Original Article

Investigating the Effect of Quince Seed Mucilage Film Reinforced With Carboxymethyl Cellulose Containing Ginger Essential Oil on the Microbial, Physicochemical and Sensory Characteristics of Turkey Meat

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ABSTRACT

The prevention of spoilage in food products, particularly those types that are susceptible to rapid deterioration, such as poultry meat, has historically posed a significant challenge within the food industry. The objective of this study was to examine the impact of a castor bean mucilage film fortified with carboxymethyl cellulose and incorporating ginger essential oil (GEO) on the characteristics of turkey meat. The preparation of GEO and the subsequent chemical composition analysis via gas chromatography (GC/MS) were undertaken to ascertain its properties.The experimental design involved the utilization of a control group (C), a quince seed mucilage film reinforced with carboxymethyl cellulose (film), a film containing 1% essential oil (film+1% GEO), and a film containing 2% essential oil (film+2% GEO). Subsequently, an array of assessments was conducted to ascertain the microbial properties (aerobic, psychrotrophic, lactic acid, and Enterobacteriaceae bacteria), chemical properties (pH, PV, TVB-N, and TBARS), and sensory evaluation. Additionally, the physical properties of the films, including tensile strength (TS), water vapor transmission rate (WVTR), elongation at break (EAB), humidity, swelling, thickness, and transparency, were investigated. The results of this investigation indicated the presence of zingiberene (15.71%), α-curcumene (11.39%), and β-sesquiphellandrene (10.69%) as the predominant compounds in GEO. The film+2% GEO treatment was identified as the most effective treatment in all microbial properties, exhibiting a significant difference compared to the other treatments, particularly the control group ($P<0.05$). The findings demonstrated enhancements in the physical and chemical characteristics of the samples treated with film, particularly with film+2% GEO in comparison to the control group. For instance, the level of TVB-N escalated from 10.67 mg/100g on day 0 to 21.61 mg/100g on the final day, whereas the levels observed for the control treatment on day 0 and 12 were 10.68 mg/100g and 10.0 mg/100g, respectively. The increase in TVB-N content was 39.95%. The sensory evaluation revealed that the application of the film led to an enhancement in the sensory characteristics of the samples across all parameters, with the exception of appearance. The study's findings indicate that the incorporation of Quince seed mucilage film reinforced with carboxymethyl cellulose, particularly when supplemented with essential oil, can be regarded as a contributing factor in the preservation and enhancement of the quality of food items, particularly meat products.

Keywords: Shelf Life, Food Safety, Essential Oil, Edible Films.

1. Introduction

Meat is regarded as the primary animal-derived foodstuff with high nutritional value. In recent decades, an increasing global preference for poultry meat has been observed, driven by its recognized nutritional benefits (1). Turkey meat, a type of poultry meat, is particularly noteworthy due to its low fat content, low cholesterol levels, high protein content, and vitamins (such as B12 and niacin) and minerals (e.g., calcium, phosphorus, zinc, sodium, selenium, and potassium) (1, 2). Turkey meat is available in various forms, including fresh and frozen whole-bird carcasses or cut into pieces such as breasts and legs (1, 2). However, it is important to note that poultry meat is considered a perishable food item. This means that it is vulnerable to adverse microbial activity and oxidative reactions. Additionally, it can act as a matrix for the growth of pathogenic and spoilage bacteria (3). A variety of methods are employed to protect food; one such method that has emerged in recent years is the use of biodegradable compounds (polysaccharides, proteins, lipids, and composites) in the form of edible film and coating (4, 5, 6), which has reduced dependence on antibiotics and chemical preservatives in food products (7, 8, 9). Mucilages can be classified as a type of compound. Mucilage is a combination of polysaccharides, proteins, and minerals found in plants and seeds. The utilization of mucilages has witnessed a marked increase in recent times, owing to their numerous benefits. These materials have found widespread application in the food and pharmaceutical industries. In the food industry, mucilages serve a variety of functions, including stabilizing, thickening, and prebiotic properties (10). The technological and nutritional characteristics of plant seeds have rendered mucilage a premier material in the fabrication of edible films (10). The seeds of the fruit in question can be utilized as a source for the preparation of mucilage. Quince fruit, with a diameter ranging from 10 to 12 centimeters, is a product of the Quince tree (11) and is classified as a member of the Rosaceae family. The fruit's physical characteristics include an irregular and variable shape, accompanied by a distinctive aroma. Research findings indicate that the fruit composition consists of 90.6% brain (pulp), 4.4% skin, and 5.05% core with seeds. Notably, these seeds, which are characterized by their brown pigmentation, have been observed to exhibit rapid water absorption, resulting in the production of a viscous and devoid of taste substance (11, 12). In order to prepare edible films and to enhance antimicrobial and mechanical properties, the combination of several biopolymers has been demonstrated to be effective (13, 14). Cellulose, the most abundant polysaccharide in nature, is extracted from diverse sources such as wood, cotton, food waste, agricultural residues, cereal bran, fruit peel, and other materials (13). As an edible and water-soluble polymer, cellulose is widely employed in food processing as a thickener and stabilizer. Carboxymethylcellulose (CMC), an anionic polysaccharide derived from the alkaline-catalyzed reaction of cellulose with chloroacetic acid, has received GRAS approval, signifying its safety (13). This compound is among the most prevalent cellulose-derived substances, capable of forming transparent film layers that exhibit flexibility and acceptable mechanical properties, thereby safeguarding food products against oxygen, moisture, and fat (13). Edible films offer an opportunity to incorporate various additives, such as antimicrobial agents, antioxidants, and natural preservatives, including plant essential oils (15, 16, 17). Ginger essential oil is a notable example of an essential oil utilized in this industry. Ginger (Zingiber officinale Rosc.) belongs to the Zingiberaceae family. The essential oil of the ginger plant (Zingiber officinale Rosc.) is extensively cultivated in Southwest Asian countries, particularly China, and due to its distinctive organoleptic properties, it is employed as a flavoring agent in the food, cosmetic, and pharmaceutical industries that necessitate antimicrobial activities (18). The present study was conducted with the objective of providing a method to enhance food safety by investigating the effect of Quince seed mucilage film reinforced with carboxymethyl cellulose containing GEO on the microbial, physicochemical, and sensory characteristics of turkey meat.

2. Materials and Methods

2.1. Preparation of Mucilage

The seeds were meticulously washed three times with distilled water using a fabric sieve to ensure the removal of any foreign matter. The purified seeds were then dispersed in distilled water maintained at a temperature of 45°C. Subsequent to the hydration of the seeds, they were exposed to ultrasonic waves at varying power levels (20%, 60%, and 100%) and varying durations (5, 15, and 30 minutes). The ultrasonic device employed in this study had a frequency of 24 kHz and a power of 400 watts. To circumvent a sudden escalation in temperature, the sample glass was ensconced within an insulated container containing ice, with the temperature being meticulously regulated at one-minute intervals. Subsequently, the seeds were separated from the solution by means of a multilayer mesh filter and a Buchner funnel connected to a vacuum pump. Subsequently, the mucilage was precipitated using 96% ethanol in a volume three times the solution. Following this step, the sediment was subjected to drying in an oven maintained at a temperature of 50°C. Thereafter, the dried sediment was stored in plastic containers, designated as samples 19, 20, and 21 for the subsequent analysis.

2.2. Extracting GEO and Identifying Its Compounds

The ginger plant (2000 g) was collected and approved by the Institute of Plant Sciences at the University of Tehran. The essential oil was then extracted using a celevenger device (G-klm, Iran). To mitigate heat loss, insulation was applied to the celevenger pipe, which is situated prior to the refrigerant and through which the water vapor passes. Subsequently, the heat source was activated. Subsequent to the completion of the extraction process, the outlet valve of

the clip was meticulously opened, and the essential oil was decanted into a separate container. The extraction process yielded 1 microliter of plant essential oil.The essential oil was then analyzed using a gas chromatography-mass spectrometer (GC/MS) (Bruker, USA). The chemical composition of the essential oil was determined by comparing its standard mass spectra with those of known compounds and calculating the inhibition index. This index was then compared with the standard values reported in the literature. The identification of the essential oil was facilitated by the utilization of the C8-C28 alkane series (22).

2.3. Preparation of Films

First, 1% mucilage was gradually dissolved with 3.5% w/w glycerol (softener) for a period of 15 minutes at a temperature of 45°C. This was conducted under a magnetic stirrer at a speed of 750 r/min. Subsequently, GEO at varying concentrations (1% and 2%) and 1% carboxymethyl cellulose (Sigma-Aldrich, USA) (v/v) were incorporated into the solution for a duration of 1 hour at a temperature of 25°C using a magnetic stirrer. Thereafter, 0.2% Tween 80 (v/v) was added to the solution as a surfactant, and the solution was homogenized with a homogenizer (Benchmark, USA) at 12,000 rpm for 5 minutes. The solution was subsequently subjected to a centrifugal process at a speed of 3800 revolutions per minute for a duration of three minutes, with the objective of eliminating air bubbles. Subsequently, 50 g of the solution was dispensed onto a mold or a glass plate. The container was then placed under a vacuum hood for 24 hours at a temperature of 25°C and a relative humidity of 37% (23).

2.4. Preparation of Turkey Meat and Preparation of Treatments

Fresh turkey meat was procured from reputable supply centers and transported to the laboratory under refrigerated conditions. Following this, the samples were meticulously cleaned and divided into 100-gram pieces. Subsequent to this, the samples underwent a thorough washing process with water to ensure the removal of any extraneous materials. Thereafter, they were washed with sterile distilled water to assess their chemical, sensory, and microbial flora properties. The samples were meticulously arranged between two films, each prepared for a distinct treatment, and subsequently enclosed in sterile polyethylene bags. The samples were stored at refrigeration temperature for the duration of the study, which spanned 12 days (Figure 1). On days 0, 2, 4, 7, 9, and 12, samples were subjected to a series of tests to assess various parameters (1).

2.5. Film Properties

2.5.1. Thickness Measurement

The thickness of the Quince seed mucilage and carboxymethyl cellulose (CMC) films was measured using a digital hand micrometer with an accuracy close to 0.0001 millimeters for each film and at least 10 measurement points for each sample. The average of these measurements was then calculated (24).

2.5.2. Moisture

The pieces of the film were meticulously cut into dimensions of 3×3 mm and weighed. Subsequently, the samples were placed in an oven maintained at 90°C until a constant dry weight was achieved. Subsequent to this, the samples were weighed once more, with a precision of ± 0.0001 g, and the moisture content of the films was calculated using the following formula (24).

Moisture (%) = (wet sample weight- dry sample weight / wet sample weight) × 100

2.5.3. Water Vapor Transmission Rate (WVTR) and Clarity

The WVTR was performed in accordance with the method established by Moradi et al. (2012). To assess the transparency, the films were meticulously cut into square shapes and positioned within the cells of the spectrophotometer. The optical absorbance was then measured at a wavelength of 600 nm. The amount of transparency was calculated from the following formula (25).

2.5.6. Tensile Strength (TS), and Elongation at Break (EAB) and Swelling Index

A tensile strength (TS) test was conducted using a tissue tester, and the elongation at break (EAB) was measured using the Universal Testing Instrument Model AI.5000 (25).

2.6. Microbial Properties

A 10-gram sample was thoroughly mixed with 90 milliliters of 0.1% peptone water diluting solution in a Stomaker (WIGGENS HG400, Germany). Various dilutions were subsequently prepared from this mixture. The enumeration of aerobic bacteria, psychrotrophs, enterobacteriaceae, and lactic acid bacteria at multiple time points (0, 2, 4, 7, 9, and 12) was conducted on turkey meat samples (26).

2.7. Chemical Properties

The measurement of volatile nitrogen bases (TVB-N) of the samples was performed according to the method of Ojagh et al. (2010) and was reported based on milligrams of free nitrogen per 100 grams of turkey meat (24). To measure the amount of thiobarbituric acid, TBARS was performed according to the method of Khalaf et al. (2013) and was reported as mg of malondialdehyde per kg of turkey meat. To measure the pH, 10 g of turkey meat sample was mixed with 90 ml of distilled water and homogenized. Finally, the pH of the samples was measured in 3 repetitions with the help of a pH meter (Jenway, England). Subsequent to the extraction of fat from the meat, the peroxide value (PV) was determined in accordance with the AOAC (1990) standard and reported as milliequivalents of peroxide per kilogram of turkey meat oil (27).

2.8. Sensory Evaluation

A group of 12 trained panelists evaluated turkey meat samples. The participants were asked to rate various qualitative characteristics of the meat, including its color, texture, taste, aroma, and overall acceptance. A scale ranging from 0 to 5 was employed to quantify the panelists'

assessments, with 5 representing the highest level of quality or acceptance and 0 representing the lowest.

2.9. Statistical Analysis

A series of tests were conducted on fish fillet samples that had been subjected to various treatments. The resulting data were meticulously documented in Excel software. Subsequently, statistical analysis was conducted using SPSS version 21 software. A P value less than 0.05 was considered statistically significant. The analysis of variance test was employed to ascertain the statistically significant differences between the treatment and control conditions. Furthermore, the Duncan statistical test was employed to compare the differences between means at the 0.05 level. In instances where the distribution of the data obtained from the research was found to be normal, repeated measure ANOVA was utilized to investigate the changes in chemical, microbial, and sensory characteristics in the treatments.

3. Results

3.1. Chemical Composition of GEO

The results of the analysis of the identified GEO compounds are presented in Table 1. The results indicated that 19 chemical compounds, among which zingiberene with 15.71% (the most abundant compound), alpha curcumin with 11.39%, and betasesquiflandrene with 10.69%, are the primary compounds of GEO.

3.2. Physical Characteristics

The results of the physical characteristics are displayed in Figure 2. In the pure film, the tensile strength (TS), water vapor transmission rate (WVTR), elongation at break (EAB), moisture content, swelling content, thickness content, and transparency content were reported to be 43.27 MPa, 10 g mm/kPa h m2, respectively. The respective values for these parameters were recorded as 54.0%, 62.81%, 34.77%, 38.29%, 0.91 mm, and 0.85 mm. In the Film+2% GEO condition, the observed values were 29.42 MPa, 32.39 g mm/kPa h m2, 45.01%, 21.31%, and 27.06%, 0.76 mm, and 0.602 mm, respectively. The incorporation of GEO into the film resulted in a substantial decline in all physical parameters when compared to the pure film ($P<0.05$). However, when the physical properties of Film+1% GEO and Film+2% GEO were compared, no statistically significant differences were observed ($P<0.05$).

3.3 Microbial Properties

As indicated in Table 2, the population of lactic acid-producing bacteria exhibited an upward trend across all treatment groups throughout the study period. From day 2 onward, a statistically significant discrepancy was observed between the control treatment and the remaining treatments, persisting until the conclusion of the study on day 12 ($P<0.05$). Additionally, from day 7 until the study's termination, a significant difference was noted between all treatments ($P<0.05$). The control treatment exhibited an increase from 2.47 log cfu/g at the beginning of the study to 7.01 log cfu/g at the conclusion of the study, while the pure film treatment demonstrated an increase from 2.42 log cfu/g to 6.45 log cfu/g, which was a significant difference ($P>0.05$). The most effective performance was observed in the film+1% GEO and film+2% GEO treatments, which attained 5.07 and 4.39 log cfu/g, respectively, by the study's conclusion. Additionally, in Table 3 (Enterobacteriaceae), no significant difference was detected at the study's onset ($P<0.05$). However, an increasing trend was observed in all treatments throughout the study. On day 12, no significant difference was observed between control samples and pure film samples ($P<0.05$); however, significant differences were observed among the other treatments ($P<0.05$). The results pertaining to the enumeration of psychrotrophic bacteria in various treatments of turkey meat during storage at refrigerator temperature are presented in Figure 3. The initial count in the control treatment, which was set at 5.36 log cfu/g, exhibited an increase from 2.33 log cfu/g on day 0 to 7.69 log cfu/g by the study's conclusion. This observed increase was statistically significant when compared to the other treatment groups ($P<0.05$). From day 4 onward, a statistically significant difference was observed between the control treatment and the remaining treatments until the conclusion of the study (day 12) ($P<0.05$). At the conclusion of the study, the film+2% GEO treatment demonstrated the most optimal performance, exhibiting a significant difference compared to the control group ($P<0.05$). As illustrated in Figure 4, the study revealed a consistent increase in the aerobic bacterial count across all treatment groups during the study period. While no significant differences were observed at the beginning of the study ($P<0.05$), a significant divergence was apparent between the treatments by the study's conclusion ($P<0.05$). In the control treatment, a significant change in the aerobic bacteria count was observed from the beginning of the storage period to day 9 ($P<0.05$). However, the difference between day 9 (log cfu/g 7.86) and day 12 (log cfu/g 8.02) was not significant ($P<0.05$). According to the results of the aerobic bacterial count, the pure film treatment from day 4 to the end of the storage period exhibited a significant difference compared to the control group ($P<0.05$). The Film+2% GEO treatment demonstrated a notable increase in bacterial load, reaching 5.09 log cfu/g by the study's conclusion, which was the most effective treatment.

3.4. Chemical Properties

The results of the pH measurements (Table 4) demonstrated that there was no statistically significant difference between the treatments of film+1% GEO and film+2% GEO during the storage period ($P<0.05$). However, a statistically significant difference was observed when compared to the control group and the pure film group ($P>0.05$). The final pH values for the groups receiving 1% and 2% essential oil were 6.95 and 6.39, respectively. The PV measurement, which serves as an indicator of primary fat oxidation, is documented in Table 5. A statistically significant difference was observed between all treatments after the second day ($P<0.05$). The peroxide value of the control group exhibited a range from 0.91 meq/kg on day zero to 4.44 meq/kg on the final day of

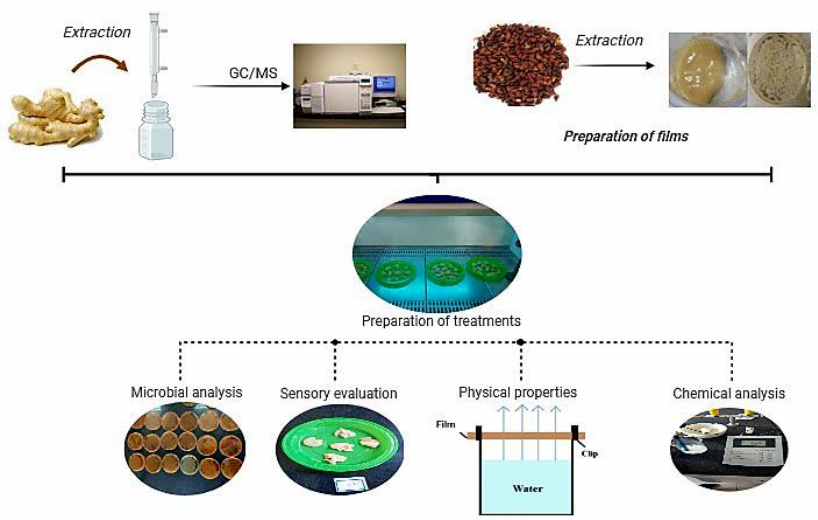

Figure 1. Procedures for preparing samples and performing tests

Table 1. The results of GEO analysis using GC/MS method.

percentage of compounds	RI	Compounds	Number
3.88	936	α-pinene	1
1.92	948	Camphene	2
2.32	990	B- myrcene	3
8.66	1037	sabinene	4
7.88	1040	1,8-cineol	5
0.99	1100	Linalool	6
3.19	1270	Z-Citral	7
4.09	1296	2-Undecanone	8
2.25	1373	α -Copaene	9
11.39	1491	α-Curcumene	10
15.71	1501	Zingiberene	11
3.02	1521	Zonarene	12
6.71	1529	franesene	13
10.69	1539	β-Sesquiphellandrene	14
6.79	1544	trans-γ-Bisabolene	15
1.33	1552	Nerolidol	16
0.81	1608	2-Dehydrolinalool	17
0.92	1618	γ-Eudesmol	18
4.58	1633	Valerianol	19
98.13			Total

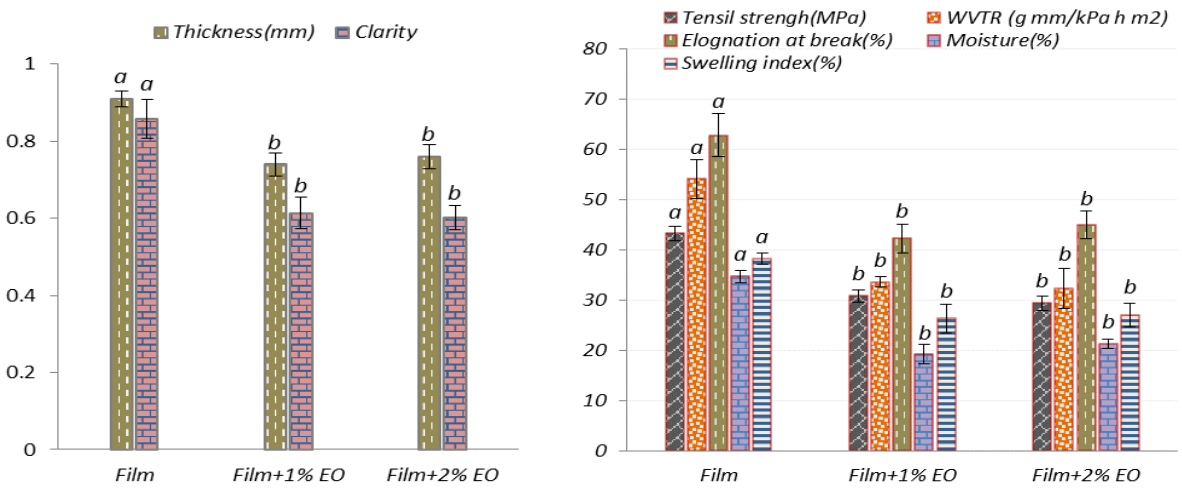

Figure 2. Physical properties of films based on quince seed mucilage reinforced with carboxymethyl cellulose containing ginger essential oil. Different lowercase letters indicate significant differences between groups (P<0.05).

Table 2. Changes in lactic acid bacterial counts of different treatments of turkey meat during storage.

Day / Treatment	0	2	4	7	9	12
C	2.47±0.10^{a}	3.09±0.13^{a}	3.64±0.14^{a}	4.60±0.10^{a}	5.51±0.11^{a}	7.01±0.14^{a}
Film	2.72±0.09^{a}	2.73±0.15^{b}	3.33±0.09^{b}	4.18±0.11^{b}	5.24±0.10^{b}	6.45±0.16^{b}
Film+1% GEO	2.51±0.11^{a}	2.70±0.11^{b}	3.20±0.14^{b}	3.84±0.15^{c}	4.45±0.06^{c}	5.37±0.11^{c}
Film+2% GEO	2.53±0.06^{a}	2.77±0.18^{b}	3.17±0.10^{b}	3.51±0.13^{d}	4.00±0.09^{d}	4.09±0.12^{d}

Different lowercase letters indicate significant differences between groups (P<0.05)

Table 3. Changes in enterobacteriaceae bacterial counts of different treatments of turkey meat during storage

Day / Treatment	0	2	4	7	9	12
C	2.11±0.08^{a}	2.81±0.09^{a}	3.55±0.12^{a}	4.25±0.11^{a}	5.03±0.10^{a}	6.14±0.09^{a}
Film	2.13±0.12^{a}	2.61±0.09^{a}	3.48±0.08^{a}	4.01±0.04^{b}	4.88±0.12^{a}	5.96±0.10^{a}
Film+1% GEO	2.10±0.06^{a}	2.57±0.12^{a}	3.03±0.11^{b}	3.39±0.13^{c}	3.61±0.09^{b}	4.01±0.12^{b}
Film+2% GEO	2.15±0.10^{a}	2.36±0.06^{b}	2.66±0.14^{c}	2.95±0.12^{d}	3.24±0.07^{c}	3.77±0.08^{c}

Different lowercase letters indicate significant differences between groups (P<0.05)

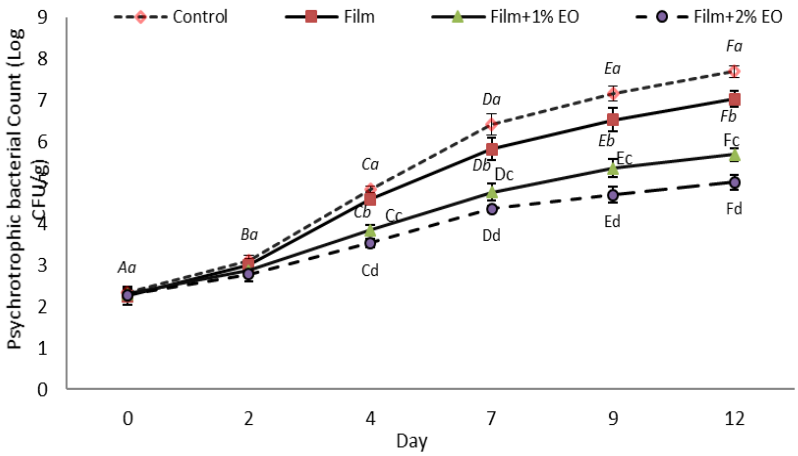

Figure 3. The results of counting psychrotrophic bacteria in different treatments of turkey meat during storage. Different lowercase letters indicate significant differences between groups and different uppercase letters indicate significant differences within days for each treatment (P<0.05).

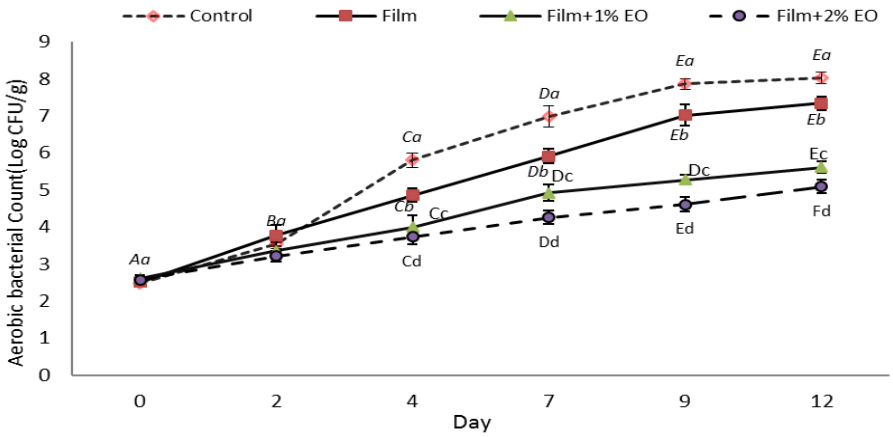

Figure 4. The results of counting aerobic bacteria in different treatments of turkey meat during storage. Different lowercase letters indicate significant differences between groups and different uppercase letters indicate significant differences within days for each treatment (P<0.05).

Table 4. Change in pH of different treatments of turkey meat during storage

Day / Treatment	0	2	4	7	9	12
C	6.29±0.02^{a}	6.39±0.03^{a}	6.64±0.01^{a}	6.83±0.04^{a}	7.03±0.02^{a}	7.39±0.03^{a}
Film	6.28±0.00^{a}	6.37±0.02^{a}	6.51±0.02^{b}	6.75±0.02^{b}	6.92±0.03^{b}	7.02±0.01^{b}
Film+1% GEO	6.29±0.01^{a}	6.38±0.03^{a}	6.48±0.04^{b}	6.70±0.05^{b}	6.77±0.03^{c}	6.95±0.01^{c}
Film+2% GEO	6.30±0.02^{a}	6.39±0.01^{a}	6.43±0.03^{b}	6.69±0.01^{b}	6.80±0.04^{c}	6.93±0.02^{c}

Different lowercase letters indicate significant differences between groups (P<0.05).

Table 5. Change in PV of different treatments of turkey meat during storage

Day / Treatment	0	2	4	7	9	12
C	0.91±0.00^{a}	1.51±0.03^{a}	2.01±0.02^{a}	3.25±0.04^{a}	3.96±0.00^{a}	4.44±0.03^{a}
Film	0.90±0.02^{a}	1.30±0.03^{b}	1.88±0.01^{b}	2.79±0.04^{b}	3.55±0.02^{b}	4.01±0.00^{b}
Film+1% GEO	0.92±0.01^{a}	1.09±0.02^{c}	1.43±0.01^{c}	1.93±0.03^{c}	2.66±0.04^{c}	3.11±0.02^{c}
Film+2% GEO	0.90±0.00^{a}	1.06±0.04^{c}	1.24±0.03^{d}	1.65±0.05^{d}	2.04±0.01^{d}	2.70±0.03^{d}

Different lowercase letters indicate significant differences between groups (P<0.05).

the study, marking the most substantial increase. Notably, the treatment of film+2% GEO with 1.80 meq/kg demonstrated an increase compared to its initial level. The study demonstrated a range from 0.90 meq/kg on day zero to 2.70 meq/kg, which was the lowest amount and exhibited the most significant discrepancy from the control group (P<0.05). The results of evaluating the amount of volatile nitrogenous substances (TVB-N) as one of the most important indicators of chemical spoilage in the treatments of turkey meat packed in film+GEO during 12 days of study with storage conditions at refrigerator temperature are reported in Table 6. The increase in the amount in the control group was significantly higher than in the other groups (P < 0.05), increasing from 10.68 mg/100 g on day 0 to 39.95 mg/100 g on day 12 (the final day of the study). In contrast, the film treatment resulted in an increase of 10.66 mg/100g and 33.29 mg/100g, respectively. In treatments containing 1 and 2% essential oil, this increase occurred with a lower slope, so that at the beginning of the study, there was no significant difference with the control group; however, at the end of the study, 26.41 and 21.61 mg/100g were reported, respectively (P<0.05). The results reported in Table 7 correspond to the TBARS evaluation, which was employed as an index of secondary fat oxidation. The treatments that were found to be the most effective in controlling the increase in TBARS were Film+2% GEO treatment followed by Film+1% GEO treatment. These treatments showed a significant difference with pure film and the control group (P<0.05). In the control group, the amount of malondialdehyde decreased from 0.32 milligrams per 1,000 grams on day 0 to 2.47 milligrams per 1,000 grams on day 12. During the study

Table 6 Change in TVB-N of different treatments of turkey meat during storage.

Day / Treatment	0	2	4	7	9	12
C	10.68±0.06[a]	12.31±0.03[a]	15.33±0.02[a]	26.24±0.05[a]	34.51±0.03[a]	39.95±0.04[a]
Film	10.66±0.04[a]	12.24±0.05[b]	14.17±0.03[b]	24.18±0.01[b]	29.36±0.02[b]	33.29±0.05[b]
Film+1% GEO	10.69±0.03[a]	11.78±0.03[c]	13.26±0.03[c]	17.41±0.04[c]	22.20±0.01[c]	26.41±0.03[c]
Film+2% GEO	10.67±0.04[a]	11.52±0.04[d]	12.34±0.01[d]	15.33±0.02[d]	18.19±0.05[d]	21.61±0.04[d]

Different lowercase letters indicate significant differences between groups (P<0.05)

Table 7 Change in TBARS of different treatments of turkey meat during storage.

Day / Treatment	0	2	4	7	9	12
C	0.32±0.01[a]	0.71±0.02[a]	1.23±0.03[a]	1.87±0.03[a]	2.19±0.01[a]	2.47±0.03[a]
Film	0.30±0.00[a]	0.63±0.03[b]	1.12±0.02[b]	1.50±0.01[b]	1.74±0.00[b]	1.99±0.02[b]
Film+1% GEO	0.31±0.02[a]	0.56±0.01[c]	0.95±0.01[c]	1.11±0.01[c]	1.31±0.01[c]	1.48±0.02[c]
Film+2% GEO	0.30±0.03[a]	0.57±0.00[c]	0.89±0.01[d]	1.06±0.02[d]	1.20±0.02[d]	2.33±0.01[d]

Different lowercase letters indicate significant differences between groups (P<0.05).

period, the amount of malondialdehyde in the film+2% GEO treatment group was lower than in the other groups (P<0.05). The study also examined the pH, PV, TVB-N, and TBARS levels in packaged turkey meat samples. The permissible limits for volatile nitrogen substances were established at a maximum concentration of 25 mg/100g. On day 12 (the conclusion of the study), the edible film treated with Quince seed mucilage reinforced with carboxymethyl cellulose containing 2% GEO exhibited a concentration of 21 mg/100g, falling below the permissible limit. (21/61 mg/100g), surpassing the established limit.

3.5. Sensory Evaluation

The changes in sensory characteristics, encompassing aroma, texture, appearance, taste, and overall acceptance of turkey meat samples packaged in film+GEO under refrigerated storage conditions, are delineated in Figure 5. According to the results, the treatments containing GEO exhibited the highest scores in terms of aroma and texture. In terms of appearance, the control treatment exhibited the highest score, while the film+1% GEO treatment demonstrated the strongest preference in terms of taste and overall acceptance.

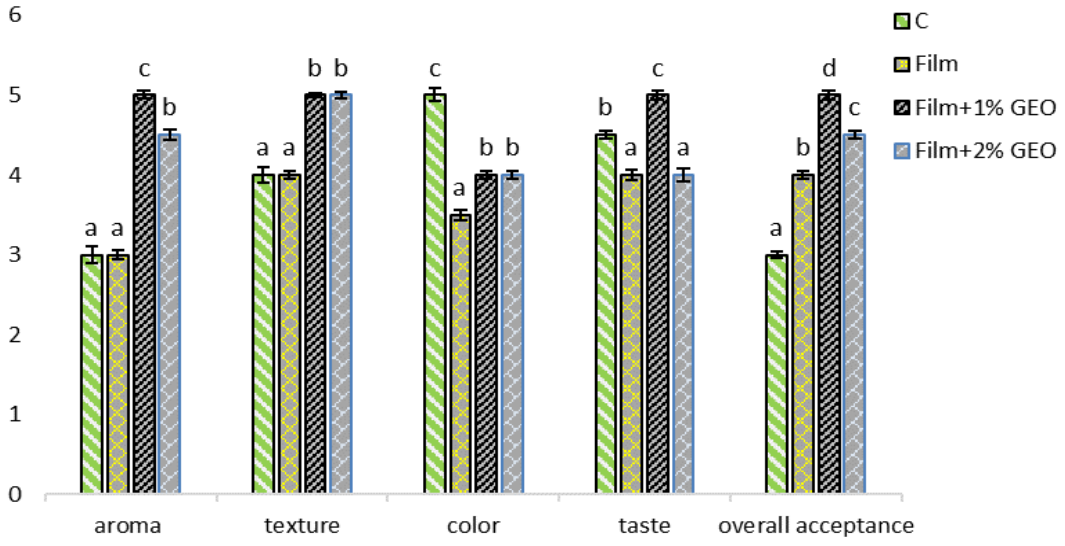

Figure 5 Sensory properties of different treatments stored in cold storage (4±1 °C). Different lowercase letters indicate significant differences between groups (P<0.05).

4. Discussion

4.1. Chemical Composition of GEO

Essential oil is derived from the plant through various extraction methods and is chemically defined as terpenoids, specifically monoterpenes and oxygenated forms. The composition of ginger essential oil varies in different studies. This variability is attributed to factors such as plant species, environmental influences, genetic characteristics, extraction methodologies, and other variables (28). In a study by Kamaliroosta et al. (2013), for instance, ginger essential oil was extracted and identified using a Cloninger device. The findings indicated that the predominant compound in the essential oil was identified as zingiberene, a sesquiterpene that is prevalent in the oil extracted from the root (29). This observation aligns with the results of the present study. In a subsequent study by El-Baroty et al. (2010), the essential oils extracted from ginger rhizomes were identified through analytical TLC and GC/MS. The ginger essential oil was found to contain a high percentage of hydrocarbons, including beta-sesquiflandrene (27.16%), caryophyllene (15.29%), zygibarne (13.97%), alpha-frensene (10.52%), and alpha-curcumin (6.62%) (30). The majority of the compounds identified in this study align with the findings reported in the extant literature.

4.2. Physical Characteristics

The physical properties of edible films are determined by their resistance, stability, and potential to improve structural mechanical uniformity. A variety of factors influence these properties, including the composition and characteristics of the film, the type and amount of additives such as lubricants, the solvent utilized, and the method employed during film preparation. Ensuring the uniformity and homogeneity of the edible film during storage of food products necessitates the examination of these properties (23). The findings of this study demonstrated that the incorporation of GEO into the edible film composed of Quince seed mucilage reinforced with carboxymethyl cellulose led to a substantial decline in the physical-mechanical characteristics when compared to the film composed of pure GEO ($P<0.05$). In a study by Jouki et al. (2014), mucilage films containing oregano essential oil in different concentrations were prepared and their physical, thermal, microstructural, and mechanical properties were investigated. The films were prepared in four different concentrations of essential oil, ranging from 0% to 2% by volume. The results of the study indicated that the incorporation of oregano essential oil into Quince seed mucilage films led to an enhancement in their mechanical properties. This finding is in alignment with the results reported in this study (23). Erkaya-Kotan et al. (2023) in a study aimed at investigating the effects of an edible coating solution based on Quince seed mucilage containing thyme essential oil on the physicochemical characteristics of Kashar cheese. They stated that the coating of Kashar cheese with mucilage of Quince seeds increased the moisture loss compared to conventional and vacuum-packed cheeses. They also stated that the mucilage coating of Quince seed provides good potential as a coating material to improve the physicochemical properties of cheese, and this potential is increased by adding thyme plant essential oil, and with increasing concentration of essential oil, this property improves (31), which is consistent with the results of this study. Muñoz-Tébar et al. (2022) investigated the physical and mechanical properties of the edible film prepared using chia seed mucilage along with oregano and savory essential oils in different concentrations. The researchers reported that increasing the concentration of essential oils up to 1.5% by volume in volume leads to a decrease in strength, tensile, and elongation at break (10). The findings indicated that the incorporation of essential oils resulted in the formation of heterogeneous layers, characterized by a surface devoid of pores or cracks, and a more pronounced integration of oregano essential oil within the polymer network. Abdollahi et al. (2019) prepared carboxymethyl cellulose-agar biocomposite film with summer savory essential oil in different concentrations and investigated its effects on the structural, mechanical, and water sensitivity of the films. Their findings indicated that the incorporation of essential oil into the edible film enhanced its water vapor permeability and swelling, while concomitantly reducing its tensile strength and transparency. Conversely, the mechanical flexibility and hydrophobicity of the films' surface exhibited significant enhancement, a finding that aligns with the results of this study (32). In a subsequent study by Noshirvani et al. (2017), the impact of incorporating cinnamon and ginger essential oils on the edible films composed of a mixture of oleic acid and carboxymethyl cellulose was investigated. According to the findings, the mechanical properties of the films were found to have been improved by adding essential oil to the studied edible films (33), which is consistent with the results of this study.

4.3. Microbial Properties

Poultry meat is classified as a perishable food item, susceptible to adverse microbial activity and oxidative reactions (3). It is imperative to impede microbial activity, and the findings of this study demonstrated that turkey meat samples packaged in film were efficacious in regulating microbial proliferation. In order to enhance the antimicrobial properties of polysaccharide films, such as carboxymethyl cellulose and mucilage, hydrophobic compounds with antimicrobial activity, such as plant essential oils, can be incorporated into their composition (32). The findings of the present study further demonstrated that the pure films exhibited limited antimicrobial properties; their efficacy was enhanced by the incorporation of essential oils. In a related study, Zhang et al. (2021) prepared edible coatings based on agar/sodium alginate with ginger essential oil and investigated their effect on the microbial properties of fresh beef during refrigerated storage. The findings indicated continuous control of the microbial population. It is noteworthy that the prepared coatings exhibited the ability to increase the shelf life of

meat up to nine days (34), which is consistent with the results of this study. In a related study, Raeisi et al. (2015) examined the antimicrobial properties of carboxymethyl cellulose and found that combining this substance with thyme and grape seed extract enhanced the microbial characteristics of rainbow trout fillets during storage (35). This finding is consistent with the results of the present study. Noshad et al. (2020) evaluated the effect of active edible coatings of seed mucilage and green tea extract (as an antimicrobial antioxidant compound) on the quality characteristics of shrimp in refrigerated storage. The researchers concluded that the total aerobic count of shrimp treated with green tea extract coating was lower than the control group (12), which is consistent with the results of this study. In a separate study, El-Baroty et al. (2010) noted that the majority of microbial spoilage in poultry meat and products stored in refrigerators is associated with cold-tolerant bacteria. They suggested that leveraging the substantial antimicrobial properties of plant essential oils, such as ginger, could serve as a source of compounds with potential for preservation. In a subsequent study by Jouki et al. (2014), the effects of castor bean mucilage film (QSMF) containing oregano (O) or thyme (T) essential oil on increasing the shelf life of rainbow salmon fillets and enumerating aerobic and cold-oriented bacteria, H2S-producing bacteria, lactic acid, and Enterobacteriaceae were analyzed. The results of this study indicated that bacteria grew the fastest in salmon fillets stored in air, followed by samples wrapped with QSMF, and the lowest number was observed in samples wrapped with QSMF+2% T. The number of enterobacteriaceae and lactic acid bacteria species in the samples packaged with QSMF+2% T was significantly lower (23), which is consistent with the performance of the essential oil treatments of this study in controlling the microbial load of the samples.

4.4. Chemical Properties

In a study by Jouki et al. (2014), the effects of castor bean mucilage film (QSMF) containing oregano (O) or thyme (T) essential oil on the chemical characteristics (TBARS, TVB-N, TMA-N) of fish were analyzed. The findings revealed that the lowest levels of TBARS were observed in wrapped QSMF fillets containing 2% oregano essential oil. The study also found that the amount of TBA differed among the treatments and remained less than 2 mgMDA/kg during storage. Furthermore, TVB-N was identified as a reliable indicator of spoilage in fillets (23). In a subsequent study by Noshad et al. (2020), the impact of seed mucilage coating (QSM) with green tea extract (GTE) on the pH, total volatile base nitrogen (TVB-N), and the chemical composition of Pacific white shrimp during refrigerated storage was examined. The findings demonstrated that the application of QSM coating in conjunction with GTE led to a substantial increase in pH and TVB-N levels in shrimp samples ($P < 0.05$). However, these values remained significantly lower than those observed in the control group (12). This observation is in alignment with the results of the present study. In the study by Zhang et al. (2021), edible coatings based on agar/sodium alginate were prepared with ginger essential oil, and their effects on the chemical properties of fresh beef during refrigerated storage were investigated. The results indicated the improvement of the chemical properties (TBARS, PV and TVB-N) of coated and essential oil samples compared to the uncoated group during storage (34), which is consistent with the results of this study. In a subsequent study by Raeisi et al. (2015), the potential application of carboxymethyl cellulose coatings combined with thyme and grape seed extract was investigated. According to the results of this study, the studied edible coating was found to improve the chemical characteristics of rainbow trout fillets during the improved retention period (35), which is consistent with the results of the present study.

4.5. Sensory Evaluation

In the evaluation of aroma and texture characteristics, the control group and the pure film received the lowest score and did not have a significant difference ($P<0.05$). However, there was a significant difference with other treatments ($P<0.05$). In terms of overall acceptance, significant differences were observed among all treatments, with the film+1% GEO treatment demonstrating the highest level of acceptance ($P<0.05$). The films developed for edible coatings did not adversely affect the quality of the samples; in some cases, they enhanced the texture and sensory characteristics. Overall, the samples packaged with edible films containing GEO, particularly those with 1% essential oil, exhibited superior sensory attributes and organoleptic characteristics compared to the samples packaged with edible films in their pure form and the control group. While the initial use of edible coatings can reduce product transparency, subsequent storage periods demonstrate the efficacy of these coatings in preventing chemical and microbial deterioration reactions and moisture loss, as evidenced by the findings of studies (12, 36, 37).A study by Zhang et al. (2021) examined the effects of edible coatings based on agar/sodium alginate, supplemented with ginger essential oil, on the sensory characteristics of fresh beef during refrigerated storage. The evaluation demonstrated that coated meat exhibited superior sensory quality during the storage period (34), which is consistent with the findings of this study. Raeisi et al. (2015) investigated the sensory characteristics of rainbow trout fillets coated with carboxymethyl cellulose containing thyme and grape seed extract. The researchers reported that the texture, taste, and overall acceptance of the coated samples improved during the storage period (36). This finding is consistent with the results of the present study. The findings of this study demonstrated that the edible film composed of quince seed mucilage reinforced with carboxymethyl cellulose, particularly when combined with GEO, was effective in preserving and enhancing the quality and safety of turkey meat. Consequently, it can be posited that the aforementioned edible film has the potential to be utilized in the food industry to enhance the control of

microbial load, improve chemical properties, and maintain the sensory characteristics of meat and analogous products.

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Authors' Contribution
R.R. was responsible for collecting the samples, conducting the experimental work, and analyzing the data. A. MM. was responsible for analyzing the data. L. G. and H. K. were responsible for writing and revising the manuscript, respectively.

Ethics
Not Applicable.

Conflict of Interest
The authors certify that they have no conflicts of interest

Data Availability
The data that were utilized to substantiate the conclusions of this study are available upon request from the corresponding author.

References

1. Kazemeini H, Azizian A, Adib H. Inhibition of *Listeria monocytogenes* growth in turkey fillets by alginate edible coating with *Trachyspermum ammi* essential oil nano-emulsion. *International* Journal of Food Microbiology. 2021;16(344):109104.
2. Keykhosravy, K., Khanzadi, S., Hashemi, M., & Azizzadeh, M. Chitosan-loaded nanoemulsion containing *Zataria Multiflora* Boiss and *Bunium persicum* Boiss essential oils as edible coatings: Its impact on microbial quality of turkey meat and fate of inoculated pathogens. International journal of biological macromolecules. 2020;150:904-913.
3. Mojaddarlangroodi, A., Nematollahi, A., & Sayadi, M. Chitosan coating incorporated with grape seed extract and Origanum vulgare essential oil: An active packaging for turkey meat preservation. Journal of Food Measurement and Characterization, 2021;1(15):2790-2804.
4. Ebrahimzadeh Mousavi, H., Taheri Mirghaed, A., Hoseini, S. M., Ghelichpour, M., Aghaei Moghaddam, A., Gharavi, B., Aydın, B. Effects of Myrcene Addition to Water on Plasma Biochemical Characteristics of Common Carp, Cyprinus carpio, During Transportation. Iranian Journal of Veterinary Medicine. 2024;18(1):131-140.
5. Alighazi, N., Noori, N., Gandomi, H., Akhondzadeh, A. Effect of *Ziziphora clinopodioides* Essential Oil Stress on Viability of *Lactobacillus acidophilus* and *Bifidobacterium bifidum* Microencapsulated with Alginate-Chitosan and Physicochemical and Sensory Properties of Probiotic Yoghurt. Iranian Journal of Veterinary Medicine. 2021;15(2):234-252.
6. Houshmand, E., Kamalifar, H. S., Elmi, H. In vitro Scolicidal Effect of Ginger (*Zingiber officinale Roscoe*) Ethanolic Extract Against Protoscolices of Hydatid Cyst. Iranian Journal of Veterinary Medicine. 2019;13(1):87-99.
7. Peidaei, F., Ahari, H., Anvar, S. A. A., Ataee, M. Nanotechnology in Food Packaging and Storage: A Review. Iranian Journal of Veterinary Medicine. 2021;15(2):122-153.
8. Mohiti Asli, M., Khedmatgozar, M., Darmani kuhi, H., Farzaneh, M. Efficacy of Different Blends of Essential Oils on Growth Performance, Blood Metabolites, Gut Microflora, and Meat Quality of Broilers. Iranian Journal of Veterinary Medicine. 2019;13(2):199-215.
9. Talebi, F., MIsaghi, A., Khanjari, A., Kamkar, A., Gandomi, H., Saeedi, M. Evaluation of antimicrobial activity of Poly Lactic Acid (PLA) films containing cellulose nanoparticle and *Bunium persicum* and *Mentha pepperita* essential oils (EOs). Iranian Journal of Veterinary Medicine. 2017;11(4):289-298.
10. Muñoz-Tébar, N., Carmona, M., Ortiz de Elguea-Culebras, G., Molina, A., & Berruga, M. I. Chia seed mucilage edible films with *Origanum vulgare* and *Satureja montana* essential oils: Characterization and antifungal properties. Membranes, 2022;12(2):213.
11. Kashiri, M., & Davtalab, M. Effect of sorbitol concentration on physical and mechanical properties of bio-based film of quince seed mucilage. Journal of food science and technology (Iran). 2023;19(132):199-210.
12. Noshad, M., Nasehi, B., & Anvar, A. (2020). Effects of Quince Seed Mucilage and Green Tea Extract as Active Edible Coatings on Quality of Pacific White Shrimps During Cold Storage. *Nutrition and Food Sciences Research*,7(2), 29-36.
13. Dashipour, A., Razavilar, V., Hosseini, H., Shojaee-Aliabadi, S., & Khaksar, R. Antioxidant and antimicrobial carboxymethyl cellulose films containing Zataria multiflora essential oil. International journal of biological macromolecules. 2015;3(72):606-613.
14. Mohammadian M, Moghaddam AD, Sharifan A, Dabaghi P, Hadi S. Structural, physico-mechanical, and bio-functional properties of whey protein isolate-based edible films as affected by enriching with nettle (Urtica dioica L.) leaf extract. Journal of Food Measurement and Characterization. 2021;15(5):4051-60.
15. Khanzadi S, Azizian A, Hashemi M, Azizzadeh M. Chemical Composition and Antibacterial Activity of the Emulsion and Nano-emulsion of Ziziphora clinopodioides Essential Oil against Escherichia coli O157: H7. Journal of Human, Environment and Health Promotion. 2019;5(2):94-7.
16. Vanaki E, Kamkar A, Noori N, Azizian A, Mohammadkhan F. The effect of aqueous extract of Arctium lappa root on the survival of Lactobacillus acidophilus La-5 and Bifidobacterium bifidum Bb-12 and sensorial and physicochemical properties of synbiotic yogurt. Food Science & Nutrition. 2024;12(3):2182-91.
17. Kazemeini H, Azizian A, Shahavi MH. Effect of chitosan nano-gel/emulsion containing *bunium persicum* essential oil and nisin as an edible biodegradable coating on

Escherichia coli o157: H7 in rainbow trout fillet. Journal of Water and Environmental Nanotechnology. 2019 Oct 1;4(4):343-9.
18. Munda, S., Dutta, S., Haldar, S., & Lal, M. Chemical analysis and therapeutic uses of ginger (*Zingiber officinale* Rosc.) essential oil: a review. Journal of essential oil bearing plants. 2018;21(4):994-1002.
19. Silva, L. A., Sinnecker, P., Cavalari, A. A., Sato, A. C. K., & Perrechil, F. A. Extraction of chia seed mucilage: Effect of ultrasound application. Food Chemistry Advances. 2022;1(3):100024.
20. Dabbagh Moghaddam A., Kazemi M., Jebraeel m., Sharifan A.. Design of Zein Electrospinning Nanofiber Packaging Containing *Zataria Multiflora* Essential Oil to Preserve the Ration Food. Journal of Food Technology and nutrition. 2019;16(63):91-102.
21. Rabbani, S., Ali Anvar, S. A., Allahyaribeik, S., Jannat, B., & Ahari, H. Effect of ultrasound technique to improve quality of Iranian industrial honey by controlling crystallization process. Food Science & Nutrition. 2024;12(4):2932-2946.
22. Eghbal, H., Mohammadi, A., Mohammad Nejad Khiavi, N., Ahmadi Sabegh, M., & Jahani, N. Comparison of the Antibacterial Properties of Essential Oils of Malva Sylvestris and Salvia Officinalis on Common Bacteria of Oral Infection with Chlorhexidine Mouthwash. Journal of Mashhad Dental School. 2021;45(3):217-229.
23. Jouki, M., Mortazavi, S. A., Yazdi, F. T., & Koocheki, A. Characterization of antioxidant–antibacterial quince seed mucilage films containing thyme essential oil. Carbohydrate polymers. 2014;1(99):537-546.
24. Ojagh, S. M., Rezaei, M., Razavi, S. H., & Hosseini, S. M. H. Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water. Food Chemistry. 2010;122(1):161–166.
25. Moradi, M., Tajik, H., Rohani, S. M. R., Oromiehie, A. R., Malekinejad, H., Aliakbarlu, J., & Hadian, M. Characterization of antioxidant chitosan film incorporated with *Zataria multiflora* Boiss essential oil and grape seed extract. LWT-Food Science and Technology. 2012;46(2):477-484.
26. Kakaei, S., & Shahbazi, Y. Effect of chitosan-gelatin film incorporated with ethanolic red grape seed extract and *Ziziphora clinopodioides* essential oil on survival of *Listeria monocytogenes* and chemical, microbial and sensory properties of minced trout fillet. LWT-Food Science and Technology. 2016;2(72):432–438.
27. Khalaf, H. H., Sharoba, A. M., El-Tanahi, H. H., & Morsy, M. K. Stability of antimicrobial activity of pullulan edible films incorporated with nanoparticles and essential oils and their impact on turkey deli meat quality. Journal of Food and Dairy Sciences. 2013:4(11):557-573.
28. Nedorostova, L., Kloucek, P., Kokoska, L., Stolcova, M., & Pulkrabek, J. Antimicrobial properties of selected essential oils in vapour phase against foodborne bacteria. Food control. 2009:20(2):157-160.
29. Kamaliroosta, Z., Kamaliroosta, L., & Elhamirad, A. H. Isolation and identification of ginger essential oil. Journal of Food Biosciences and Technology. 2013:3(3):73-80.
30. El-Baroty, G. S., Abd El-Baky, H. H., Farag, R. S., & Saleh, M. A. Characterization of antioxidant and antimicrobial compounds of cinnamon and ginger essential oils. African journal of biochemistry research. 2010:4(6):167-174.
31. Erkaya-Kotan, T., Gürbüz, Z., Dağdemir, E., & Şengül, M. Utilization of edible coating based on quince seed mucilage loaded with thyme essential oil: Shelf life, quality, and ACE-inhibitory activity efficiency in Kaşar cheese. Food Bioscience. 2023:2(54):102895.
32. Abdollahi, M., Damirchi, S., Shafafi, M., Rezaei, M., & Ariaii, P. Carboxymethyl cellulose-agar biocomposite film activated with summer savory essential oil as an antimicrobial agent. International journal of biological macromolecules. 2019:3(126):561-568.
33. Noshirvani, N., Ghanbarzadeh, B., Gardrat, C., Rezaei, M. R., Hashemi, M., Le Coz, C., & Coma, V. Cinnamon and ginger essential oils to improve antifungal, physical and mechanical properties of chitosan-carboxymethyl cellulose films. Food Hydrocolloids. 2017;70:36-45.
34. Zhang, B., Liu, Y., Wang, H., Liu, W., Cheong, K. L., & Teng, B. Effect of sodium alginate-agar coating containing ginger essential oil on the shelf life and quality of beef. Food Control. 2021;130:108216.
35. Raeisi, M., Tajik, H., Aliakbarlu, J., Mirhosseini, S. H., & Hosseini, S. M. H. Effect of carboxymethyl cellulose-based coatings incorporated with *Zataria multiflora* Boiss. essential oil and grape seed extract on the shelf life of rainbow trout fillets. LWT-Food Science and Technology. 2015;64(2):898-904.
36. Kazemeini H, Azizian A, Ahmadi K. Preparation of Synbiotic Yogurt Sauce Containing *Spirulina platensis* Microalgae Extract and Its Effect on the Viability of *Lactobacillus acidophilus*. BioMed Research International. 2023;26;2023.
37. Banuree SA, Noori N, Gandomi H, Khanjari A, Karabagias IK, Faraki A, Ghadami F, Azizian A, Banuree SZ. Effect of *Stevia rebaudiana* aqueous extract and microencapsulation on the survivability of *Bifidobacterium bifidum* Bb-12 and *Lactobacillus acidophilus* La-5 in functional ice cream. International Journal of Food Science & Technology. 2022;57(12):7615-21.