*. 2015). The acceptability of *O. niloticus* fillets was up to the 6th day (control), 12th day (GEO 1% and CEO 1%), and 15th day (GEO 2% and CEO 2%) according to the acceptable range of Egyptian standards (ES, 2005) below 6.5. A rise in volatile bases like ammonia produced by the enzymatic breakdown of the fish muscles by microbial or muscular enzymes could be the cause of the higher pH values of the control and low concentration treated samples GEO 1% and CEO 1% (Li *et al*., 2012; Ruiz-Capillas and Moral, 2001). Additionally, Sikorski *et al*. (1990) found that fluctuations in pH were caused by the release of inorganic phosphate and ammonia as a result of the enzymatic breakdown of ATP.

The mean value TMA-N at zero days ranged from 0.86±0.01 to 0.90±0.01mg N/100 g. This indicates the high quality of the *O. niloticus* fillet used in the experiment. The control group on the 6th day of storage nearly exceeded the maximum permissible limit of 10 mg N /100 g recorded by ES (2005). Meanwhile, the GEO 2% and CEO 2% groups on the 15th day of storage were 9.52±0.20 and 10.28±0.19 mg N/100, respectively. An important spoiling index is TMA-N, especially for marine fishes. Trimethyl amine oxide (TMAO), which is essential for osmoregulation in marine fish, is the source of TMA-N. Enzymes reduce TMAO to TMA during spoiled food (Kilinc *et al*. 2008). The increase in TMA-N is due to that After the fish is caught, a variety of proteolytic enzymes are discovered in the muscle and viscera. During storage and processing, these enzymes aid in the post-mortem breakdown of fish muscle and fish products. The presence of garlic or coriander essential oils retards microbial growth, which results in the reduction of TMA-N levels in treated groups.

Thiobarbituric acid (TBA) is frequently employed as a gauge for the extent of lipid oxidation, which can modify the flavor, color, and odor of fish products as well as their texture. The partial dryness of fish during refrigerated storage and the enhanced oxidation of unsaturated fatty acids may be to blame for the rise in TBA value (Mendes *et al*., 2008). Regardless of the increasing pattern in the TBA in all examined groups, the TBA values were much lower than the maximum permissible value (4.5 mg malondialdehyde /kg fish flesh) as recommended by ES (2005) for chilled fish on the 6th day of storage. The antioxidant effect of garlic essential oil in this study agreed with Babatunde and Adewumi (2015), and El-Sherif and Abd El-Ghafour (2016). Whereas the antioxidant activity of coriander essential oil as a natural inhibitor against oxidative rancidity; these findings coincided with results obtained by Viuda–Martos *et al*. (2011) and Kuzgun *et al*. (2020).

Staphylococcus count is considered an essential index of fish processing hygiene. The counts of *Staphylococcus* reduced under the effect GEO 1% and 2% due to the presence of allicin, the main biologically active component of garlic that functions as a broad-spectrum antibiotic and can prevent a variety of infections (Benkeblia, 2004). The effect of CEO 1% and 2% due to the presence of Linalool, camphor, linalyl acetate, phellandrene, α -pinene, p -cymene, geranyl acetate, γ -terpinene, α -cedrene, citronellal, cis -dihydro carvone which poses antibacterial properties in contradiction of both Gram +ve and Gram -ve bacteria (Aelenei *et al*., 2019).

Pseudomonads are a useful fish spoilage indicator for fish deterioration. Additionally, *Pseudomonas* spp. makeup practically the whole microbial population of fish maintained aerobically under chilling conditions (Gram and Huss, 1996). The initial *Pseudomonas* count agreed with Hussein *et al*. (2019); li *et al*. (2016), and Angiş and Oğuzhan (2013). Meanwhile, inferior values were obtained by Khalafalla *et al*. (2015). The *Pseudomonas* population decreased with increasing of the essential oil concentration and the best effect related to GEO 2% the count was 4.84 ±0.24 log_{10}CFU/g in comparison to 5.11±0.23 log_{10}CFU/g for CEO 2% on the 15th day of storage. The effect of GEO in this study is supported by the finding of Smyth *et al*. (2010) who found the great effect of garlic on *Pseudomonas aeruginosa*. Diallyl disulfide, a component of garlic oil, may also have the ability to reduce *Pseudomonas aeruginosa* pyocyanin and elastase synthesis as well as swarming motility and biofilm formation (Li *et al*., 2018). The previously documented antibacterial effects of coriander essential oil on *Pseudomonas aeruginosa* (Aelenei *et al*., 2019).

CONCLUSION

Garlic and coriander essential oils can enhance sensory, delay spoilage parameters, and reduce bacterial load in cold stored *O. niloticus* fillet in addition to prolonging the shelf life.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Abdel-Hamied, A.A., Nassar, A.G.,El-Badry, N., 2009. Investigations of antioxidant and antibacterial activities of some natural extracts. World J. Dairy Food Sci. 4, 1-7.

Aelenei, P., Rimbu, C.M., Guguianu, E., Dimitriu, G., Aprotosoaie, A.C., Brebu, M., Horhogea, C.E. ,Miron, A., 2019. Coriander essential oil and linalool - interactions with antibiotics against Gram-positive and Gram-negative bacteria. Lett. Appl. Microbiol. 68, 156-164.

Ahmed, H.A., Hussein, M.A., El-Ashram, A.M., 2013. Some zoonotic bacteria in Zagazig, Egypt, with the molecular detection of Listeria monocytogenes virulence genes. Vet. Ita. 49, 299-308.

Angiş, S., Oğuzhan, P., 2013. Effect of thyme essential oil and packaging treatments on chemical and microbiological properties of fresh rainbow trout (Oncorhynchus mykiss) fillets during storage at refrigerator temperatures. Afr. J. Microbiol. Res. 7, 1136-1143.

APHA (American Public Health Association), 2001. Compendium of Methods for the Microbiological Examination of foods (4thEd.) APHA Technical Committee on Microbiological Methods for foods. Washington, D.C., USA.

APHA (American Public Health Association), 2001. Compendium of Methods for the Microbiological Examination of Foods (4 Ed.) APHA Technical Committee on Microbiological Methods for

Foods. Washington, D.C., USA.
Asik, E.,Candogan, K., 2014. Effects of chitosan coatings incorporated with garlic oil on quality characteristics of shrimp. J. Food Qual. 37, 237-246.
Babatunde, O.A., Adewumi, A.O., 2015. Effects of ethanolic extract of garlic, roselle, and ginger on quality attributes of chicken patties. Afr. J. Biotechnol. 14, 688-694.
Benkeblia, N., 2004. Antimicrobial activity of essential oil extracts of various onions (Allium cepa) and garlic (*Allium sativum*). LWT-Food Sci. Technol. 37, 263-268.
Carbonell, I., Izquierdo, L,Costell, E., 2002. Sensory profiling of cooked gilthead sea bream (Sparus aurata): Sensory evaluation procedures and panel training. Food Sci. Technol. Inter. 8, 169-177.
Claudiu-Nicolae, S., Maria-Mihaela, M., 2009. Antimicrobial Effect of Seed Extract of Coriander. J. Agroalim. Process. Technol. 15, 298-300.
Dergal, N.B., Abi-Ayad, S.M., Douny, C., Brose, F., Daube, G., Rodrigues, A., Scippo, M.L., 2013. Microbial, biochemical, and sensorial quality assessment of Algerian farmed tilapia (*Oreochromis niloticus*) stored at 4 and 30oC. Afri. J. Food Sci., 7, 498-507.
El-Sherif, S.A., Abd-Ghafour , S.A., 2016. Effectiveness of garlic, rosemary, and ginger essential oils on improving the quality and shelf life of Bagrus bayad fish sausage preserved by cold storage. Inter. J. Adv. Res. 4, 276-289.
ESO (Egyptian Organization for Standardization), 2005. Standard specifications for chilled and frozen fish fillets (3494) and (2889). Egypt: EOS, 2005.

Gafar, M.K., Itodo, A.U., Warra, A.A.,Abdullahi, L., 2012. Extraction and physicochemical determination of garlic (*Allium sativum* L.) oil. Inter. J. Food Nutr. Sci. 1, 4-7.
Gandotra, R., Sharma, S., Koul, M.,Gupta, S., 2012. Effect of chilling and freezing on fish muscle. J. Pharm. Biol. Sci. 2, 5-9.
Gram, L.,Huss, H.H., 1996. Microbiological spoilage of fish and fish products. Inter. J. Food Microbiol. 33, 121-137.
Hernández, M.D., López, M.B., Álvarez, A., Ferrandini, E., García, B.G., Garrido, M.D., 2009. Sensory, physical, chemical, and microbiological changes in aquacultured meager (Argyrosomus regius) fillets during ice storage. Food Chemistry 114, 237-245.
Hussein, M.A., Hammad, O.S., Tharwat, A.E., Darwish, W.S., Sayed-Ahmed, A., Zigo, F., Farkašová, Z.,Rehan, I.F., 2022. Health risk assessment of organochlorine pesticide residues in edible tissue of seafood. Front. Vet. Sci. 9, 1042956.
Hussein, M.A., Merwad, A.M., Elabbasy, M.T., Suelam, I.I., Abdelwahab, A.M.,Taha, M.A., 2019. Prevalence of Enterotoxigenic *Staphylococcus aureus* and Shiga Toxin-Producing Escherichia coli in fish in Egypt: quality parameters and public health hazard. Vector-Borne Zoon. Dis. 19, 255-264.
ISO 6888-1,1999. Incorporating amendment No. A1 2003. Microbiology of food and animal feeding stuff – Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species). Part 1: Technique using Baird-Parker agar medium.
ISO 13720, 2010. Meat and meat products — Enumeration of presumptive *Pseudomonas* spp.
Kelly, K., Jones, N.R., Love, R.M.,Olley, J., 1966. Texture and pH in fish muscle related to 'cell fragility measurements. Inter. J. Food Sci. Technol. 1, 9-15.
Khalafalla, F.A., Ali, F.H.,Hassan, A.R., 2015. Quality improvement and shelf-life extension of refrigerated Nile tilapia (*Oreochromis niloticus*) fillets using natural herbs. Beni-Suef University Journal of Basic and Applied Sciences 4, 33-40.
Kilinc, B., Cakli, S., Cadun, A., Dincer, T, Tolasa, S., 2008. Chemical, microbiological, sensory, and color changes in warty Venus (Venus verrucosa) flesh during marination. Journal of Muscle Foods 19, 385-398.
Kuzgun, N.K., Sonmez, P.E., Tanyildizi, M.S., 2020. Preservative effect of coriander essential oil applied in different proportions on the storage of rainbow trout (Oncorhynchus mykiss) fillets. Progress Nutr. 22, e2020081.
Li, T., Hu, W., Li, J., Zhang, X., Zhu, J., Li, X., 2012. Coating effects of tea polyphenol and rosemary extract combined with chitosan on the storage quality of large yellow croaker (Pseudosciaena crocea). Food Control 25, 101-106.
Li, W.R., Ma, Y.K., Shi, Q.S., Xie, X.B., Sun, T.L., Peng, H, Huang, X.M., 2018. Diallyl disulfide from garlic oil inhibits *Pseudomonas aeruginosa* virulence factors by inactivating key quorum-sensing genes. Appl. Microbiol. Biotechnol. 102, 7555-7564.
Mendes, R., Pestana, C., Gonçalves, A., 2008. The effects of soluble gas stabilization on the quality of packed sardine fillets (Sardina pilchardus) stored in air, VP and MAP. Inter. J. Food Sci. Technol. 43, 2000-2009.
Nahid, M.N., Latifa, G.A., Chakraborty, S.C., Farid, F.B,Begum, M., 2014. Comparative study of biochemical composition and sensory characteristics of salt and garlic treated smoke-dried Chapila (Gudusia chapra, Hamilton; 1822) and Guchi Baim (Mastacembelus pancalus, Hamilton-Buchanan; 1822) stored at refrigeration temperature (4°C). J. Agri. Vet. Sci. 7, 1-07.
Nielsen, S.S., 2003. Food analysis. (3rd edn), Kluwer Academic/Plenum Publishers, New York, USA.
Özer, E., Ünlüsayin, M., Erdilal, R., 2012. Microbiological, physicochemical, and sensorial quality of vacuum-packed sausage from thornback ray (Raja clavata L., 1758) at chilled storage. Journal of Agroalimentary Processes and Technologies 18, 1-7.
Özkan, G., Sag˘diç, O., Baydar, N.G., Baydar, H., 2004. Note: Antioxidant and Antibacterial Activities of Rosa damascena Flower Extracts. Food Science and Technology International 10, 277–281.
Pearson, D., 1976. The Chemical Analysis of Food. Churchill Livingstone Edinburgh. London and New York. 27-72.
Ruiz-Capillas, C., Moral, A. 2001. Correlation between Biochemical and Sensory Quality Indices in Hake Stored in Ice. Food Research International, 34, 441-447.
Sallam, S. M. A., Nasser, M. E. A., El-Waziry, A. M., Bueno, I. C. S. and Abdalla, A. L., 2007. Use of an in vitro rumen gas production technique to evaluate some ruminant feedstuffs. J. Appl. Sci. Res. 1, 34-41
Sherman, P.W,Billing, J., 1999. Darwinian gastronomy: Why we use spices: Spices taste good because they are good for us. BioSci. 49, 453-463.
Sikorski, Z.E., Kolakowska, K,Burt, J.R., 1990. Postharvest, biochemical, and microbial changes. In Z.E. Sikorski (Ed.), Seafood: resources, nutritional composition, and preservation .Boca Raton: CRC Press. Inc. pp. 55-75
Smyth, A.R., Cifelli, P., Ortori, C.A., Righetti, K., Lewis, S., Erskine, P., Holland, E.D., Givskov, M., Williams, P., Cámara, M., Barrett, D.A,Knox, A., 2010. Garlic as an inhibitor of *Pseudomonas aeruginosa* quorum sensing in cystic fibrosis--a pilot randomized controlled trial. Pediatric Pulmonol. 45, 356-362.
Verbeke, W., Sioen, I., Pieniak, Z., Van Camp, J.,De Henauw, S., 2005. Consumer perception versus scientific evidence about health benefits and safety risks from fish consumption. Public Health Nutr. 8, 422-429.
Viuda-Martos, M., Mohamady, M.A., Fernández-López, J., Abd ElRazik, K.A., Omer, E.A., Pérez-Alvarez, J.A,Sendra, E., 2011. In vitro antioxidant and antibacterial activities of essential oils obtained from Egyptian aromatic plants. Food Control 22, 1715-1722.