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Effect of Orange Peel Essential Oil as a Natural Preservative on Characteristics of Turkey Meat Stored in Refrigerator

Hamidreza Kazemeini[1*], Sanaz Aras Khalaji[2]

1. Assistant Professor, Department of Food Hygiene, Faculty of Veterinary Medicine, Amol University of Special Modern Technologies, Amol, Iran.
2. MSc in Food Hygiene and Quality Control, Amol University of Special Modern Technologies, Amol, Iran.

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ABSTRACT

Introduction: The tendency to consume turkey meat and meat products is increasing due to its high nutritional value. But due to its perishability, many researchers are looking for new solutions to increase its storage time and maintain its quality. Thus the purpose of this study was to evaluate the chemical composition of orange peel essential oil (OPEO) and its effect on the microbial, physicochemical and sensory properties of turkey meat during 12 days of storage at refrigerator temperature.

Methods: The chemical composition of OPEO was identified using GC/MS device. Three groups of turkey meat samples (control, 0.5 and 1%) of OPEO were packed and kept in the refrigerator and at regular intervals (days 0, 3, 6, 9, 12) for microbial tests (total count of aerobic, Pcychrotrophic, Enterobacteriaceae, *Pseudomonas aeruginosa*, lactic acid, MIC and MBC), chemical (pH, TV-N, TBARS) and sensory (taste, aroma, appearance, texture and overall acceptance) were evaluated.

Results: The results of GC/MS showed the presence of effective compounds with antimicrobial and antioxidant activity, especially D-limonene (71.47%). The results of microbial tests showed that treatments of turkey meat containing 1% OPEO had a significant effect ($P<0.05$) on the reduction of the bacteria population compared to the treatment of 0.5% OPEO and control samples. The MIC for *Listeria monocytogenes* and *Pseudomonas aeruginosa* was determined as 4 mg/ml and MBC was determined as 8 and 4 mg/ml, respectively. Lower values of pH, TV-N and TBARS, the highest sensory scores in terms of taste, aroma, appearance, texture and general acceptability were obtained in turkey meat treatments containing orange peel essence compared to the control group.

Conclusions: It can be said that due to its antimicrobial properties OPEO can be used as a natural preservative to increase the shelf life and sensory improvement of turkey meat samples during storage at refrigerator temperature.

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Introduction

Due to the importance of food safety, efforts have been made to improve it in all governments and pay more attention to the healthiness of food with the gradual increase in the population and lifestyle changes (1). Providing needed food, especially animal protein, is one of the most important needs of today's society, and poultry farming plays a significant role in providing protein needs. One of the main factors to pay attention to in this industry is the high growth rate, low food conversion factor and high nutritional value compared to other animal meat. Also, due to the high need for protein sources, the change in the taste of human societies and its high quality, has led to the development of turkey breeding in the world and especially in Iran (2).

Turkey meat is type of white meat with good nutritional value. It has the lowest level of fat and cholesterol compared to beef and sheep meat and also contains minerals such as iron, zinc, copper, potassium, magnesium, phosphorus, manganese, and is a good source of vitamins ascorbic acid, thiamine, riboflavin, pentatonic acid, It is B12, B6 and A. According to the FAO report, Iran ranks third in Asia in terms of turkey meat production. Meanwhile, turkey meat is a suitable environment for the growth of pathogenic microorganisms and is highly perishable due to

* *Corresponding authors:* Hamidreza Kazemeini; Assistant Professor, Department of Food Hygiene, Faculty of Veterinary Medicine, Amol University of Special Modern Technologies, Amol, Iran. Tel: +98 9168017542, Email: h.kazemeini@ausmt.ac.ir.

the presence of moisture, protein and high pH. During the storage period, exposure to oxidative, microbial spoilage and adverse organoleptic changes is considered as a limitation in the production and trade of this product. Often, microbial spoilage of poultry meat is caused by Gram-negative bacteria, thermophilic bacteria, lactic acid bacteria, yeasts, and several types of Gram-positive bacteria. (3,4,5). Spoilage of raw meat during storage in the refrigerator occurs due to two reasons: microbial growth and oxidative spoilage. Spoilage of fresh poultry meat is an economic loss for producers of this product. Therefore, developing methods to increase shelf life, safety and quality is an important issue that the poultry meat production industry is facing (6). The presence of light, oxygen, chemical characteristics of meat, storage temperature and processing methods affect fat oxidation and this has been proven (7).

The common strategy adopted to prevent quality loss due to fat oxidation, which has led to a decrease in nutritional value and meat quality, is the use of antioxidant compounds (8). The negative effects of artificial antioxidants such as mutagenicity, poisoning and carcinogenicity have made the use of natural antioxidants suitable as alternatives (9). In recent years, a lot of attention has been paid to the waste of factories producing juice and concentrates (jams, tomatoes, apples and grapes), which contain natural antioxidants and their positive effect on human health and their antioxidant properties have been proven (10, 11).

Citrus fruits are one of the most important fruit products in the world, which can protect human health with a variety of phytochemicals, and are a good source of vitamin C, folic acid, potassium and pectin (12). In order to improve the management of these wastes and create added value, new processes are carried out to recover them through fertilizer, pectin, essential oil and antioxidant compounds, biodiesel, biogas and bioethanol (13, 14). Citrus peel is a perishable material with a very low shelf life due to its high moisture content (60-75%) (12). It also has more polyphenols and ascorbic acid than fruit pulp (15). The presence of bioactive compounds in orange peel has made it a suitable alternative to artificial antioxidants; there have been many reports on the antioxidant properties of orange peel (16, 17, 19, 18, 20, and 21). orange peel is rich in flavonoids, alkaloids, carotenoids, phenolic acids, limonoids, coumarins and polyethoxylated flavones, it is very valuable and rarely found in other plants, also the extracted essential oil of orange peel is used in pharmaceuticals, health and food industries (22). Also, there is interest in developing and using citrus waste as antioxidant compounds in meat products, in order to increase oxidative stability and maintain meat quality for longer shelf life as a way to maintain food safety according to consumer demand (23). Therefore, in this study, the chemical composition of essential oil extracted from orange peel is evaluated on the microbial, physicochemical sensory and properties of turkey meat stored at refrigerator temperature.

Materials and Methods

Preparation of Essential Oil and Its Analysis

Orange peel was collected from the waste of juice shops in Amol, Iran and after drying, it was ground. After drying and then grinding the orange peel, the essential oil was extracted by a Clevenger machine (Ambala, India) and by steam distillation for 3 hours. And the essential oil analysis was done by Gas Chromatography-Mass spectrometer (GC/M) (Biobase, China) (24). To prepare different concentrations, The OPEO was dissolved in distilled water containing Tween 80 (0.2%, w_{OPEO}) (25).

Preparation of Turkey Meat and Studied Treatments

Turkey meat was purchased from supply centers in Amol, Iran. The meat was transported to the laboratory in ice cubes and prepared. Fillets weighing 10 g were manually prepared for the treatments. The samples were packed in zipped bags and stored in a refrigerator at 4°C. Turkey meat in 3 groups including, the first treatment (control group) is immersion of meat in sterile distilled water for 30 minutes, the second treatment is immersion of meat in a solution of 0.5% OPEO for 30 minutes and the third treatment is immersion of meat in solution 1% OPEO was applied for 30 minutes in 3 repetitions.

Microbial Tests

For this purpose, the microbial culture of the samples for the total count of aerobic bacteria, cold sores, Enterobacteriaceae, *Pseudomonas aeruginosa*, lactic acid bacteria, MIC and MBC were performed at 5 different times, i.e. day 0

(beginning of the study), 3, 6, 9 and 12 (end of the study).

Preparation of Dilution from Samples

To prepare serial dilutions and count bacteria, 10 g of the sample was weighed in sterile zippered bags containing 90 ml of sterile 0.1% peptone water and homogenized with the help of a Stomacher stirrer. 1 ml of the dilution prepared under sterile conditions was added to tubes containing 9 ml of sterile 0.1% peptone water and different dilutions were prepared in the same way.

Examining the Antibacterial Activity of MIC and MBC Essential Oil

To determine the MIC or the minimum inhibitory concentration, a sterile 96-well plate was used with the broth micro-dilution method. 100 µl of Muller Hinton Broth culture medium was poured into rows 1 to 10 of houses, and then 100 µl of essential oil was added to the first house of each row. Row 10 contains 100 µl of culture medium without essential oil, 100 µl of microbial suspension was added and kept in an incubator at 25 °C for 24 hours. In order to determine the MBC or the minimum lethal concentration, 100 µl of the prepared dilutions were cultured on Mueller Hinton agar medium and incubated in an incubator with a temperature of 37 ˚C for 24 hours (25).

Cultivation and Enumeration of Bacteria

For enumeration of aerobic and Pcychrotrophic bacteria The amount of 100 µl of dilution prepared from each sample was cultured on plates containing Plate count Agar (PCA; Merck, Germany) medium and kept in incubator at 37 °C for 48-72 h and 7 °C for 10 days respectively (26). In order to enumeration of Enterobacteriaceae, 1 ml from different dilutions prepared from each sample was transferred to empty plates, then 10 to 15 ml of VRBGA (Violet Red Bile Agar) culture medium, which has a temperature of approximately 45 ˚C, was added to the plate, the sample was mixed with the culture medium and after the medium cooled down culture, another layer of the same medium was added to the plate in the amount of 4 to 5 ml. After completely closing the environment, it was kept in incubator at 37 °C for 18-24 hours (6).

Plates containing Pseudomonas base agar culture medium were used for *Pseudomonas aeruginosa* and stored in 20 °C for 2 days (6). Also, MRS agar medium was used to count the lactic acid of bacteria and it was stored at 25 ˚C for 5 days. The results were reported as the log CFU/g (6).

pH and Total Volatile Basic Nitrogen (TV-N)

5 g of the sample was homogenized with 45 ml of distilled water for 1 minute. The reading was done using a pH meter (Janco, Taiwan) (27). Then the amount of 10 g of sample along with 2 g of magnesium oxide as a catalyst was done by adding 300 ml of distilled water inside the Kjldahl flask. An Erlenmeyer flask containing 25 ml of 2% boric acid and methyl red and methylene blue reagents was placed at the end of the device, and boiling of the contents of the kjldahl flask and distillation of the emitted gases, which are nitrogen bases reagents, were performed. Distilled solution with hydrochloric acid 0.01 molar per titer, and volatile nitrogen substances were calculated in terms of mg of nitrogen per 100 g of sample (28).

Thiobarbituric Acid Reactive Substances (TBARS)

5 g of sample was homogenized with 15 ml of deionized water in 50 ml tubes for 15 seconds, 1 ml of the solution was transferred to another tube and 2 ml of acetic acid was added to it. Then the mixture was vortexed and kept for 15 minutes in a bain-marie at 90°C. The sample was vortexes for 10 minutes after cooling, then centrifuged at 3000 rpm for 15 minutes at 5°C. The optical absorbance of the upper layer was read at a wavelength of 531 nm (29).

Evaluation of Organoleptic Characteristics (color and appearance, smell, taste and texture)

In order to check the sensory and organoleptic characteristics of the sample, a panel of 5 people, whose members were educated people present in the laboratory, was used, and for evaluation, a three-point hedonic scoring system (score 1 is very bad and score 3 is very good) was performed (30).

Statistical Analysis

Statistical analysis of the obtained data was done with spss software. First, the normality of the data was checked using the Kolmogorav-Smirnov test, and then the homogeneity of the variance of the data was performed using the Leven test. Repeated measure (ANOVA) test was used to compare the average number of bacteria in the study period between the groups.

Results

Chemical composition of orange peel essential oil

The results of the analysis of chemical compounds identified in the OPEO sample are presented in Table 1. Quantitative and qualitative results of the analysis of the chemical composition of OPEO prepared by gas chromatography-mass spectrometry (GC/MS) led to the identification of 10 chemical compounds with a total of 97.88%. The results showed that D-limonene (71.74%) is the main chemical compound identified in OPEO. The main compounds identified in OPEO are linalool (7.76%), valencen (4.23%), β- pinene (4.02%), α-pinene (3.86%), acetamide (4.23%), Octanal (2.02%) and other compounds such as phenol, β-cadinene, 2- and 6-octadiene were (0.98, 0.88, 0.56%), respective.

Table 1. Analysis results of the studied orange peel essential oil using GC/MS method

Relative percentage of compounds	Compounds	number
0.98	phenol	**1**
7.76	linalool	**2**
2.02	Octanal	**3**
4.02	β-pinene	**4**
71.47	D-limonene	**5**
0.56	2,6-octadiene	**6**
3.86	α-Pinene	**7**
2.10	Acetamide	**8**
4.23	Valencen	**9**
0.88	β-cadinene	**10**
97.88%	-	**Total**

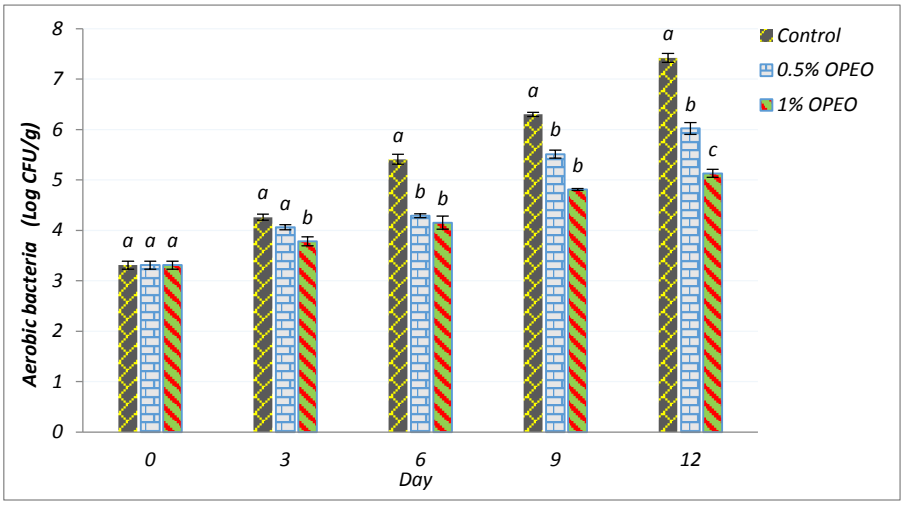

Figure 1. Results of the total count of aerobic bacteria in different treatments during storage (Mean ± SD)

Examining the Results of Microbial Tests

The results of total aerobic bacteria changes during storage are shown in Figure 1. The initial count of total bacteria in the present study increased significantly for the treatments over time ($P<0.05$). On the 0 days of the study, the bacterial population of the control group was 3.31 log CFU/g, which reached 7.42 log CFU/g (beyond the acceptable limit) at the end of the 12th day of storage. Total counts of aerobic bacteria in treated and control samples on 0 days were not significantly different from each other ($P>0.05$). The amount of bacteria in the treatment containing 0.5% and 1% OPEO on the 12th day of storage respectively was 6.02 log CFU/g and 5.13 log CFU/g, which were acceptable.

The results of changes in Pcychrotrophic bacteria during storage are shown in Table 2 and Figure 2. The amount of hypothermia for all treatments

increased significantly over time, while this increase was more intense in the control treatment. In all samples treated with different concentrations of OPEO, the number of hypothermia was significantly (P<0.05) lower was from the control group. The lowest count on the 12th day was observed in the group treated with OPEO of 1% of the Pcychrotrophic bacteria population (5.01 log CFU/g).

Table 2. The results of total count of Pcychrotrophic bacteria in different treatments during storage (Mean ± SD).

Treatment	Day				
	0	3	6	9	12
Control	3.11±0.06[a]	4.36±0.12[a]	5.08±0.14[a]	5.87±0.08[a]	7.09±0.07[a]
0.5% OPEO	3.11±0.06[a]	4.02±0.07[b]	4.25±0.08[b]	4.93±0.09[b]	5.81±0.11[b]
1% OPEO	3.11±0.06[a]	3.69±0.11[c]	4.11±0.10[c]	4.57±0.09[c]	5.01±0.06[c]

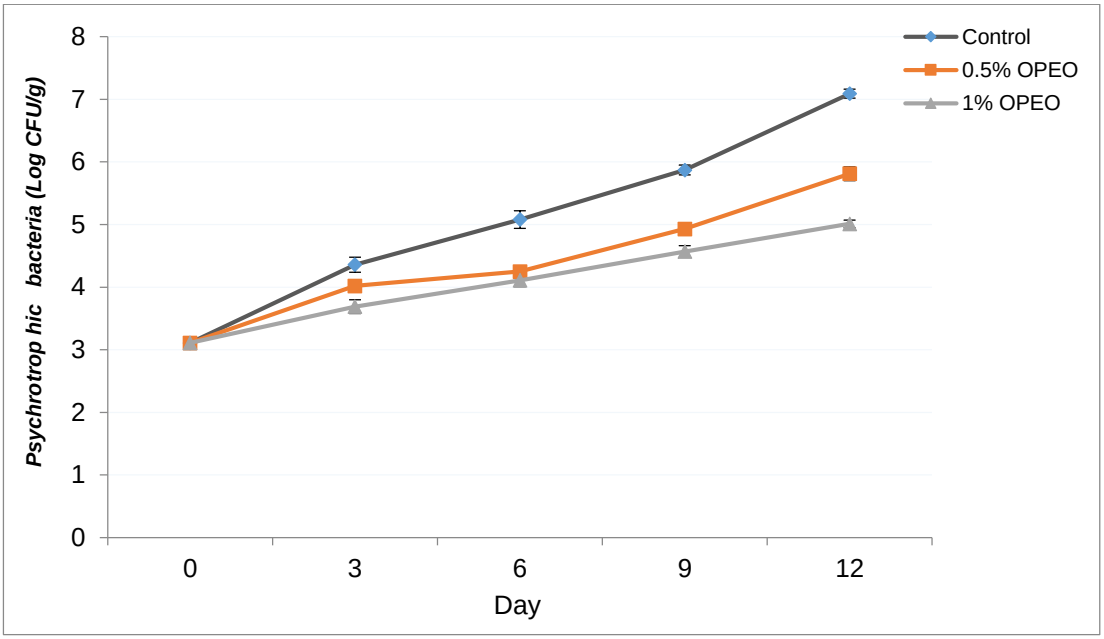

Figure 2. The results of total count of Psychrotrophic bacteria in different treatments during storage (Mean ± SD)

The results of changes in Enterobacteriaceae bacteria during storage are shown in Table 3. With the passage of storage time, the number of Enterobacteriaceae bacteria increased significantly for all treatments, reaching 6.39 log CFU/g in the control group on the last day of the study. In all samples treated with different concentrations of OPEO, the count of Enterobacteriaceae was significantly (P<0.05) lower than the control group. The results of the changes related to the counting of *Pseudomonas aeruginosa* species during storage are shown in Table 4. The number of *Pseudomonas aeruginosa* bacteria in the treated and control samples on 0 days did not differ significantly (P>0.05). In all study days, the population of *Pseudomonas aeruginosa* was significantly lower than the control group (P<0.05) in the groups treated with OPEO concentrations (0.5 and 1%). The results of the changes related to the counting of lactic acid bacteria are shown in Table 5. With time, the maintenance of the population of these bacteria increased over time for all treatments (it was the lowest on day 0 and the highest on day 12th) (P<0.05). So that this increase was more intense in the control sample and its value reached 5.60 log CFU/g. In the samples treated with 1% OPEO, it was significantly lower than the other two groups (P<0.05).

Table 3. The results of the total count of Enterobacteriaceae bacteria in different treatments during storage (Mean ± SD).

Treatment	Day				
	0	3	6	9	12
Control	2.16 ±0.05[a]	2.59±0.03[a]	3.99±0.04[a]	4.80±0.08[a]	6.39±0.087[a]
0.5% OPEO	2.16 ±0.05[a]	2.41±0.06[b]	3.03±0.06[b]	3.91±0.08[b]	5.12±0.13[b]
1% OPEO	2.16 ±0.05[a]	2.40±0.05[b]	2.78±0.07[c]	3.21±0.01[c]	4.15±0.12[c]

Table 4. The results of the total count of *Pseudomonas aeruginosa* bacteria in different treatments during storage (Mean ± SD).

Treatment	Day				
	0	3	6	9	12
Control	2.41 ±0.05[a]	4.02±0.02[a]	5.52±0.06[a]	6.42±0.05[a]	7.74±0.08[a]
0.5% OPEO	2.41 ±0.05[a]	3.68±0.07[b]	4.97±0.13[b]	5.87±0.09[b]	6.22±0.04[b]
1% OPEO	2.41 ±0.05[a]	3.11±0.12[c]	4.17±0.10[c]	4.71±0.03[c]	5.65±0.03[c]

Table 5. The results of total count of lactic acid producing bacteria in different treatments during storage (Mean ± SD).

Treatment	Day				
	0	3	6	9	12
Control	2.05±0.04[a]	2.55±0.02[a]	3.83±0.11[a]	4.53±0.02[a]	5.60±0.01[a]
0.5% OPEO	2.05±0.04[a]	2.37±0.04[b]	3.12±0.05[b]	3.46±0.05[b]	4.91±0.10[b]
1% OPEO	2.05±0.04[a]	2.35±0.05[b]	2.75±0.12[c]	3.10±0.04[c]	3.95±0.00[c]

The results related to the antimicrobial activity of OPEO by the agar whole method, the minimum growth inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) on the investigated strains are given in Table 6. The results related to the minimum growth inhibitory concentration of *Listeria monocytogenes* and *Pseudomonas aeruginosa* bacteria were determined to be 4 mg/ml. Also, the results of OPEO MBC for two strains of *Listeria monocytogenes* and *Pseudomonas aeruginosa* were determined as 8 and 4 mg/ml.

Table 6. MIC and MBC results of orange peel essential oil

Bacteria	MIC(mg/ml)	MBC(mg/ml)
Listeria monocytogenes	4	8
Pseudomonas Aeruginosa	4	4

Examining the Results of Chemical Tests

Changes in the pH of turkey meat samples during storage are presented in Figure 3. The trend of pH in all groups was increasing, so this increase was more intense in the control sample and reached 7.03 on the 12th day. On 0 day, no significant difference was observed between the treatments ($P < 0.05$) in the samples treated with OPEO (1%), the pH value was significantly ($P < 0.05$) lower than the control group, which is On the 12th day, this amount reached 6.72.

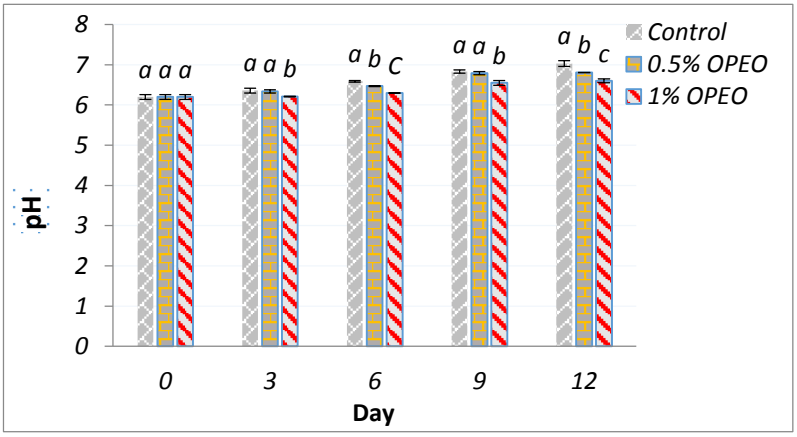

Figure 3. Average pH changes in different treatments (Mean ± SD)

The changes in the amount of total volatile (TV-N) of turkey meat samples during storage are reported in Figure 4 With the increase in storage time, the trend of the amount of total volatile nitrogen substances in all groups was increasing, so this increase in the control treatment compared to the other treatments was more and reached 60.8 mg/100g on the 12th day. In the samples treated with OPEO (1%), the amount of TV-N was significantly (P<0.05) lower than the control group, which reached 21.05 mg/100g on the 12th day.

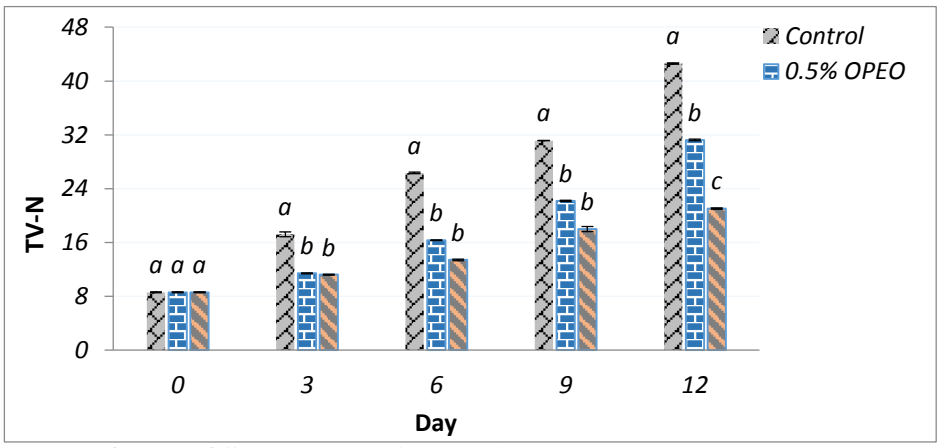

Figure 4. Average TV-N changes in different treatments (Mean ± SD)

Changes in Thiobarbituric acid of turkey meat samples during storage are shown in Table 7. With increasing storage time, the amount of Thiobarbituric acid in all samples increased (P<0.05). However, the increase in TBARS in OPEO samples (0.5% and 1%) was less than in the control group (P<0.05). On the 12th day of storage, the lowest TBARS values obtained in the 1% OPEO sample were observed, which was equal to 2.01.

Table 7. Average TBARS changes in different treatments (Mean ± SD)

Treatment	Day				
	0	3	6	9	12
Control	0.15±0.02^{a}	0.46±0.01^{a}	1.60±0.07^{a}	2.44±0.02^{a}	3.15±0.01^{a}
0.5% OPEO	0.15±0.02^{a}	0.27±0.01^{b}	1.02±0.04^{b}	1.93±0.00^{b}	2.66±0.04^{b}
1% OPEO	0.15±0.02^{a}	0.25±0.05^{b}	0.76±0.03^{c}	1.19±0.05^{c}	2.01±0.03^{c}

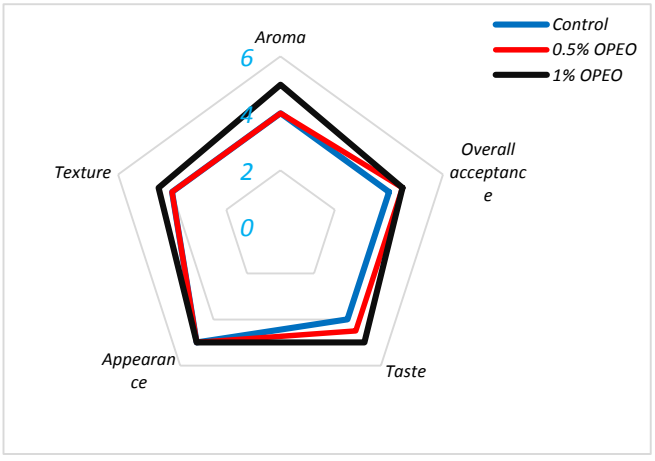

Figure 5. Sensory evaluation results of samples in different treatments

Sensory Evaluation

Changes in sensory characteristics (taste, aroma, appearance, texture and general acceptance) of turkey meat samples stored at refrigerator temperature are reported in Figure 5. During the maintenance period, the treatments obtained a higher and acceptable score in terms of sensory characteristics including taste, aroma, texture and overall acceptance ($P<0.05$) and no statistically significant difference was observed between the treatments in terms of appearance ($P>0.05$) According to the results shown, 1% OPEO treatment, compared to other treatments, it had more aroma, taste, appearance, texture and overall acceptance score during the storage period.

Discussion

According to the analysis of chemical constituents in OPEO in this study, D-limonene was the most abundant compound OPEO with 74.71%, which was lower than the values reported in previous researchers' studies (31, 32). Of course, the amounts of these compounds can be different due to different factors such as the type of essential oil extraction, plant variety, genetic factors, geographical location, climatic conditions, and soil. In line with the findings of this research, Khan et al. (2012) also reported D-limonene as the main compound in OPEO (33). There have been many reports regarding the antioxidant properties of citrus essential oil (5, 6, and 7). In meat and meat products, the highest allowed amount of aerobic bacteria count is 7 log cfu/g (34). In this study, the count of aerobic bacteria in the control sample did not exceed the maximum acceptable value until the 9th day, and the samples were treated with OPEO until the 12th day. The results of this study are in line with the results of Milani et al (2020) study, which stated that the use of edible gelatin-Hydroxypropyl β-cyclodextrin coating containing Nano-emulsion leads to a significant reduction in the number of aerobic bacteria in turkey meat (35). The highest amount of spoilage in the meat and meat products industry occurs through Pcychrotrophic bacteria, which are aerobic (36). In the present study, the number of Pcychrotrophic bacteria in the samples treated with the highest concentration of OPEO was reduced compared to the control sample. The reason for the low number of these bacteria is the presence of phenolic amounts in OPEO. The chemical structure and hydroxyl groups in them are factors that can play a role as an antimicrobial property in essential oils (37). Similar results were reported by Noshad et al. (1400) who showed that the number of Pcychrotrophic bacteria in the buffalo meat sample treated with fruit Cordia myxa mucilage-orange peel essence was lower than in the control group (38).

Enterobacteriaceae are present in large quantities in the meat industry and meat products and play their role as the main cause of spoilage and endangering people's health. In the present study, the population of Enterobacteriaceae in the samples treated with OPEO was lower than in the control sample. In a similar study by Fayaz far et al. (1400), it was reported that adding high concentrations of Shirazi thyme essential oil (0.1 and 0.2%) to fresh turkey sausages significantly reduces the number of Enterobacteriaceae during 17 days of storage. Also, as the concentration of essential oil increases, the population of bacteria decreases (39).

In the present study, the initial number of *Pseudomonas aeruginosa* bacteria in the groups treated with different concentrations of OPEO (0.5% and 1%) was lower than the control group, so their count on the twelfth day of storage in the treatment with 1% OPEO was 4.15 log cuf/g arrived. The results of this research were in line with the study of Fayaz Far et al. (1400), which showed that the population of *Pseudomonas bacteria* in concentrations (0.2 and 0.1%) of Shirazi thyme essential oil to fresh turkey sausages was lower than the control group (39).

Lactic acid bacteria are the main spoilage organisms in vacuum or low oxygen and their large number causes spoilage and discoloration in meat. In the present study, the population of lactic acid bacteria in samples containing OPEO decreased significantly compared to the control sample of turkey meat. The results of counting lactic acid bacteria were consistent with the results of Vasiliki et al. (2016) (40). In this study, the results of (MIC) of OPEO for *Listeria monocytogenes* and *Pseudomonas aeruginosa* were determined as 4 mg/ml. In the study of Oraii et al. (2018), the MIC level of the ethanolic extract of orange peel in vitro for *Pseudomonas aeruginosa bacteria* was 5% (41) and in the study of Noshad et al. (2019) for *Listeria bacteria*, it was less than 4 mg/ml. (38). In the present study, the results of MBC of OPEO for *Listeria*

monocytogenes and *Pseudomonas aeruginosa* were determined as 4 and 8 mg ml. Yun-Chen et al. (2008) stated that there are flavonoids, pectin, carotenoid and phenol in orange peel, which can have antimicrobial properties (42). In the present study, OPEO can have a significant antibacterial effect on both strains. In a similar study, Milani et al. (2019) reported the MBC of these two bacteria as 1.250 mg/ml and 0.625 mg/ml. In the present study, the increase in pH in the samples treated with OPEO was much lower than in the control sample, which could be due to the antioxidant activity of OPEO. Taheri et al. (2016) also conducted a study on the effect of acetic acid on turkey and stated that there was a slight increase in the pH value of the treated samples (6.21), but this increase in the control sample (7.03) quickly has been more (34). The reason for the increase in the pH value in the control sample is the increase in the number and activity of microorganisms, which can affect the proteins and the separation of amino compounds. Ali Beigi et al. (2012) studied the antioxidant effect of orange peel extract on the quality of carp fillets and reported that the pH increased with increasing storage time, and this trend was higher in the control treatment. During the beginning of storage, a decrease in pH occurs due to the breakdown of glycogen and the formation of inorganic acids (such as lactic acid) and leads to the inhibition of the growth of microorganisms (44).

The amount of volatile nitrogen (TV-N) is used to determine the quality of food of animal origin. Factors such as autolysis (self-digestion) of meat protein and the increase in the number of game compounds during the storage period cause a bad smell, and the role of this quality index is to help determine and evaluate the quality of the product because the increase in its amount decreases the duration. The maintenance and activity of spoilage bacteria and internal enzymes are related (45).

According to the results obtained in the present study, the amount of volatile nitrogen in the control group up to day 6, as well as in the OPEO treatment of 0.5% up to day 9, and in the OPEO treatment of 1% up to day 12, was lower than the standard limit by the country's veterinary organization (27 mg/100g). The results of this research were similar to the results of Taheri et al.'s study (2016) regarding the effect of acetic acid on reducing the amount of TV-N in the treatment of turkey meat fillets (43). The process of fat oxidation in meat, in which unsaturated fats are oxidized by free radicals, can play an important role in meat color (46).

The TBARS index is related to measuring the amount of malonaldehyde, which is a secondary product of the oxidation of unsaturated fatty acids. Based on the results obtained in the present study, regarding the antioxidant activity of OPEO, the treated samples showed lower amounts of TBARS during the storage period compared to the control sample. In Kang et al.'s (2006) study, the amount of TBARS in the sample treated with OPEO was lower compared to the control sample due to the prevention of the essential oil from fat oxidation (10). In 2008, Tiets et al. stated the amount of 3 mg malondialdehyde /kg of fat as spoilage in meat. The results of the present study were consistent with the findings of Milani et al. (2020) who stated that the use of nettle essential oil nanoemulsion leads to a significant reduction of TBARS values in turkey meat (35).

In this study, the results of evaluating the sensory scores of turkey meat samples treated with OPEO compared to the control sample were in more favorable conditions in terms of all factors, and this antioxidant effect of OPEO on preventing the growth of microorganisms, improving quality and increasing storage time it shows samples containing essential oil (47). In the study of Ali Beigi et al. (2012), investigating the effect of orange peel extract on the quality of carp fillets, adding orange peel extract (0.5%) led to an increase in sensory properties and shelf life and also reported that fat oxidation was delayed (44).In another similar study, Naseri et al. (2018) stated that adding Chovir essential oil, in addition to inhibiting the growth and proliferation of microorganisms, increases the shelf life and improves the sensory characteristics of turkey meat (48).

Conclusion

The result of this research showed that OPEO, having natural antimicrobial and antioxidant properties and suitable sensory properties, has the ability to be effective and usable in order to increase the shelf life and improve the sensory properties of turkey meat. Among all the samples of turkey meat examined during 12 days of storage in refrigerated conditions, it was found that the sample treated with a concentration of

1% has a favorable effect on the microbial and chemical characteristics in order to reduce the total count of aerobic bacteria, Pcychrotrophic bacteria, Enterobacteriaceae bacteria, and *Pseudomonas Aeruginosa* and lactic acid bacteria and MBC in comparison with MIC on *Listeria monocytogenes* and *Pseudomonas Aeruginosa* also, there was a decrease in pH, TV-N and TBARS indicators during the storage period. In addition, they had a good and acceptable score in terms of sensory characteristics useful for studying. Therefore, the attention and use of citrus peel essential oil as a preservative in the food industry can reduce waste and create added value.

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