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The antimicrobial effect of edible alginate-gelatin coating containing emulsion and nanoemulsion of dill (*Anethum graveolens*) essential oil against *Listeria monocytogenes* inoculated into turkey meat

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ABSTRACT

In this study, the effect of sodium alginate-gelatin edible coating (2% / 2%) containing dill essential oil emulsion (16 and 32 mg/ml) and dill essential oil nanoemulsion (16 and 32 mg/ml) during the storage period of turkey meat at 4 °C was investigated. The main components of the essential oil were measured using GC-MS, which included α-phellandrene (51.89%), carvone (10.21%), and limonene (8.26%). The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of dill essential oil emulsion against *Listeria monocytogenes* were 8 mg/ml and 16 mg/ml, respectively, and the MIC and MBC of dill nanoemulsion were 2 mg/ml and 4 mg/ml, respectively. On day 12, the bacterial count in the control treatment was Log 8.1 CFU/g, in the gelatin-alginate coating treatment Log 7.75, in the emulsion treatment Log 7.34, and in the dill essential oil nanoemulsion treatment Log 6.57 CFU/g. With increasing dill essential oil concentration, antimicrobial properties increased, and the treatment containing nanoemulsion had a better effect in controlling the growth of *Listeria monocytogenes* compared to the essential oil emulsion. The lowest thiobarbituric acid (TBA) levels were found in the dill essential oil emulsion (0.68 mg MDA/kg) and nanoemulsion (0.41 mg MDA/kg) treatments. The essential oil treatments had lower pH during the period than the control sample and showed lower TVN levels. The results showed that sodium alginate-gelatin edible coating containing dill essential oil emulsion and nanoemulsion had a positive effect on controlling the growth of *Listeria monocytogenes*, oxidation factors, and sensory properties in turkey meat.

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1. Introduction

Food poisoning and foodborne infections are major public health concerns. Beyond consumer health, spoilage microorganisms decrease the shelf life of food products, result in economic losses, and food waste [1]. Meat serves as a principal and rich source of protein. Turkey, classified under the genus Meleagris and the order Galliformes, is experiencing increasing consumption [2]. Turkey meat is considered both red and white meat: the white portion is found in the breast (65%), while the red portion is located in the thigh (35%). These parts differ significantly in flavor. Grass-fed turkeys, compared to those raised in intensive farming systems, contain higher levels of nutrients, micronutrients, vitamins, fat, and calories [3].The presence of these components-including micronutrients, vitamins, proteins, carbohydrates, fat and high moisture content, and optimal pH - makes turkey meat a highly suitable environment for the growth of pathogens and microbes [4].

Listeria is a gram-positive, rod-shaped, facultative anaerobic, non-spore-forming bacterium. The most important and pathogenic species of this genus is *Listeria monocytogenes*. Listeriosis is a zoonotic disease that can be transmitted between humans and animals. In adults, this disease can cause infections and inflammation of the brain, including meningitis, encephalitis, and septicemia. In pregnant women, listeriosis initially presents with flu-like symptoms; however, if treatment is delayed, it can result in miscarriage or, in the case of delivery, the birth of a stillborn or ill infant. The primary route of transmission for this bacterium is fecal-oral, mainly through contaminated food. Foods such as meat, milk, and products derived from milk and meat are particularly susceptible to contamination with this bacterium [5].

Nowadays, the use of innovative food preservation methods—including natural compounds such as plant essential oils, nanotechnology, natural preservatives derived from bacteria, biodegradable coatings and films, irradiation, and others—has attracted considerable attention from researchers. In this context, Sabzali et al. (2019) investigated the effects of sodium alginate edible coatings containing wild garlic on the microbial and chemical properties of beef fillets, while Maleki et al. (2022) examined the impact of carboxymethyl cellulose films containing titanium dioxide nanoparticles and dill essential oil on rainbow trout fillets [4, 6]. Edible coatings form a thin layer on the surface of foods, preventing the penetration of moisture and oxygen into the product. The incorporation of natural antimicrobial and antioxidant agents, such as plant essential oils, further extends the shelf life of food products. Another advantage of edible coatings over synthetic ones is their biodegradability and biocompatibility with the environment [6, 7].

Alginate is a polysaccharide compound. Edible alginate coatings improve the texture and enhance the stability of food products. When dissolved in water, alginate forms a stable gel that creates a coating layer around the product. The resulting film exhibits good impermeability to oil and oily substances; however, due to its hydrophilic nature, it has low resistance to water vapor permeability [8]. Gelatin is a protein-based compound derived from collagen. It contains 18 amino acids and possesses favorable properties for the preparation of edible coatings. When gelatin is dissolved and subsequently cooled, it forms a reversible gel. Gelatin-based films are transparent and have good consistency. The molecular weight of the gelatin used plays

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a key role in the characteristics of the resulting film or coating; higher molecular weights generally yield coatings of superior quality [8]. Dill (*Anethum graveolens*) is an annual or biennial plant known by various names, including "Shebet" or "Shevid". Dill is rich in phenolic compounds with antioxidant and antimicrobial properties. Traditionally, this plant has been used to treat convulsions, reduce pain and inflammation, stimulate appetite, strengthen the stomach, and, in postpartum women, to promote lactation [9]. As mentioned, replacing synthetic and chemical additives with plant-based and natural compounds is essential for both consumer health and environmental protection. Furthermore, the use of these natural compounds with antimicrobial and antioxidant properties in meat products helps preserve meat quality during storage [10].

Given the growing demand for natural compounds in food industries and their associated benefits, the present study aimed to develop an alginate-gelatin edible coating incorporating dill essential oil emulsion and nanoemulsion, and to evaluate its antimicrobial efficacy against *Listeria monocytogenes* inoculated in turkey meat during refrigerated storage.

2. Materials and Methods

2.1. Materials

A pure culture of *Listeria monocytogenes* (ATCC 7644) was obtained from the Department of Food Hygiene, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, and was cultured under sterile conditions. Other materials, including sodium alginate, gelatin, and Tween 80, were purchased from Sigma (Germany), while BHI (Brain Heart Infusion) broth and agar, peptone water, PALCAM agar, and Mueller-Hinton agar (MHA) were obtained from Merck (Germany).

2.2. Preparation and Analysis of Dill Essential Oil

Dill essential oil was purchased from Johareh Taam Shargh Company (Mashhad, Iran). To analyze the chemical composition of the essential oil, gas chromatography-mass spectrometry (GC-MS) was employed. An Agilent HP-6890 GC system (Palo Agilent Technologies, Alto, CA, USA) equipped with an HP-5MS capillary column (30 m length, 250 µm internal diameter, 0.25 µm stationary phase thickness) and a mass spectrometer (Agilent AHP-5973) operating at 70 eV was used. Initially, the oven temperature was held at 50 °C for 5 minutes, then increased to 290 °C at a rate of 5 °C per minute, and maintained at this temperature for 3 minutes. Helium was used as the carrier gas at a flow rate of 0.8 mL/min. The injector temperature was set at 240 °C, and the essential oil sample was injected manually. The chemical constituents of the essential oil were identified by comparing their retention indices, calculated using a series of normal alkanes, and by matching their mass spectra with those in the NIST05 library and the instrument's own GC-MS library. The relative percentage of each component was calculated based on the area under the corresponding peak in the chromatogram [11].

2.3. Preparation of Bacterial Culture and Microbial Suspension

Listeria monocytogenes (ATCC 7644) was obtained from the Department of Food Hygiene, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad. The bacterium was cultured on nutrient agar plates and incubated at 37 °C for 24 hours. Twenty-four hours prior to inoculation, the bacterium was sub cultured onto Mueller-Hinton agar slants. A bacterial suspension equivalent to 0.5 McFarland standard (approximately 1.5×10^8 CFU/mL) was then prepared using sterile Ringer's solution. The concentration of the prepared suspension was adjusted using a spectrophotometer at 625 nm to achieve an optical density in the range of 0.08–0.1. This procedure was performed with slight

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modifications according to the method described by Rabiey et al. (2013) [17].

2.4. Determination of MIC[1] and MBC[2] of Emulsion and Nanoemulsion of Dill Essential Oil

The microbroth dilution method was employed to determine the minimum inhibitory concentration (MIC). Initially, a bacterial suspension equivalent to 0.5 McFarland standard (approximately 1.5×10^8 CFU/mL) was prepared using sterile Ringer's solution. This suspension was then diluted to achieve a final concentration of 10^6 CFU/mL for the antimicrobial assessment. Dimethyl sulfoxide (DMSO) was used to prepare various concentrations of dill essential oil. Serial dilutions of the essential oil were prepared in the range of 0.125 to 32 mg/mL. For each well, 160 µL of BHI broth, 20 µL of the prepared essential oil concentrations, and 20 µL of the bacterial suspension were added sequentially. The assay was performed in triplicate. One well was designated as the negative control (without bacteria), and another as the positive control (without essential oil). The 96-well microplates containing the test mixtures were incubated at 37 °C for 24 hours. After incubation, the lowest concentration of essential oil in a well showing no visible turbidity was recorded as the MIC. To determine the MBC, samples from wells without visible turbidity were sub cultured onto BHI agar plates and incubated at 37 °C for another 24 hours. The lowest concentration at which no bacterial growth was observed on the agar plates was considered the MBC.

2.5. Preparation of Dill Essential Oil Emulsion and Nanoemulsion

Based on the results of the MIC and MBC assays, specific concentrations of dill essential oil (16 and 32 mg/mL) were prepared using Tween 80 at a ratio of 0.2 g/g of essential oil and deionized distilled water. The mixture was homogenized using an Ultra-Turrax homogenizer (T10 basic, IKA, Germany) at 3000 rpm for 5 minutes to obtain a uniform emulsion. For the preparation of the nanoemulsion, a modified method based on Azizian et al. (2019) was used. Initially, the desired concentrations of essential oil were mixed with Tween 80 and deionized water. The mixture was homogenized with the Ultra-Turrax homogenizer at 3000 rpm for 3 minutes, followed by sonication using a probe-type ultrasonic device (50 °C, pulse: 45 s, rest: 15 s) for 15 minutes to achieve nanoemulsion formation [13].

2.6. Evaluation of Antioxidant Activity of Dill Essential Oil by DPPH Method

The antioxidant activity of dill essential oil was assessed based on its ability to donate hydrogen atoms or electrons, as indicated by the decolorization of the purple DPPH solution in methanol. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) was used as the radical compound. For the assay, 0.1 mL of various concentrations of dill essential oil were added to 3.9 mL of 0.1 mM DPPH solution (39.43 mg/L). The prepared solutions were kept at room temperature in the dark for 30 minutes, after which the absorbance was measured at 517 nm. The percentage of DPPH radical scavenging was calculated using the following formula:

$$I\% = (A_{blank} - A_{sample} / A_{blank}) \times 100$$

where, A_{blank} represents the absorbance of the negative control (without essential oil), and A_{sample} indicates the absorbance of the different concentrations of dill essential oil [14].

1 -Minimum inhibitory concentration

2 -Minimum bactericidal concentration

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2.7. Particle Size Determination of Dill Essential Oil Nanoemulsion

Dynamic light scattering (DLS) (VASCO, Nano-Particle Size Analyzer, France) was used to determine the particle size and distribution of the dill essential oil nanoemulsion. For this purpose, 1 mL of the solution was placed in the instrument, and the particle size was measured [15].

2.8. Preparation of Turkey Meat

Turkey meat samples were purchased from Esteghlal Market (Mashhad, Iran), transported to the laboratory in special containers under refrigerated conditions (4 °C), and processed within one hour. The meat was cut into 10 g portions, washed with sterile distilled water, and then sterilized with 70% ethanol prior to bacterial inoculation.

2.9. Bacterial Inoculation into Meat Samples

Initially, a suspension of *L. monocytogenes* equivalent to 0.5 McFarland standard was prepared. Serial dilutions were then performed to achieve a final concentration of 10^6 CFU/mL, which was subsequently inoculated onto the meat samples. All experiments were conducted in triplicate.

2.10. Preparation of Alginate-Gelatin Edible Coating and Coating of Meat Samples

To prepare the sodium alginate-gelatin coating with a total solid concentration of 4%, 2 g of alginate and 2 g of gelatin were dissolved in sterile distilled water to a final volume of 100 mL. The mixture was heated on a magnetic stirrer at 60 °C until a clear solution was obtained. Tween 80 (0.2 g/g of essential oil), as well as dill essential oil emulsion and nanoemulsion at two concentrations (16 and 32 mg/mL), were added to the coating solutions. Turkey meat samples, cut to the desired sizes for chemical, microbiological, and sensory analyses, were prepared in six different treatment groups (Table 1). The meat pieces were immersed in the coating solutions for approximately 2 minutes, followed by immersion in a 2% calcium chloride solution to form a strong gel. Control samples were prepared without any coating. Both coated and uncoated (control) turkey meat pieces were packaged in sterile polyethylene zip-lock bags and stored at 4 °C [19].

Table 1. Research treatments

	Treatment
1	Control
2	ALG+G
3	ALG+G+AEO1 (16 mg/ml)
4	ALG+G+AEO2 (32 mg/ml)
5	ALG+G+NEO1 (16 mg/ml)
6	ALG+G+NEO2 (32 mg/ml)

2.11. Enumeration of *Listeria monocytogenes*

To each 10 g meat sample, 90 mL of sterile 0.1% peptone water was added. The mixture was thoroughly homogenized using a stomacher (Bag Mixer 400CC, Interscience, France), and serial dilutions (10^{-1} to 10^{-6}) were prepared. Aliquots were then surface-plated onto PALCAM agar. The plates were incubated at 37 °C for 24 hours, and the results were expressed as Log10 CFU/g [19].

2.12. pH Determination

10 g of the meat sample were thoroughly homogenized with 90 mL of distilled water. The pH was then measured using a digital pH meter (Metrohm, Switzerland).

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2-13. Measurement of Total Volatile Basic Nitrogen (TVB-N[3]):

For TVB-N analysis, 10 g of turkey meat, 2 g of magnesium oxide, and 300 mL of distilled water were added to a distillation flask. The mixture was heated for 15 minutes. The volatile nitrogenous bases released during distillation were collected in an Erlenmeyer flask containing 25 mL of 2% boric acid and a few drops of methyl red indicator. When the total volume of boric acid and condensed distillate reached 150 mL, the final solution was titrated with 0.1 N sulfuric acid until a reddish onion skin color appeared. The TVB-N content (mg TVB-N/100 g) was calculated based on the volume of sulfuric acid consumed during titration using the following formula:

$$TVB\text{-}N = 14 \times N \times V \times 100$$

2.14. Measurement of Thiobarbituric Acid (TBA)

10 g of the sample were thoroughly mixed with 90 mL of distilled water. The mixture was transferred to a distillation flask, and 2.5 mL of 4 N hydrochloric acid, along with antifoam and anti-bumping agents, were added. The flask was connected to a distillation apparatus, and the mixture was heated. After boiling, 50 mL of the distillate were collected. Subsequently, 5 mL of the distillate and 5 mL of TBARS reagent (prepared by mixing 10 mL of 90% glacial acetic acid and 0.2883 g TBARS powder) were transferred to stoppered test tubes, thoroughly mixed, and placed in a boiling water bath for 35 minutes. All steps were simultaneously performed for the control sample. After heating, the samples were cooled for 10 minutes, and the absorbance of TBA was measured against the control at 538 nm and TBA value demonstrated as mg of malonaldehyde equivalents per kg of meat [20].

2.15. Sensory Evaluation

Sensory and organoleptic properties of the samples were assessed using a 9-point hedonic scale by a panel of eight trained evaluators. The test was performed in triplicate. Raw samples were evaluated for odor, color, texture, and overall acceptability. Sensory evaluation was conducted over a 12-day period at 3-day intervals.

2.16. Statistical Analysis

All experiments were performed in triplicate. Data analysis was carried out using SPSS version 16. One-way analysis of variance (ANOVA) followed by Duncan's test was used to determine significant differences between mean values. A p-value of <0.05 was considered statistically significant.

3. Results and Discussion

3.1. Determination of Dill Essential Oil Composition

The composition of plant essential oils varies depending on climatic conditions, harvest time, harvesting method, plant genotype, species, and extraction conditions. Analysis of the dill essential oil in the present study revealed that α-phellandrene (51.89%), carvone (10.21%), and limonene (8.26%) were the main constituents. In the study by Hartmans et al. (1995), carvone (40%), limonene (32%), and α-phellandrene (20%) were reported as the primary components of dill essential oil [21]. Similarly, in the study by Carvalho and Fonseca (2006), carvone was identified as a major constituent, which is consistent with the findings of the present study [22].

3.2. Characteristics of Dill Essential Oil Nanoemulsion

The polydispersity index (PDI) numerically indicates the distribution of colloidal nanoparticle sizes; lower values reflect greater particle uniformity. Generally, a PDI value below 0.3 indicates a relatively homogeneous emulsion [30]. In this study, the PDI was 0.23 and the particle size of the dill essential oil nanoemulsion was 141.92 nm, indicating a uniform nanoemulsion solution.

3.3. MIC and MBC of Dill Essential Oil Emulsion and Nanoemulsion

The use of plant essential oils offers a suitable alternative to synthetic compounds, as these natural substances are environmentally friendly and exhibit both antibacterial and antioxidant activities. According to the results, the MIC for

3- Total volatile basic nitrogen

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the emulsion and nanoemulsion of dill essential oil was 8 and 2 mg/mL, respectively, while the MBC was 16 and 4 mg/mL, respectively. The MIC and MBC values of this essential oil can be attributed to the presence of active compounds such as the monoterpenes limonene and carvone, which inhibit bacterial growth [22]. Derakhshan et al. (2017) investigated the antimicrobial effects of dill essential oil against *Staphylococcus aureus* and *Vibrio cholerae* and demonstrated that dill essential oil exhibited desirable antimicrobial activity against both bacteria [23]. In the study by Nanasombat and Wimuttigosol (2011), the antimicrobial effects of dill essential oil were evaluated against a group of microorganisms, and the MIC values for *S. aureus* and *Escherichia coli* were found to be 6 and 10 mg/mL, respectively, which are in agreement with our findings [24]. Another study examined the antibacterial activity of dill seed essential oil against several pathogenic bacteria, including *Vibrio cholerae*, *E. coli*, *Pseudomonas aeruginosa*, and *S. aureus*, as well as its effect on biofilm formation by *Klebsiella pneumoniae*. The results showed that dill essential oil exhibited significant activity against the tested strains, which is consistent with the findings of our study [25].

3.4. Antioxidant Activity of Dill Essential Oil

The results of the DPPH assay indicated that the IC50 value of dill essential oil was 44.11 µg/mL. The antioxidant activity of flavonoids, which are specific phenolic compounds, is attributed to their ability to donate hydrogen atoms. In the study by Bahramikia and Yazdanparast (2008), the fractions of extracts obtained using diethyl ether and ethyl acetate were evaluated, and the EC50 values for the diethyl ether and ethyl acetate fractions were 124.1 µg/mL and 75.6 µg/mL, respectively, which are consistent with our findings [26]. Similarly, Faramarzi Dozein et al. (2021) reported the antioxidant activity of dill essential oil to be less than 200 µg/mL, in agreement with our results [31]. In another study by Zeilab Sendijani et al. (2020), the antioxidant activity of the hydroalcoholic extract of dill was found to be 69.84 µg/mL, which also aligns with our findings [32].

3-5. Microbial Changes

The mean logarithmic growth of *L.monocytogenes* during the storage period is presented in Figure 1. On day zero, the mean bacterial count in all samples was approximately 5.4-12.95 Log CFU/g. During storage, bacterial growth increased, with the rate of increase being higher in the control group compared to the other treatments. On the final day, the mean bacterial count in the control sample reached 8.10 Log CFU/g, representing the highest bacterial load among all groups. The mean logarithmic bacterial count in the alginate-gelatin coating without essential oil was considerably higher than in the samples containing essential oil, indicating that the addition of essential oil enhanced the antimicrobial properties of the coating. The mean logarithmic bacterial count in the alginate-gelatin coating increased from 5.04 Log CFU/g on day zero to 7.75 Log CFU/g on day 12. In samples containing essential oil, the results demonstrated that higher concentrations of essential oil exhibited greater antimicrobial activity, and the use of dill nanoemulsion provided superior antimicrobial effects compared to the emulsion. In the present study, the lowest *Listeria monocytogenes* count was observed in the treatment with alginate-gelatin coating containing dill nanoemulsion. Overall, all coated treatments showed a good ability to inhibit the growth of *L.monocytogenes* compared to the control. In the study by Raeisi et al. (2016) on poultry meat, *Listeria* counts increased during storage, and in the control sample, the bacterial count reached 8.23 Log CFU/g on the last day. Their results showed that sodium alginate coatings containing cinnamon and rosemary essential oils, combined with the antimicrobial agent nisin, were effective in preserving chicken meat, which is consistent with our findings [27].

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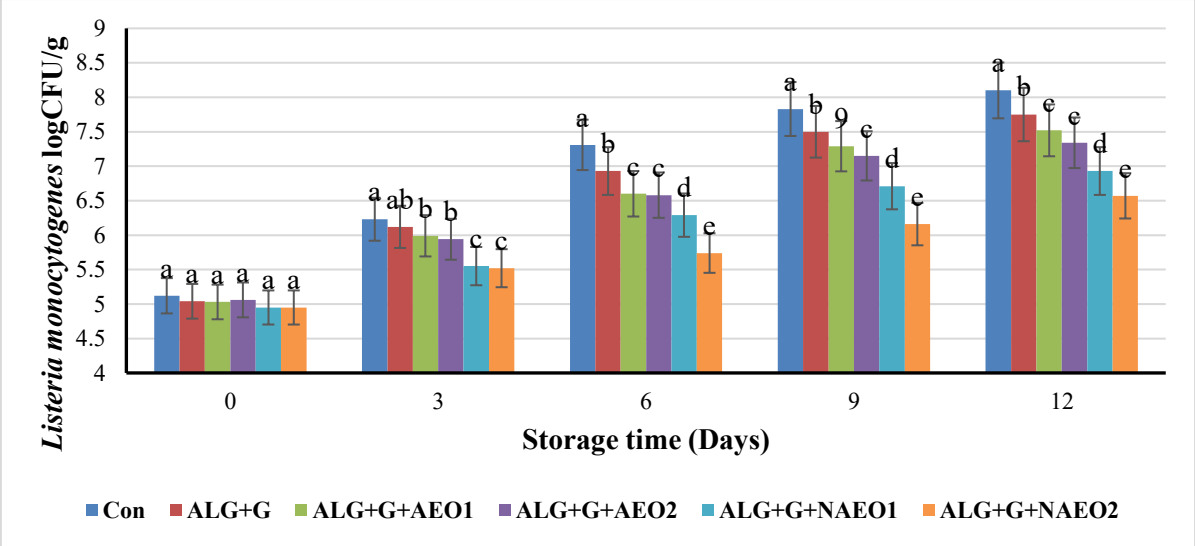

Fig 1 Bacterial survival of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

3.6. Chemical Changes

3.6.1. pH

The results of pH evaluation for refrigerated turkey meat are presented in Figure 2. The pH assessment in this study indicated that, with increasing storage time, protein degradation and the production of alkaline compounds increased, resulting in a rise in pH [28]. In samples containing essential oil, especially the nanoemulsion, the pH values were significantly lower than those of the control group. The findings demonstrated that the use of alginate-gelatin edible coatings containing dill essential oil emulsion and nanoemulsion effectively extended the shelf life of turkey meat and controlled pH levels throughout the storage period. In the study by Ehsani et al. (2019) on turkey meat, the initial pH in samples without antimicrobial compounds was 5.86, rising to 7.07 after 15 days of storage, which is consistent with our results [29].

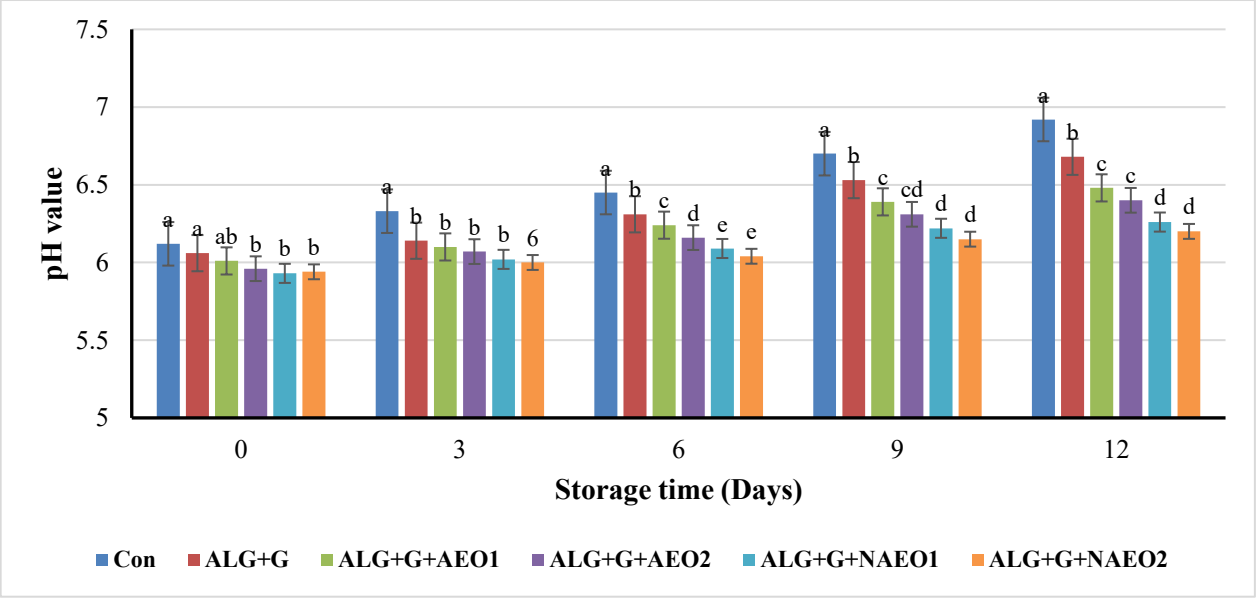

Fig 2 Average of pH changes of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

3.6.2. Total Volatile Basic Nitrogen (TVB-N)

The levels of total volatile basic nitrogen (TVB-N) were evaluated in all six groups during the storage period (Figure 3). The results showed

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that TVB-N values increased over time, with the highest increase observed in the control samples. However, the TVB-N content in the coated samples was significantly lower than in the control group, with the lowest levels detected in samples containing dill nanoemulsion. Compounds such as ammonia, primary, secondary, and tertiary amines, as well as the accumulation of monoethylamine and trimethylamine, constitute the total volatile basic nitrogen. The TVB-N test measures all of these compounds collectively as volatile basic nitrogen [29].

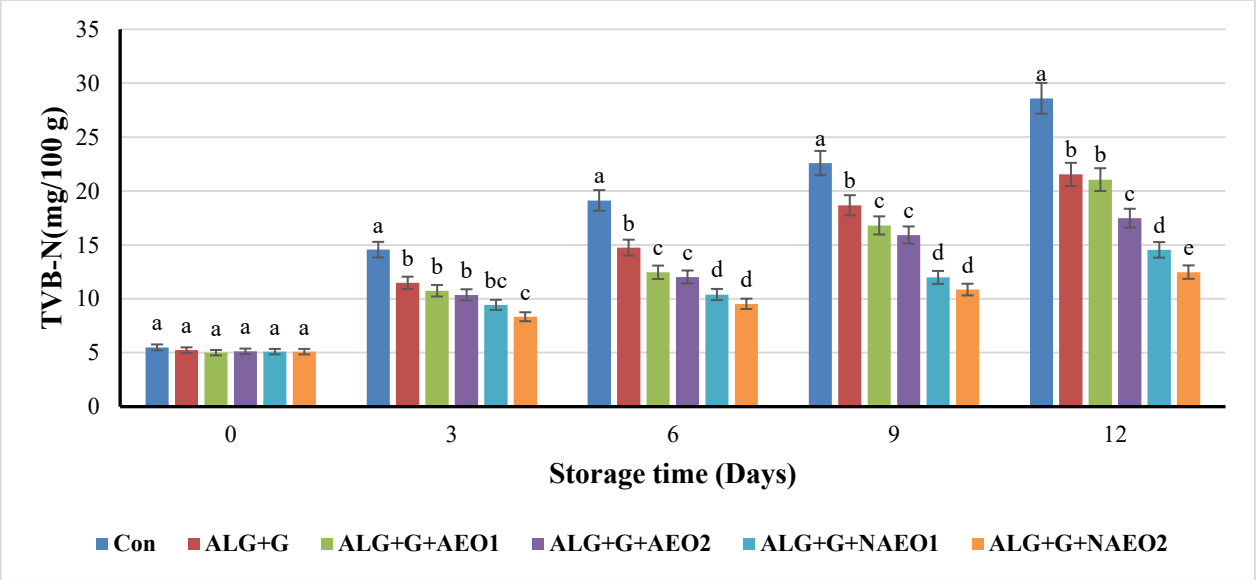

Fig 3 Average TVB-N changes of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

3.6.3. Thiobarbituric Acid (TBA)

As shown in Figure 4, the thiobarbituric acid (TBA) value increased throughout the storage period in all groups. Samples containing dill essential oil exhibited the lowest TBA values due to the antioxidant properties of the oil. At the beginning of the study, the mean TBA values ranged from 0.23 to 0.25 mg MDA/kg. In the control group, TBA levels increased more rapidly, reaching a mean value of 1.80 mg MDA/kg by the end of the storage period. In contrast, in the samples containing essential oil, TBA values on day 12 ranged from 0.41 to 0.82 mg MDA/kg. TBA levels in the nanoemulsion-containing samples were significantly lower than those in the emulsion-containing samples. The lowest TBA value, with a mean of 0.41 mg MDA/kg, was observed in the alginate-gelatin coating containing 32 mg/mL dill nanoemulsion.

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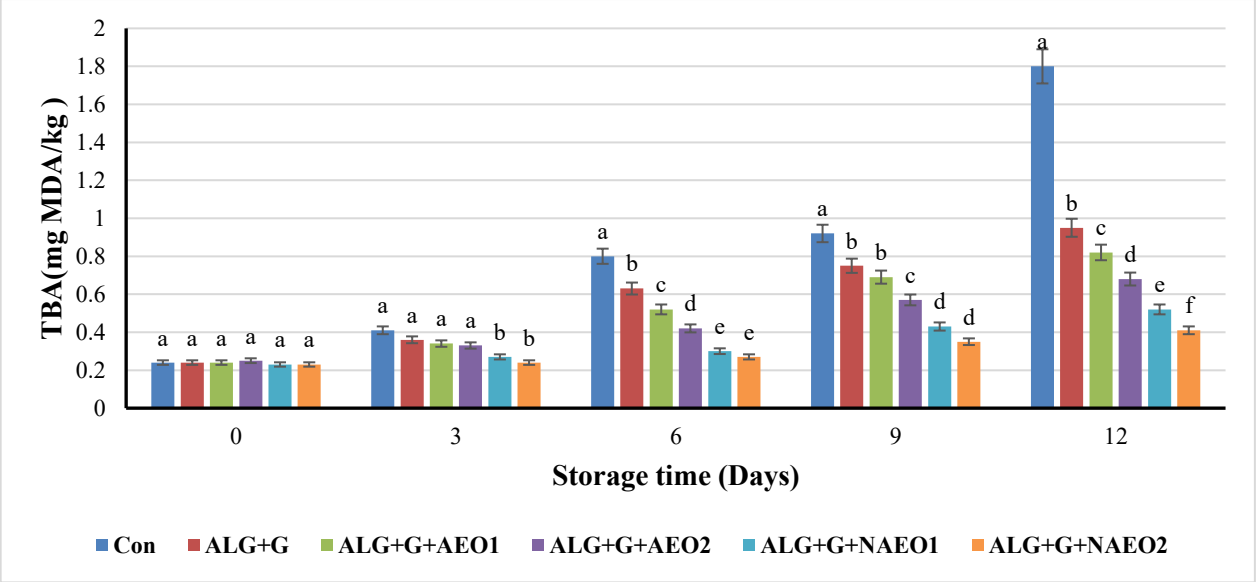

Fig 4 Average TBA changes of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

3.7. Sensory Evaluation

The results of the sensory evaluation in the present study (Figures 5, 6, 7, and 8) showed that all assessed factors—including odor, color, texture, and overall acceptability—received acceptable scores in all samples at the beginning of the study. Over time, the scores for all samples decreased; however, in the control group (without any coating), the samples were deemed unacceptable and organoleptically unsuitable by the end of the storage period. In contrast, the coated samples, especially those containing essential oil, received higher scores. The results further indicated that samples coated with the dill essential oil nanoemulsion achieved higher sensory scores than those coated with the essential oil emulsion.

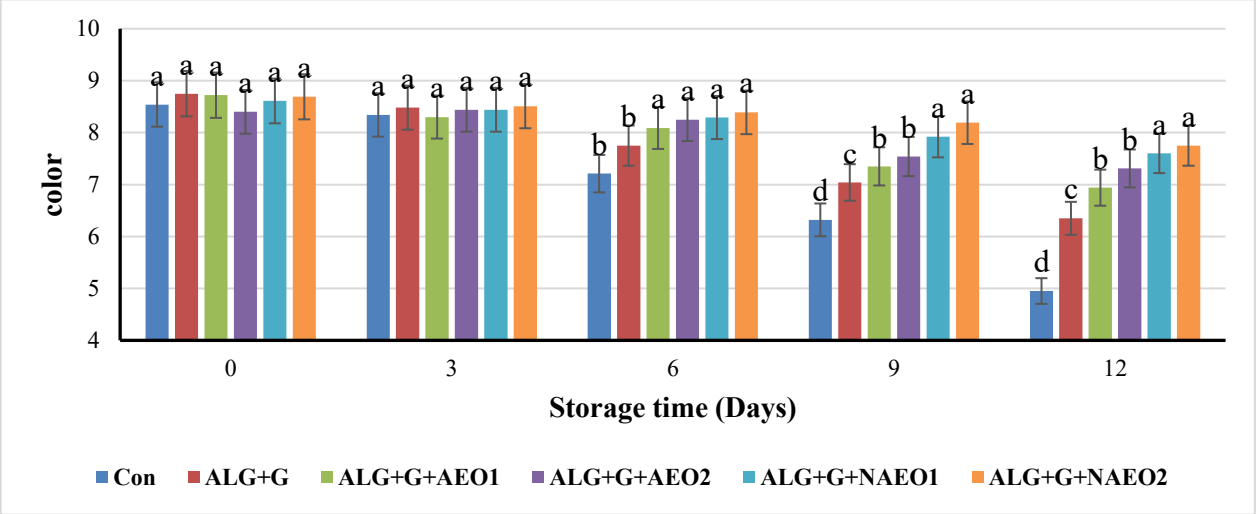

Fig 5 Changes of color in sensory evaluation of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

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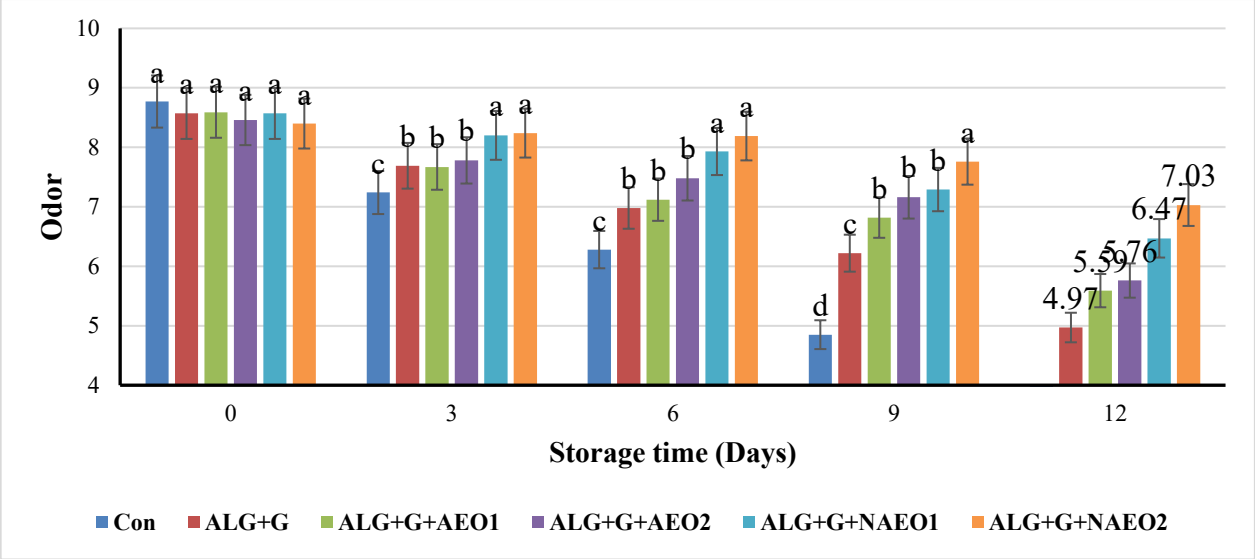

Fig 6 Changes of odor in sensory evaluation of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different (p <0 .05).

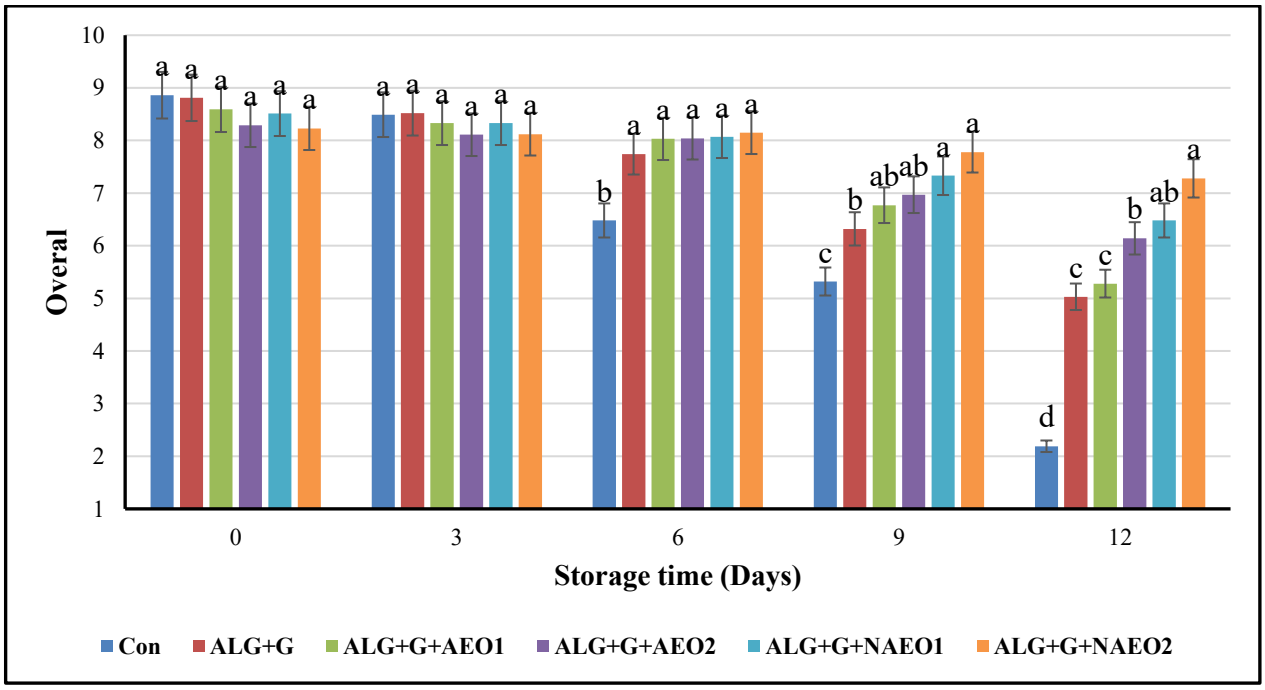

Fig 7 Changes of overall acceptance in sensory evaluation of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different (*p <0 .05*).

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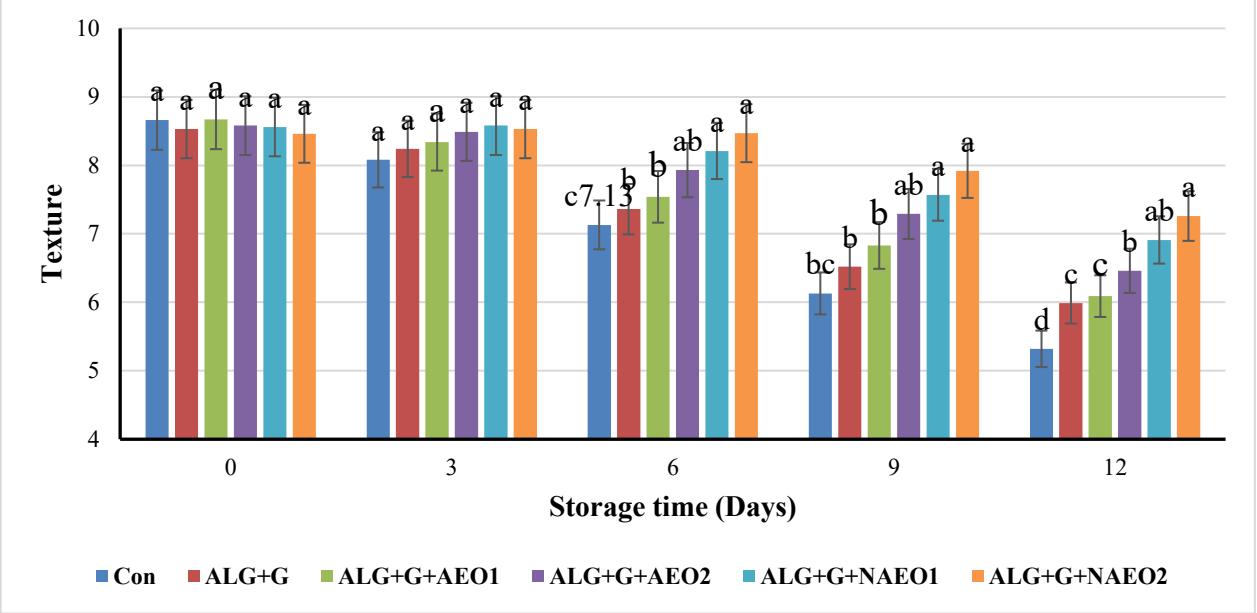

Fig 8 Changes of texture in sensory evaluation of different treatments during storage at 4 °C for 12 days. Mean values for the same column with different letters are significantly different ($p < 0.05$).

4. Conclusion

The results of the present study demonstrated that the incorporation of dill essential oil, in both emulsion and nanoemulsion forms, into alginate-gelatin edible coatings effectively extended the shelf life of turkey meat. The findings indicated that alginate-gelatin coatings containing dill essential oil emulsion and nanoemulsion were able to effectively control the growth of *L. monocytogenes*, a major foodborne pathogen in the food industry. Moreover, the application of nanotechnology and the preparation of dill essential oil nanoemulsion enhanced its antimicrobial and antioxidant properties. Overall, it can be concluded that alginate-gelatin edible coatings containing dill essential oil emulsion and nanoemulsion, due to their favorable antimicrobial and antioxidant activities, have significant potential for use in the packaging of meat products to inhibit the growth of pathogenic and spoilage bacteria and to increase product shelf life.

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مقاله علمی_پژوهشی

اثر ضد میکروبی پوشش خوراکی آلژینات- ژلاتین حاوی امولسیون و نانوامولسیون اسانس شوید (*Anethum graveolens*) علیه *لیستریا مونوسیتوژنز* تلقیح شده به گوشت بوقلمون

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چکیده

در این پژوهش اثر پوشش خوراکی آلژینات سدیم-ژلاتین (۲٪ / ۲٪)، حاوی امولسیون اسانس شوید (۱٦ و ۳۲ میلی گرم در میلی لیتر) و نانوامولسیون اسانس شوید (۱٦ و ۳۲ میلی گرم در میلی لیتر) در طول دوره نگهداری گوشت بوقلمون در دمای ٤ °C بررسی شد. ترکیبات اصلی اسانس با دستگاه GC-MS اندازه گیری شد که شامل آلفافلاندرن(۵۱/۸۹ ٪)، کارون(۱۰/۲۱ ٪) و لیمونن(۸/۲٦ ٪) بود. حداقل غلظت مهار کنندگی(MIC) و حداقل غلظت کشندگی(MBC) امولسیون اسانس شوید علیه *لیستریا مونوسیتوژنز* به ترتیب ۸ mg/ml و ۱٦ mg/ml و MIC و MBC نانوامولسیون اسانس شوید به ترتیب ۲ mg/ml و ٤ بود. میزان باکتری در روز ۱۲ در تیمار کنترل (۸/۱ Log)، تیمار پوشش ژلاتین-آلژینات (۷/۷۵ Log)، تیمار امولسیون (۷/۳٤ Log) و تیمار نانوامولسیون اسانس شوید (٦/۵۷ Log) بود. با افزایش غلظت اسانس شوید، خاصیت ضدمیکروبی افزایش یافت و تیمار حاوی نانوامولسیون در مقایسه با امولسیون اسانس، تاثیر بهتری در کنترل رشد *لیستریا مونوسیتوژنز* داشت. کمترین میزان تیوباربیتوریک اسید (TBA) مربوط به تیمارهای حاوی امولسیون (۰/٦۸ mg MDA/kg) و نانوامولسیون (mg MDA/kg ۰/٤۱) اسانس شوید بود. تیمارهای حاوی اسانس در طول دوره pH پایین تری نسبت به نمونه کنترل داشتند و میزان TVN کمتری را نشان دادند. نتایج نشان داد، پوشش خوراکی ژلاتین-آلژینات سدیم حاوی امولسیون و نانوامولسیون اسانس شوید دارای اثر مثبت برای کنترل رشد باکتری *لیستریامونوسیتوژنز*، فاکتور های اکسیداسیون و حسی در گوشت بوقلمون می باشد.

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