

Original Research Articles

Effect of aqueous ozone treatment on some quality changes of vacuum-packed meagre (*Argyrosomus regius*) fillets

Ismail Y. GENÇ¹^a, Muhammet H. KAYHAN²¹ Fishing and Processing Technology Department, Eğirdir Fisheries Faculty, Isparta University of Applied Sciences, Isparta, Turkey, ² Aquaculture Department, Eğirdir Fisheries Faculty, Isparta University of Applied Sciences, Isparta, Turkey

Keywords: bacteria, meagre, ozone treatment, packaging, quality, shelf life

<https://doi.org/10.46989/001c.83904>

Israeli Journal of Aquaculture - Bamidgeh

Vol. 75, Issue 2, 2023

In this study, microbiological, sensory and color changes in vacuum-packed meagre fillets treated with aqueous ozone for different periods of time were investigated. Meagre fillets were treated with ozone for 15 (O-15) and 30 (O-30) minutes and vacuum-packed and stored at +2 °C for 12 days. Control group (C) was not treated with ozone and stored after vacuum packaging. For microbiological changes, Total Mesophilic Aerobic Bacteria (TMAB), *Pseudomonas sp.*, Lactic Acid Bacteria (LAB) and Total Psychrophilic Aerobic Bacteria (TPAB) counts were analyzed. At the end of storage, the highest bacterial counts were found in group C (>7.00 log cfu/g). In ozone-treated samples, *Pseudomonas sp.* counts did not exceed 7.00 log cfu/g only in the O-30 group. In the sensory evaluation of the samples, it was determined that the total demerit points were 18 points for group C, 16.25 points for O-15 and 14.75 points for O-30 at the end of storage over 30. No significant change was found according to the color results of the samples, but at the end of storage, it was observed that the L value of the ozone-treated samples was higher and the samples had a lighter color. In the conclusion of the results, it was observed that ozone treatment prolonged the shelf life of vacuum-packed meagre fillets for 4 days for the O-30 group compared to control and O-15 group without causing the sensory and color loss.

INTRODUCTION

Preservation of the quality and extension of shelf-life stability of perishable products such as seafood is one of the most important factors throughout the seafood production process.¹ The spoilage in seafood is caused by reactions related to the enzymatic activities of the own, oxidation of lipids and metabolic activities of microorganisms. The fact that seafood contain high nitrogen compounds and low acidity are factors that accelerate spoilage.² With seafood processing technology, this quality loss is prevented, ensuring food safety, meeting customer demands in a sustainable way, and preventing food waste by extending shelf life.³

Traditional methods such as curing, drying, fermentation, smoking, chilling and freezing used in the processing of seafood have disadvantages such as limited shelf life and protection, changes in sensory properties and high energy requirement. With the developments in technology and Industry 4.0, applications such as cold plasma, radiofrequency, ultrasound, microwave and smart packaging will be new technologies that are being used in the processing of seafood. The demand for natural preservatives and ecolog-

ically friendly implementations in these the conservation processes has gradually expanded as consumer awareness has grown. This increase has accelerated the spread of environmentally friendly practices with the emergence of new packaging technologies.⁴ Ozone is one of the most sustainable disinfection applications thanks to its cost-effective production,⁵ with no environmental impact.⁶ Ozone is currently widely used in many fields such as aquaculture, livestock and vegetable-fruit production and processing⁷. To explain the mechanism of action of ozone on the pathogen, it oxidizes the cell wall and the membranes in its structure, disrupts the structural integrity of the cell, and then inactivates the DNA by destroying it. Studies on the processing of seafood have shown that the use of ozone extends the shelf life of the product by lowering the number of germs on the product's surfaces.⁷ It has been reported that this increase may extend up to 2 to 5 days, depending on the application dose, duration, ambient temperature, method and the product to which the application is made.⁸ It has been reported in some studies that the use of ozone in seafood products has an important effect on shelf life and quality preservation. Gelman et al.⁷ studied the quality changes in

^a * Corresponding author. e-mail: ismailgenc@isparta.edu.tr

tilapia fish stored at 0 and 5°C for 30 days and reported that 6 ppm ozone application significantly increased the shelf life of tilapia fish stored at 0°C. In another study, Dehko-rdi and Zokaie⁹ reported that the shelf life of ozone-treated trout was extended from 4 days to 6 days. Nerantzaki et al.¹⁰ evaluated the quality changes in rainbow trout which were vacuum packed as a whole and stored at 4°C for 15 days with 0.6 and 0.4 mg/l and 60- and 90-minutes ozone treatment. According to the results of microbiological and sensory analysis, it was reported that the shelf life of rainbow trout treated with ozone for 60 and 90 minutes was 10 and 12 days.

Meagre (*Argyrosomus regius*) has a high market value due to its attractive appearance, high nutritional value and selenium, texture suitable for processing and consumption, low-fat content, deliciousness and high processing efficiency.¹¹ It is expected that meagre cultivation will increase gradually, especially in European countries and Türkiye (4771 tonnes in 2022, TUIK¹²), thanks to the existing demand and the advantages it has in cultivation such as rapid growth, good feed intake and late sexual maturation.¹³

In the frame of the cited literature, the aim of this study is to determine the effect of aqueous ozone (1ppm) applied for variable time durations (15 and 30 minutes) on the microbiological and sensory quality together with the color changes of vacuum-packed meagre fillets stored at +2°C for for 12 days.

MATERIALS AND METHODS

SAMPLE PREPARATION

Whole meagre samples (at total 20 fish) with an average weight of 305.37±30.96 were obtained from a local fish market. Specimens were placed in Styrofoam boxes with ice cover and immediately transported to the laboratory in 15 min. Upon arrival at the laboratory whole meagre were washed and filleted. The average weight of the fillets was 123.30±23.28. The fillets were randomly divided into 3 groups. The first group was marked as the control (C), the second group indicates the fillets that are treated for 15 min (O-15) and the last group stands for the group treated for 30 min (O-30) in aqueous ozone. The application times considered to have best reduction in the numbers of microorganisms and prevent odor formation^{14,15} Following to the ozone treatment fillets were individually vacuum-packed with low-density pouches. Fillets were stored at +2°C for 12 days. Microbiological, color and sensory analyses were performed periodically. In each sampling day, repetitions for microbiological and sensory analysis were consisted of 2, while color analyses were performed from 10 repetitions.

AQUEOUS OZONE TREATMENT

In the study, ozone applied by dissolving in water (aqueous ozone) was produced using an ozone generator (EDF A-25 model, EDF Industrial Ozone Systems, Turkey). The generator has a 25 g/hour capacity and uses corona discharge mechanism. Ozone, which comes out of the generator in

gas form, was dissolved in water by using a water pump with a venturi and given to a plastic container filled with 20 liters of sterile pure water in which the fillets were immersed for 15 and 30 min. The ozone level in the water was 1 ppm (875 mV) which is the maximum capacity of the generator, and the water pump was used to process the fillets in a uniform manner. The ozone level in the water was measured and monitored with the ADWA ORP/Redox Meters throughout the entire process, including the preparation of the washing water and the washing of the fillets.

MICROBIOLOGICAL ANALYSIS

Ten grams of sample was aseptically obtained on sampling days from control and aqueous ozone-treated and vacuum-packed meagre fillets. Samples were homogenized in 90 ml buffered peptone water (Merck, Darmstadt, Germany) for 3 min. From the homogenized sample, serial dilutions were prepared. The counts of microorganisms namely Total Mesophilic Aerobic Bacteria (TMAB), Total Psychrophilic Aerobic Bacteria (TPAB), *Pseudomonas* sp. and Lactic Acid Bacteria (LAB) were determined in accordance with the method described by Sallam.¹⁶ Plate count Agar (PCA, Merck, Darmstadt, Germany) was used for the enumeration of TMAB and TPAB. LAB was enumerated on De Man Rogosa and Sharp (MRS) agar (Merck, Darmstadt, Germany) and *Pseudomonas* sp. was quantified on Cephaloridin-Fucidin-Cetrimide (CFC) agar with CFC supplement (Merck, Darmstadt, Germany) with spread plate method. Microorganisms were incubated at 30, 4 and 25°C for 2, 10 and 2 days for TMAB, TPAB, *Pseudomonas* sp. and LAB, respectively.

COLOR ANALYSIS

Color measurements of the samples were performed using a 3NH color meter (Shenzhen ThreeNH Tech. China). Ten different measurements were taken from each fillet. The parameter L were used for brightness, a for red-green and b for yellow-blue. Hue and chroma was calculated based on the Eqs. 1 and 2, respectively.

$$Chroma = (a^2 + b^2)^{1/2} \quad (1)$$

$$Hue = \arctan(b^*/a^*) \quad (2)$$

SENSORY ANALYSIS

Sensory analysis of ozone-treated vacuum-packed meagre fillets was carried out according to the method described by Hernández et al.¹⁷ Raw and skinned meagre fillets were evaluated by 4 trained panelists for the appearance of the flesh and skin, odor and texture and the attributes are given in [Table 1](#). Samples were placed on the bench in the laboratory free from any odor source to prevent odor contamination during the analysis. Additionally, samples were analyzed in terms of color changes under the natural day light. The samples were considered inconsumable when the total scores of sensory analyses reached 15 out of 30.

Table 1. Attributes of ozone-treated vacuum-packed meagre fillets

Parameters	Attributes	Score
Skin	Color	1-5 (intensity)
	Texture	1-5 (elasticity)
Flesh	Color	1-5 (intensity)
	Muscle	1-5 (adhereness)
	Shine	1-5 (brightness)
	Odor	1-5 (fresh – putrefied)
	Texture	1-5 (elasticity)

STATISTICAL ANALYSIS

The comparison of the mean scores to the corresponding analysis was performed in duplicate. The results were expressed as mean $\pm$ standard deviation. The significance of the mean scores was analyzed by analysis of variance (ANOVA) and Tukey's HSD test was applied as the post-hoc tests. A statistical package (SPSS Inc. Chicago, USA) was used to for the calculation of significant differences between groups. The confidence intervals were adjusted to $p < 0.05$ level.

RESULTS

MICROBIOLOGICAL CHANGES

Microbiological changes in vacuum-packed meagre fillets treated with gaseous ozone for different application times during storage at $+2^\circ\text{C}$ are shown in [Figure 1a-d](#). The initial *Pseudomonas* sp., TMAB, LAB and TPAB counts of the C, O-15 and O-30 groups were 4.00 ± 0.03 , 3.80 ± 0.08 and 3.35 ± 0.17 log cfu/g; 4.08 ± 0.01 , 3.90 ± 0.02 and 3.71 ± 0.02 ; 2.14 ± 0.10 , 1.23 ± 0.33 and 1.15 ± 0.21 and 4.01 ± 0.04 , 3.95 ± 0.02 and 3.79 ± 0.11 log cfu/g, respectively. In all evaluated bacterial groups, an increase was observed for each group until the end of the storage period and the increase in bacterial counts was found to be statistically significant ($p < 0.05$). In this framework, although there were significant differences ($p < 0.05$) between the groups in terms of *Pseudomonas* sp. and TMAB counts in ozone-treated samples on the first day of storage, there was no significant effect on LAB and TPAB counts ($p > 0.05$).

However, at the end of the storage, substantial variations were noticed between the groups. The growth of *Pseudomonas* sp. and LAB in the O-30 group was significantly lower than the other groups ([Figure 1a-d](#)). On the other hand, TMAB counts revealed no significant variations between groups ($p > 0.05$). Regarding TPAB counts, significant differences were observed between O-15 and O-30 groups and C group ($p < 0.05$). All bacterial groups except *Pseudomonas* sp. of the O-30 group exceeded 7.00 log cfu/g. In the O-30 group, *Pseudomonas* sp. was determined as 6.88 ± 0.15 log cfu/g on the 12th day. On the last day of storage, the number of *Pseudomonas* sp. TMAB, LAB and TPAB were determined to be 7.84 ± 0.08 , 8.06 ± 0.30 , 7.38 ± 0.12 and 8.32 ± 0.10 log cfu/g for the C group, 7.50 ± 0.28 , 7.65 ± 0.06 ,

7.30 ± 0.00 and 7.86 ± 0.12 log cfu/g for the O-15 group and 6.88 ± 0.15 , 7.03 ± 0.61 , 7.00 ± 0.00 and 7.65 ± 0.06 log cfu/g for the O-30 group.

SENSORY CHANGES

The sensory changes in vacuum-packed meagre fillets treated with ozone for different periods of time are given in [Figure 2 a-g](#). Panelists examined the skin and flesh color, muscle, brightness, odor and texture changes of the samples during 12 days of storage. Skin and flesh color parameter showed a notable increase in all samples on the last day of storage ($P < 0.05$), but no influential difference was observed between the groups for skin and flesh color ($p > 0.05$) ([Fig. 2 a-b](#)). Demerit points, which characterize the muscle structure of the samples, increased according to the storage time. Significant differences were determined for the control group on days 8 and 12, and for the O-15 group on day 12 compared to the initial values ($p < 0.05$). No significant increase was observed for the O-30 group, depending on the storage time ($p > 0.05$). There was no statistical difference between the samples during 12 days of storage ($p > 0.05$) ([Fig. 2c](#)). The brightness increased considerably with time ($p < 0.05$). Major differences ($p < 0.05$) were seen in ozone-treated samples compared to the control group ([Fig. 2d](#)). The odor parameter showed a substantial alterations from the first days of storage for the C group ($p < 0.05$).

Among the ozone-treated groups, the O-15 group exhibited a significant increase from the 4th day of storage and the O-30 group showed a meaningful increase from the 8th day of storage ($p < 0.05$) ([Fig. 2e](#)). The last parameter that increased based on the storage time was texture and the change of demerit points was determined increased on the 12th day in the control group and on the 8th day in the O-15 group. In the O-30 group, the change with storage time was not statistically significant ($p > 0.05$) ([Fig 2f](#)). The changes in total demerit points, which give the sum of the variables evaluated by the panelists, are given in [Fig 2g](#). In total, out of 30 demerit points, on the last day of storage, the control group had 18, the O-15 group was 16.25 and the O-30 group had 14.75 points. There was a notable increase in the total points of all groups according to the storage time ($p < 0.05$), but there was no significant difference between the groups at the end of the storage time ($p > 0.05$). It was observed that the odor and texture parameters approached the highest score of 5 and the other parameters increased up to 3 when the sensory changes occurred during 12 days of storage in the ozone-treated vacuum-packed meagre fillets. Regarding the total points, it was observed that none of the groups reached the highest value of 30. However, it was determined that the acceptability limit of 15 was exceeded by the control and O-15 groups, and the O-30 group was very close to this value at 14.75. In the determination of these data, the storage time in which the quality of ozone-treated vacuum-packed meagre fillets could be stored under chilled conditions at 2.00°C was determined as 8 days for the control and O-15 group and 12 days for the O-30 group.

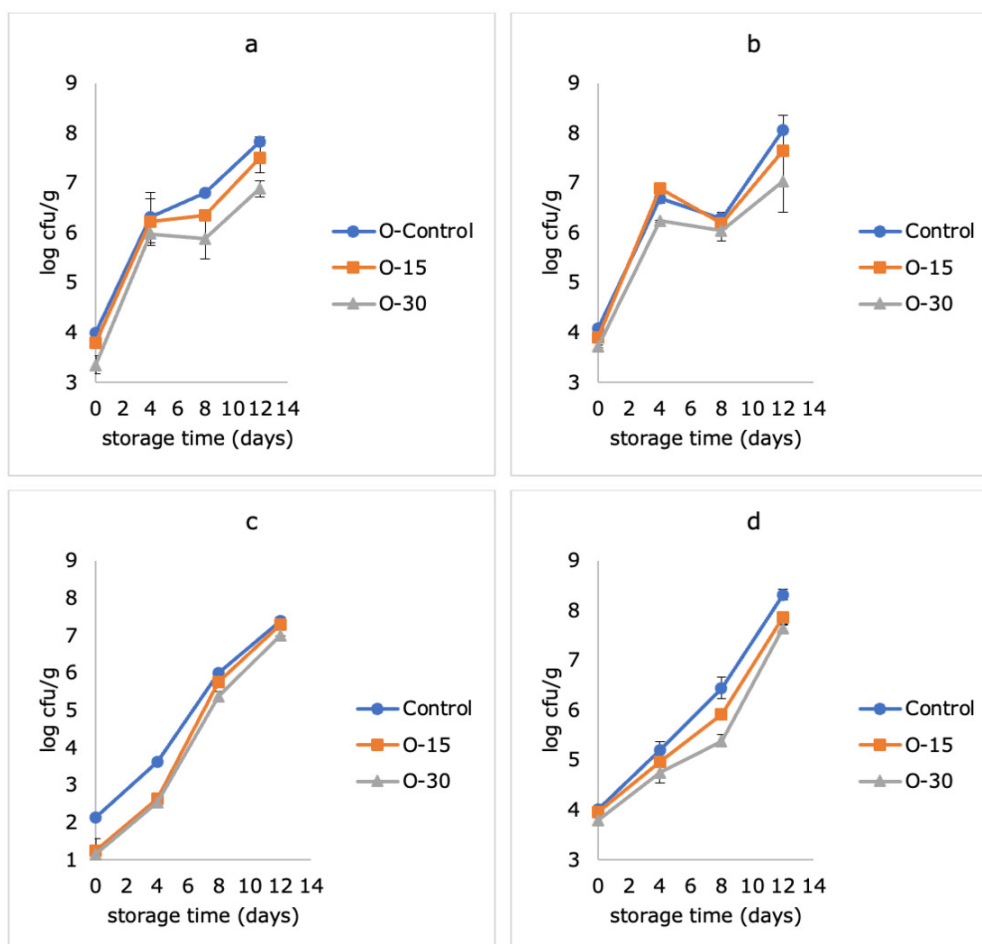


Figure 1. Changes in microbial quality of ozone-treated vacuum-packed meagre fillets. a) *Pseudomonas* sp., b) Mesophilic bacteria, c) LAB, d) Psychrophilic bacteria. Results were presented in log cfu/g mean $\pm$ SD.

COLOR CHANGES

The color changes in the ozone-treated vacuum-packed meagre fillets during storage are given in [Table 2](#). Significant variations ($p < 0.05$) were found between the chromatic parameters (L-lightness, a-redness-greenness, and b blue-ness-yellowness) between the groups only on the 12th day of storage ($p < 0.05$). While lightness increased in C group samples ($p > 0.05$), no increase was observed in the O-15 and O-30 groups ($p > 0.05$).

For a parameter, it was observed that the redness value of the samples in the O-15 and 30 groups increased compared to the control group and statistically significant differences were determined on the 12th day of storage ($p < 0.05$). In the b value, which indicates the blueness-yellowness, no significant change was found in the groups during storage ($p > 0.05$). However, differences were observed in the chroma value between the samples on the first and last day of storage ($p < 0.05$). In this context, it was observed that the chroma value of the ozone-treated samples was higher than the control group ($p < 0.05$). The Hue angle did not show a significant difference between the groups during storage ($p > 0.05$).

DISCUSSION

ICMSF has determined consumable limits for the microbial load of seafood for human consumption. In this context, the maximum number of total mesophilic bacteria that can be found in good quality seafood was reported as 5.70 log cfu/g and the acceptance limit for consumption as 7.00 log cfu/g.^{18,19} In this context, the total mesophilic bacteria count determined for all groups were below the limits determined by ICMSF ([Fig. 1b](#)) and in this scope, it is seen that the meagre fillets are of good quality. It was observed that ozone treatment significantly reduced the number of mesophilic bacteria in vacuum-packed meagre ($p < 0.05$). Similar to our study, researchers examined the quality changes that occurred during the storage of Pacific white shrimp treated with minimal ozone on ice. According to the results of the study, the initial total viable count (TVC) of shrimp treated for 1 minute at a concentration of 100 mg/h was reported as 4.44 and 4.01 log cfu/g after ozone treatment.²⁰ Psychrophilic bacteria are microorganisms that are able to proliferate in low temperatures and can be found in almost every food and can pose a threat to food safety in some cases along with food spoilage.²¹ In the changes of the total number of psychrophilic bacteria during cold storage in vacuum-packed meagre fillets treated with ozone for

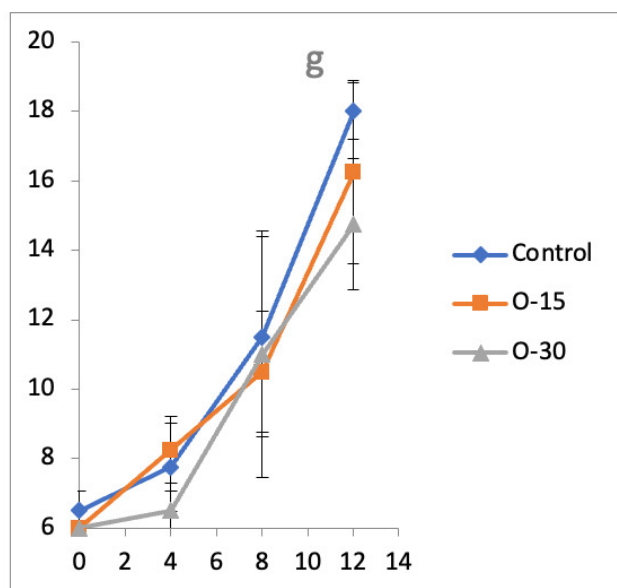


Figure 2. Sensory changes of ozone-treated vacuum-packed meagre fillets a) skin color, b) flesh color, c) muscle, d) brightness, e) odor, f) texture, and g) total points.

different periods of time, it was observed that ozone treatment did not have a significant effect on the total number of psychrophilic bacteria in the samples on the first day of storage ($p>0.05$) (Fig. 1d). However, significant increases in the total number of psychrophilic bacteria of each group were determined depending on the storage time ($p<0.05$). At the end of the storage period, total psychrophilic bacteria counts were significantly higher in the control group than in the ozone-treated O-15 and O-30 groups ($p<0.05$). In a study, microbial and chemical quality changes in tiger groupers stored in slurry ice containing 0.1 mg/l ozone and 3.3% NaCl were investigated. The researchers reported that

the number of psychrotrophic bacteria in ozone-treated slurry ice was significantly lower than in the control and NaCl-containing slurry ice samples. Furthermore, on the 20th day of storage, the researchers reported that the number of psychrotrophic bacteria in the ozone-containing group was significantly lower compared to the other groups.²² It is assumed that the results obtained in ozone-treated and vacuum-packed meagre fillets have a repressive effect on the number of psychrophilic bacteria that cause spoilage in seafood.

Pseudomonas sp. is a psychrotrophic, non-fermentative, aerobic bacterium that causes spoilage and thus quality losses in seafood.²³ On the first day of storage, ozone treatment significantly lowered the counts of *Pseudomonas* sp. in the O-30 group compared to the O-15 and control groups ($p<0.05$). The inhibitory effect of ozone treatment on the growth of *Pseudomonas* sp. in seafood was shown by Glatman et al.²⁴ and in this context, the results were in agreement with that ozone treated vacuum packed meagre fillets. The researchers indicated that the shelf life of tilapia fish stored under chilled conditions increased by 40% at 0°C and that this was due to the suppression of the growth of *Pseudomonas* sp. by ozone. However, the development of *Pseudomonas* sp. in ozone-treated vacuum-packed meagre fillets increased rapidly in all groups with time ($p<0.05$). At the end of the storage time, the number of *Pseudomonas* sp. was statistically significantly lower in the O-30 group than in the O-15 and control group ($p<0.05$) and it could be considered that the ozone treatment applied in the O-30 group suppressed the growth of *Pseudomonas* sp. In the study conducted by Lan et al.,²⁵ it was reported that ozone application inhibited the growth of *Pseudomonas* sp. in seafood stored under cold conditions. The researchers examined the quality changes of ozonized slurry ice application in the cold chain cycle of large yellow croaker (*Pseudosciaena crocea*) and reported that ozonized slurry ice application significantly decreased the number of *Pseudomonas* sp. in the samples on the 21st day, the last day of storage. In our

Table 2. Color values of ozone-treated vacuum-packed meagre fillets*

Sample	Storage time (days)	L	a	b	Chroma	Hue angle
Control	0	9.47±0.95 ^A	-0.55±1.98 ^A	2.72±2.19 ^{Aa}	3.51±1.89 ^{Ab}	-0.75±0.74 ^A
	4	9.52±0.98 ^A	-0.66±2.08 ^A	2.83±2.23 ^{Aa}	3.88±1.38 ^A	-0.59±1.12 ^A
	8	10.61±1.15 ^A	-2.65±2.24 ^A	5.24±2.69 ^{Aa}	5.85±3.43 ^A	-0.89±0.75 ^A
	12	10.17±1.22 ^{Ab}	-1.84±2.42 ^{Ab}	4.33±2.84 ^{Aa}	5.33±2.78 ^{Ab}	-0.90±0.49 ^A
O-15	0	10.03±1.81 ^A	-1.64±3.76 ^A	4.11±4.15 ^{Aa}	6.45±2.44 ^{Ab}	-0.95±0.32 ^A
	4	10.87±1.41 ^A	-2.91±2.33 ^A	5.45±2.81 ^{Aa}	6.29±3.47 ^A	-0.87±0.76 ^A
	8	11.13±1.40 ^A	-3.84±2.71 ^A	6.61±3.33 ^{Aa}	7.70±4.19 ^A	-1.12±0.18 ^A
	12	10.93±1.42 ^{Aab}	-3.15±2.52 ^{Aab}	5.76±2.98 ^{Aa}	6.89±3.34 ^{Aab}	-0.95±0.38 ^A
O-30	0	11.10±2.70 ^A	-3.66±5.45 ^A	5.07±7.74 ^{Aa}	10.13±4.27 ^{Aa}	-0.58±0.75 ^A
	4	10.34±1.65 ^A	-2.26±3.24 ^A	4.33±3.42 ^{Aa}	5.82±4.38 ^A	-0.44±0.96 ^A
	8	10.73±0.83 ^A	-3.09±1.63 ^A	5.63±1.96 ^{Aa}	6.45±2.49 ^A	-1.10±0.11 ^A
	12	11.91±1.83 ^{Aa}	-4.86±3.03 ^{Aa}	7.92±3.78 ^{Aa}	9.46±4.48 ^{Aa}	-0.86±0.46 ^A

*Different superscript lower-case letters in the same column represents statistically significant differences among the groups and different superscripts capital letters indicate statistical differences among storage time ($p<0.05$)

study, *Pseudomonas* sp. showed significant ($p < 0.05$) growth at the end of the 12-day storage period in ozone-treated vacuum-packed meagre fillets. This growth is thought to be due to the fact that *Pseudomonas* sp. is a bacterium that causes spoilage in seafood²⁶ and its initial number cannot be reduced enough to suspend its proliferation²⁷ but rather ozone treatment aids to slow down the growth of the bacteria (Fig 1a).

On the first day of storage, LAB counts in vacuum-packed meagre fillets treated at different duration were 2.07 ± 0.10 log cfu/g for the control group, 1.23 ± 0.33 log cfu/g for the O-15 group and 1.15 ± 0.21 log cfu/g for the O-30 group ($p > 0.05$) (Fig 1c). LAB counts of each group increased significantly according to the storage time and the highest was determined in the control group. On the last day of the storage period, the 12th day, significant differences were determined between the O-30 group and the O-15 and control groups ($p < 0.05$). In this context, it is considered that ozone application is effective on LAB in vacuum-packed meagre fillets of the O-30 group. Lower LAB counts were reported for ozone water treated air, vacuum and modified atmosphere-packed soft shell mud crab (*Scylla serrata* Forskal) stored under refrigerated temperatures.²⁸ Researchers were reported that the shelf life of soft-shell mud crab treated with 1.0 ppm ozone for 20 min and packed in 80% CO₂+20% NO₂ was significantly increased and the counts of LAB ozone-treated samples were not exceeded 6.87 log cfu/g. In another study conducted with sea bream fillets, similar to this study, it was reported that LAB counts decreased by 0.10 ± 0.01 log cfu/g after 640 ppm ozone concentration was applied at 25°C for 30 minutes.²⁹ From this perspective, it was concluded that ozone treatments of meagre fillets are compatible with different seafood products given in the literature in terms of LAB numbers and ozone application slows down LAB growth.

Studies have shown that ozone application in seafood extends shelf life and preserves sensory quality. Ling et al.³⁰ examined the changes occurring during the storage of ultra-high pressure combined with ozone water in catfish fillets under refrigerator conditions. The researchers reported that total demerit points increased in all groups during storage. However, they reported that ozone water and UHP reached the threshold value on the 9th day of storage. In another study, researchers examined the effect of gaseous ozone application on the quality changes occurring in salmon stored under chilled conditions. The researchers reported that the sensory threshold was exceeded on the 8th day of storage in the control group salmon, but ozone-treated samples were still consumable.³¹ In another study with stripped red mullet, researchers examined the quality changes that occurred during the storage of stripped red mullet at 1°C with the combination of ozone and modified atmosphere package. The researchers reported that the control group samples reached the maximum 13 demerit points on the 12th day and the ozone MAP and MAP samples reached the maximum demerit point on the 15th day. They reported that the control group reached the acceptable limit on the 7th day and the ozone MAP and MAP group on the 10th day.³² Additionally, the shelf life exten-

sion by 2 days in ozonated trout⁹ and ozonated vacuum packed whole rainbow trout by 4 days¹⁰ has been reported. Within the framework of these data, according to the sensory values, it was determined that the shelf life of vacuum-packed meagre fillets was extended 4 days depending on the ozone application time and was similar to that of other studies.

It was observed that the L value was higher in ozone-treated vacuum-packed meagre fillets compared to the control group. This is thought to be due to the bleaching effect of ozone.³⁰ Similarly, in a study conducted on minimally ozone-treated fresh shrimp, 100mg/h ozone-treated samples were stored in ice for 10 days. The researchers reported that the L values of minimal ozone-treated fresh shrimp on the 10th day of storage were higher than the control group, although they did not report a statistically significant difference.²⁰ In the parameter a where the redness-greenness value was determined, it was observed that the redness value of O-15 and O-30 groups was higher. The change of a parameter according to the storage time did not show significant differences ($p > 0.05$), but differences were determined between the groups on the 12th day of storage ($p < 0.05$). a values have been reported to be an important parameter in terms of color evaluation in tilapia.^{33,34} However, when evaluated in terms of meagre, it was observed that a value differed between the groups only on the 12th day. In this framework, it was observed that ozone treatment did not show a significant change in vacuum-packed meagre. No significant change was observed in the b values of ozone-treated vacuum-packed meagre fillets between storage time and groups ($p > 0.05$). However, it was observed that b values were higher in ozone-treated samples compared to the control group. This was observed to be due to the increase in yellowness value in ozone-treated fillets and it is thought that ozone application shows an oxidative effect.³⁴ Similarly, De Mendonça Silva and Gonçalves³⁴ examined the effect of aqueous ozone application on microbial and physico-chemical properties in Nile tilapia processing and reported that b values in ozone-treated groups were generally higher than non-ozone treated groups and this was due to oxidation in lipids and pigments.

In conclusion, microbiological and sensory quality and color changes in vacuum-packed meagre fillets during 12 days of storage at +2°C were investigated in this study. It was observed that ozone treatment preserved the quality changes of vacuum-packed meagre fillets. This study also showed that the growth of TMAB, *Pseudomonas* sp., LAB and TPAB was slower in ozone treated samples compared to the control group. In addition, Ozone-treatment preserved the sensory parameters of the meagre fillets and did not cause a significant difference in the color changes of the samples. Moreover, it was revealed in this study that the shelf life was prolonged by 4 days and 30 min of application time was found to be more effective compared to those of control and 15 min in ozone-treated vacuum-packaged meagre fillets.

.....

ACKNOWLEDGMENTS

The authors thank the staff of the Eğirdir Fisheries Faculty for their valuable help in the laboratory experiments and EDF Industrial Ozone Systems to provide the ozone generator.

AUTHORS' CONTRIBUTION USING [CREDIT](#)

Conceptualization: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Methodology: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Formal Analysis: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Inves-

tigation: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Writing – original draft: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Writing – review & editing: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Funding acquisition: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Resources: Ismail Y. GENÇ (Equal), Muhammet H. KAYHAN (Equal). Supervision: Ismail Y. GENÇ (Lead).

Submitted: May 26, 2023 CST. Accepted: June 21, 2023 CST.

Published: July 12, 2023 CST.



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-4.0). View this license's legal deed at <http://creativecommons.org/licenses/by/4.0> and legal code at <http://creativecommons.org/licenses/by/4.0/legalcode> for more information.

REFERENCES

1. Parlapani FF. Microbial diversity of seafood. *Current Opinion in Food Science*. 2021;37:45-51. doi:[10.1016/j.cofs.2020.09.005](https://doi.org/10.1016/j.cofs.2020.09.005)
2. Nosedá B, Vermeulen A, Ragaert P, Devlieghere F. Packaging of fish and fishery products. In: *Seafood Processing: Technology, Quality and Safety*. Wiley; 2013:237-261. doi:[10.1002/9781118346174.ch10](https://doi.org/10.1002/9781118346174.ch10)
3. Tsironi TN, Taoukis PS. Current practice and innovations in fish packaging. *Journal of Aquatic Food Product Technology*. 2018;27(10):1024-1047. doi:[10.1080/10498850.2018.1532479](https://doi.org/10.1080/10498850.2018.1532479)
4. Hassoun A, Siddiqui SA, Smaoui S, et al. Seafood processing, preservation, and analytical techniques in the age of Industry 4.0. *Applied Sciences*. 2022;12(3):1703. doi:[10.3390/app12031703](https://doi.org/10.3390/app12031703)
5. Varga L, Szigeti J. Use of ozone in the dairy industry: A review. *Int J Dairy Technol*. 2016;69(2):157-168. doi:[10.1111/1471-0307.12302](https://doi.org/10.1111/1471-0307.12302)
6. Pandiselvam R, Kaavya R, Jayanath Y, et al. Ozone as a novel emerging technology for the dissipation of pesticide residues in foods—a review. *Trends in Food Science & Technology*. 2020;97:38-54. doi:[10.1016/j.tifs.2019.12.017](https://doi.org/10.1016/j.tifs.2019.12.017)
7. Gelman A, Sachs O, Khanin Y, Drabkin V, Glatman L. Effect of ozone pretreatment on fish storage life at low temperatures. *Journal of Food Protection*. 2005;68(4):778-784. doi:[10.4315/0362-028x-68.4.778](https://doi.org/10.4315/0362-028x-68.4.778)
8. Crapo C, Himelbloom B, Vitt S, Pedersen L. Ozone efficacy as a bactericide in seafood processing. *Journal of Aquatic Food Product Technology*. 2004;13(1):111-123. doi:[10.1300/j030v13n01_10](https://doi.org/10.1300/j030v13n01_10)
9. Dehkordi BM, Zokaie N. Extension of fish shelf life by ozone treatment. *International Journal of Environmental and Ecological Engineering*. 2010;4(2):108-110.
10. Nerantzaki A, Tsiotsias A, Paleologos EK, Savvaidis IN, Bezirtzoglou E, Kontominas MG. Effects of ozonation on microbiological, chemical and sensory attributes of vacuum-packaged rainbow trout stored at 4±0.5°C. *Eur Food Res Technol*. 2005;221(5):675-683. doi:[10.1007/s00217-005-0042-x](https://doi.org/10.1007/s00217-005-0042-x)
11. Costa S, Afonso C, Bandarra NM, et al. The emerging farmed fish species meagre (*Argyrosomus regius*): How culinary treatment affects nutrients and contaminants concentration and associated benefit-risk balance. *Food and Chemical Toxicology*. 2013;60:277-285. doi:[10.1016/j.fct.2013.07.050](https://doi.org/10.1016/j.fct.2013.07.050)
12. TÜİK. Turkish Statistical Institute. 2023. Accessed June 17, 2023. <https://data.tuik.gov.tr/Bulten/Index?p=Su-Urunleri-2022-49678>
13. Pavloudi C, Tsertou MI, Antonopoulou E, Katharios P. Investigation of systemic granulomatosis in cultured meagre, *Argyrosomus regius*, using clinical metagenomics. *Aquaculture*. 2023;567:739249. doi:[10.1016/j.aquaculture.2023.739249](https://doi.org/10.1016/j.aquaculture.2023.739249)
14. Panebianco F, Rubiola S, Chiesa F, Civera T, Di Ciccio PA. Effect of gaseous ozone on listeria monocytogenes planktonic cells and biofilm: An in vitro study. *Foods*. 2021;10(7):1484. doi:[10.3390/foods10071484](https://doi.org/10.3390/foods10071484). PMID:34206833
15. Phermthong P, Worawattanamateekul W, Hinsui J. Effect of Ozone Treatments on Nile Tilapia Mince (*Oreochromis niloticus*) Off-Odor. *Rajamangala University of Technology Srivijaya Research Journal*. 2021;13(1):85-94.
16. Sallam KI. Antimicrobial and antioxidant effects of sodium acetate, sodium lactate, and sodium citrate in refrigerated sliced salmon. *Food Control*. 2007;18(5):566-575. doi:[10.1016/j.foodcont.2006.02.002](https://doi.org/10.1016/j.foodcont.2006.02.002). PMID:17471315
17. Hernández MD, López MB, Álvarez A, Ferrandini E, García B, Garrido MD. Sensory, physical, chemical and microbiological changes in aquacultured meagre (*Argyrosomus regius*) fillets during ice storage. *Food Chemistry*. 2009;114(1):237-245. doi:[10.1016/j.foodchem.2008.09.045](https://doi.org/10.1016/j.foodchem.2008.09.045)
18. International Commission on Microbiological Specifications for Foods. Sampling plans for fish and shellfish. In: *Microorganisms in Foods. Sampling for Microbiological Analysis: Principles and Scientific Applications*. Vol 2. 2nd ed. University of Toronto Press; 1986:181-196.
19. Boulares M, Mejri L, Hassouna M. Research Note Study of the Microbial Ecology of Wild and Aquacultured Tunisian Fresh Fish. *Journal of Food Protection*. 2011;74(10):1762-1768. doi:[10.4315/0362-028x.jfp-11-057](https://doi.org/10.4315/0362-028x.jfp-11-057)
20. Okpala COR. Physicochemical changes in minimal ozone-treated fresh shrimp stored on ice tandem with microbiological efficacy of treatment. *Nigerian Food Journal*. 2015;33(2):74-87.

21. Jin S, Wang Y, Zhao X. Cold-adaptive mechanism of psychrophilic bacteria in food and its application. *Microbial Pathogenesis*. 2022;169:105652. doi:[10.1016/j.micpath.2022.105652](https://doi.org/10.1016/j.micpath.2022.105652)
22. Karim NU, Nasir N, Arifin B, Ismail M. Effect of Salt and Ozonized-Slurry Ice on The Quality Indices of Tiger Grouper (*Epinephelus fuscoguttatus*). Published online 2015.
23. Boziaris IS, Kordila A, Neofitou C. Microbial spoilage analysis and its effect on chemical changes and shelf-life of Norway lobster (*Nephrops norvegicus*) stored in air at various temperatures. *International Journal of Food Science & Technology*. 2011;46(4):887-895. doi:[10.1111/j.1365-2621.2011.02568.x](https://doi.org/10.1111/j.1365-2621.2011.02568.x)
24. Glatman L, Sachs O, Khanin Y, Drabkin V, Gelman A. Ozone action on survival and storage life of live and chilled tilapia. *Israeli Journal of Aquaculture - Bamidgeh*. 2006;58(3):147-156. doi:[10.46989/001c.20445](https://doi.org/10.46989/001c.20445)
25. Lan W, Chen X, Zhao Y, Xie J. The effects of ozonated slurry ice treatment on microbial, physicochemical, and quality of large yellow croaker (*Pseudosciaena crocea*) during cold-chain circulation. *Food Control*. 2023;145:109511. doi:[10.1016/j.foodcont.2022.109511](https://doi.org/10.1016/j.foodcont.2022.109511)
26. Macé S, Cornet J, Chevalier F, et al. Characterisation of the spoilage microbiota in raw salmon (*Salmo salar*) steaks stored under vacuum or modified atmosphere packaging combining conventional methods and PCR-TTGE. *Food Microbiology*. 2012;30(1):164-172. doi:[10.1016/j.fm.2011.10.013](https://doi.org/10.1016/j.fm.2011.10.013)
27. Zhao Y, Lan W, Shen J, Xu Z, Xie J. Combining ozone and slurry ice treatment to prolong the shelf-life and quality of large yellow croaker (*Pseudosciaena crocea*). *LWT*. 2022;154:112615. doi:[10.1016/j.lwt.2021.112615](https://doi.org/10.1016/j.lwt.2021.112615)
28. Phapinyo N, Chaowalit T, Tanpipattanakul A, et al. Shelf-life extension of refrigerated soft shell mud crab (*Scylla serrata* Forskal) by ozone water and storage under air and modified atmosphere packaging. *Agriculture and Natural Resources*. 2007;41(3):539-547.
29. Giannoglou M, Dimitrakellis P, Efthimiadou A, Gogolides E, Katsaros G. Comparative study on the effect of cold atmospheric plasma, ozonation, pulsed electromagnetic fields and high-pressure technologies on sea bream fillet quality indices and shelf life. *Food Eng Rev*. 2020;13(1):175-184. doi:[10.1007/s12393-020-09248-7](https://doi.org/10.1007/s12393-020-09248-7)
30. Ling Y, Zhou M, Qiao Y, et al. Effects of ozone water combined with ultra-high pressure on quality and microorganism of catfish fillets (*Lctalurus punctatus*) during refrigeration. *Front Nutr*. 2022;9. doi:[10.3389/fnut.2022.880370](https://doi.org/10.3389/fnut.2022.880370). PMID:35873429
31. Qian YF, Zhang JJ, Liu CC, Ertbjerg P, Yang SP. Effects of gaseous ozone treatment on the quality and microbial community of salmon (*Salmo salar*) during cold storage. *Food Control*. 2022;142:109217. doi:[10.1016/j.foodcont.2022.109217](https://doi.org/10.1016/j.foodcont.2022.109217)
32. Bono G, Badalucco C. Combining ozone and modified atmosphere packaging (MAP) to maximize shelf-life and quality of striped red mullet (*Mullus surmuletus*). *LWT*. 2012;47(2):500-504. doi:[10.1016/j.lwt.2012.02.014](https://doi.org/10.1016/j.lwt.2012.02.014)
33. Li L, Hao S, He J, et al. Effects of Different color retention methods on the appearance of tilapia (*Oreochromis Niloticus*♀ × *Oreochromis Aureus*♂) fillets. *Journal of Food Processing and Preservation*. 2013;37(5):503-509. doi:[10.1111/j.1745-4549.2012.00677.x](https://doi.org/10.1111/j.1745-4549.2012.00677.x)
34. de Mendonça Silva AM, Gonçalves AA. Effect of aqueous ozone on microbial and physicochemical quality of Nile tilapia processing. *J Food Process Preserv*. 2016;41(6):e13298. doi:[10.1111/jfpp.13298](https://doi.org/10.1111/jfpp.13298)