PHYTON-ANNALES REI BOTANICAE
ISSN : 0079-2047
Volume 65 No.2 (2025)
https://phyton-annales.com

An eco-friendly meat preservation approach using oregano (*Origanum vulgare*) and sage (*Salvia sclarea*) essential oils combined with vacuum packaging

Kebir LydiaYasmine[1*], Aoues Karima[1], Lahreche Talal[2]
[1]*Laboratory of Sciences, Food Technologies and Sustainable Development, Agri-Food Department, Faculty of Nature and Life Sciences, University Saad Dahlab Blida - 1 University, BP 270, 9100 Blida, Algeria*
[2]*Departments of Biology, Faculty of Natural Sciences, Ziane Achour University, Djelfa, Algeria*
***Correspondance :**kebir_lydiayasmine@univ-blida.dz

Received: 14-08-2024 **Revised:** 12-07-2025 **Accepted:** 04-10-2025 **Published:** 08-12-2025

Abstract
To extend the shelf life of vacuum-packaged turkey legs, this study examined the antibacterial effect of oregano and sage essential oils (O&SEO) heated to the same temperature as gentle scalding (53°± 1 °C for 3 minutes) on spoilage microorganisms. Air-packaged (AP, control samples), AP with oregano oil emulsion (OOE), AP with warm (53°) OOE, AP with sage oil emulsion (SOE), AP with warm (53°) SOE, vacuum-packaged (VP, control samples), VP with OOE, VP with warm (53°) OOE, VP with SOE, and VP with warm (53°) SOE are the treatments of turkeys legs used in this study. The O&SEO composition was determined by a GC/MS analysis. The turkey legs were stored under air-packaging for 20 days and VP for 28 days at 2°C ± 0.5°C. Samples microbiological quality and sensory analysis was assessed by the enumeration of psychrotrophic bacteria, *Pseudomonas*, *Enterobacteriaceae*, yeasts and molds, *Lactobacillus sp*., and *Brochothrixthermosphacta (B. thermosphacta)*. Oregano and sage EOs contain carvacrol (Carv), o-Cymene (o-Cym), and Linalool (Lin). Using warmed oregano or SOE with air packing or VP extended turkey leg shelf life by 24 or 28 days by inhibiting SM. The treatment with oil emulsion and VP heated at high temperature received the greatest sensory evaluations from panellists for raw and cooked turkey leg samples. Based on these results, warmed oregano or SOE may be used as a natural preservative to extend turkey leg shelf life and microbiological shelf life.
Keywords: turkey legs; warmed essential oil emulsion; vacuum packaging; scalding; spoilage microorganisms

Introduction
The total output of poultry reached 139 million tonnes (Mt) in 2022, making it the type of meat that was produced and consumed the most on a global scale. According to OECD and FAO information from 2023, the countries who produced the most were discovered to be the United States of America (22.8 Mt), China (21.8 Mt), Brazil, and the European Union (14.8 Mt"). According to projections made by the Organisation for Economic Cooperation and Development (OECD) and the Food and Agriculture Organisation of the United Nations

(FAO), poultry is anticipated to be the primary contributor to the expansion of the global meat output during the course of the next ten years (2022-2032)(Linden 2014). According to FAOSTAT's 2020 report, turkey is one of the most important components of the poultry business within this sector. Today, increased demand for turkey meat is due to its excellent nutritional composition, significant health-beneficial properties (Yuan and Yuk 2018), high protein and mineral content, low fat content, cost-effective production and its sensory properties (Ribarski and Oblakova 2016).

Despite these advantages, turkey meat is considered as a very perishable commodity. Microbial growth (spoilage and pathogenic), endogenous and external enzymatic action, and oxidative degradation of lipids and heme pigments account for its short shelf life (Wang et al. 2017). Psychrotrophic bacteria, Enterobacteriaceae, Lactobacillus spp., Brochothrixthermosphacta, yeasts, and molds are the primary pathogens that degrade turkey flesh. They produce slime, tissue color change, and off-flavors with their metabolisms (Nychaset al. 2008).

The issue of microbiological safety, sensory acceptability and extended shelf life of turkey meat has continued to be a great challenge for the poultry sector. Because of an increase in consumer awareness of the potential health risk of synthetic preservatives and an emergence of the need for natural alternatives, as a result, several preservation methods have been explored. These include application of natural antimicrobials from plant origin, low temperature storage and VP (Zhang et al. 2016).

O&SEO exhibit excellent antibacterial activity and good sensory qualities, making them good chemical preservative alternatives (Jayasena et al. 2013). EOs' main bioactive compounds—Carv, thymol (Thy), linalyl acetate, and Lin —have broad-spectrum antibacterial activity against spoilage and pathogenic microbes. These chemicals, alone or with VP, have been shown to extend turkey meat shelf life (Pavelkovaet al. 2014; MojaddarLangroodi 2021).

To present, little study has examined how warmed essential oil emulsions affect VP turkey leg flesh quality and shelf life. This study examined the antibacterial effects of warmed oregano and SOE on SM in turkey legs stored at 2 ± 0.5 °C under VP. Chemical composition and sensory properties of the tested EOs were assessed.

Materials and methods

Essential oils

Essential oils (EOs) of oregano and sage were procured from Voshuiles Store (France). Both oils were certified by Ecocert FR-BIO 01 (France) as 100% pure and natural, obtained from Mediterranean biological cultivation through steam distillation. The oils were stored in sealed amber glass vials under dark conditions at 3 ± 1 °C until subsequent use.

Analysis of essential oil (GC-MS)

The study used a SHIMADZU GCMS-QP2020 system (Technical Platform of Physicochemical Analyses, PTAPC–CRAPC, Laghouat, Algeria) with a fused Rxi®-5ms capillary column (30 m × 0.25 mm i.d., 0.25 µm film thickness) for gas chromatography-mass spectrometry (GC–MS)(Bauer & Buettner, 2018). Helium (99.995% purity) was used as the carrier gas at 1 mL/min. The column oven was heated at 50 °C for 2 min, then increased at 3 °C/min to 310 °C and held for 2 min(Borucka et al. 2023). Injections of 250 µL samples were made in splitless mode (5:1). The mass spectra were compared to the Wiley 7N, NIST 02, and NIST 98 libraries to identify components.

Emulsions preparation

EOs of oregano and sage were formulated into emulsions for immersion treatments. Each EO emulsion was prepared by mixing 0.3 mL of oregano oil and 0.9 mL of sage oil in 100 mL of distilled water. To facilitate dispersion, 0.3 mL of Tween 80 was incorporated as a surfactant. The mixture was homogenized using a mechanical homogenizer for 2 min until a uniform emulsion was achieved. The emulsions were prepared immediately before application to ensure stability.

Preparation of turkey legs

A local poultry processing company provided the fresh turkey legs that were collected around one hour after the turkey had been killed. Insulated polystyrene containers were used to transfer the samples to the laboratory, and the conditions were kept at a temperature that was below freezing. In order to prepare the legs for treatment, they were first washed with cold sterile distilled water upon arrival, and then they were allowed to drain on sterile stainless-steel mesh racks for twenty minutes while being refrigerated.

Treatments of samples and storage conditions

A total of ten meat batches were prepared, with each experimental group replicated three times. Samples were packaged using two industrially relevant methods: air packaging (AP, also referred to as PVC overwrap) and vacuum packaging (VP).

For the AP control group, legs were packed in polyethylene bags without pre-treatment and stored aerobically at 2 ± 0.5 °C(Cai et al. 2014). In the treated AP groups, legs were immersed for 4 min in oregano or sage EO emulsions at either room temperature (~20 °C) or preheated to 53 °C, then packaged and stored under the same conditions.

For the VP groups, legs were subjected to the same immersion treatments (room temperature or 53 °C) and subsequently vacuum-sealed in polyethylene bags. Every sample was kept in a dark, refrigerated environment at a temperature of 2 ± 0.5 °C. On days 0, 3, 6, 9, 12, 16, 20, 24, and 28, respectively, microbiological and physicochemical studies were carried out. In contrast, VP samples were monitored for a period of up to 28 days, while AP samples were analyzed for a period of up to 20 days.

Microbiological analysis

Homogenization was performed with a stomacher (Interscience, France) on each day of the sample process. Ten grams of turkey leg flesh were put aseptically into sterile stomacher bags that contained ninety milliliters of buffered peptone water with a concentration of 0.1% (TM Media, India). Following the preparation of serial tenfold dilutions, the necessary dilutions were plated on selective media in order to count the number of microorganisms present.

A total of psychrotrophic bacteria were counted on Plate Count Agar (TM Media, India) following a 10-day incubation period at a temperature of 6.5 °C. On Cetrimide–Fusidin–Cephaloridine (CFC) agar (TM Media, India), which was incubated at 30 °C for forty-eight hours, the number of Pseudomonas species was measured. Following an incubation period of twenty-four hours at 37 °C, the counts of *Enterobacteriaceae* were determined on Violet Red Bile Glucose (VRBG) agar (TM Media, India). On YGC agar (Merck, Germany), yeasts and molds were counted after being incubated at a temperature of 25 °C for three to five days. Following incubation at 25 °C for forty-eight hours, the number of *Brochothrixthermosphacta* was counted on STAA Agar Base supplemented with STAA selective supplement (TM Media, India)(Reale et al. 2008). *Lactobacillus spp*. were cultivated on MRS agar (TM Media, India) at a temperature of thirty °C for a period of seventy-two hours.

Visual examination and documentation were performed on colonies that exhibited the morphology that is distinctive of each species of organism. It was determined that the logarithm of colony-forming units per gram of beef (log CFU/g) was the most accurate way to express the microbial counts(Gan et al. 2024).

Sensory analysis

The sensory evaluation of raw turkey legs was conducted following international standards for sensory testing—covering panelist selection, training, test execution, and sensory room design (ISO 2007). A description was conducted by blind conditions to a panel of seven judges who had no prior knowledge of the experimental treatments. Panelists were instructed to evaluate and describe meat freshness sensory qualities as look, color, odor, and general acceptability during preparatory sessions.

Sensory characteristics were general appearance (G), color (C), off-odor (O), and overall acceptability (OA). Lower hedonic scores indicated freshness and quality on a 0-point scale. A sensory shelf-life score of 5 was acceptable. The Kreyenschmidt (2003) equation was used to calculate a weighted sensory index (SI):

$$IS = 2A + 2C + 3O + 2AO/9.$$

The Patsias et al. (2006) procedure was used to sensory analyze cooked turkey meat. About 100 g of each sample was microwaved at 700 W for 6 min. The same seven professional evaluators assessed flavor, texture, appearance, and odor. Each trait was scored on a 5-point acceptability scale, with 5 being “most liked” and 0 being “least liked.” The minimum acceptable score was 3. Each sample was evaluated independently in duplicate (n = 3).

Statistical analysis

Triplicates were used for all experiments. The results are shown as mean values ± SD. After one-way analysis of variance (ANOVA), Duncan's multiple range test was used to find significant mean value changes across treatments (El-Shahatet al. 2020). The statistical analysis was done using SPSS 19.0 (SPSS Inc., Chicago, IL, USA). Significant differences were defined at $p < 0.05$(Wang et al. 2020).

Discussion of Results

Gas Chromatography-Mass Spectrometry analysis

The volatile constituents of O&SEO were 41 and 23 by GC–MS profiling, representing 99.88% and 99.81% of the overall composition, respectively. EOs of oregano contain Carv (56.77%), o-Cym (11.29%), Thy (6.61%), γ-terpinene (γ-Trp) (6.37%), Lin (3.55%), caryophyllene (Cary) (3.18%), and α-terpinene (α-Trp) (2.00%). Like Govaris et al. (2011), Boskovic et al. (2015), and Hossain et al. (2016), these findings confirm that Carv and Thy dominate oregano EO.

Sage essential oil (SEO) contains primary constituents: linalyl acetate (61.39%), Lin (18.79%), β-copaen-4α-ol (3.37%), myrcene (Myr) (2.93%), and Cary (2.52%). The large amounts of linalyl acetate and Lin in sage EO were also found by Hristova et al. (2013), Yaseen et al. (2015), and Acimovic et al. (2022).

Table 1: Chemical composition of oregano Eo.

Nom	Tr (min)	Composition %
α-Phellandrene	8.691	0.38
α-Pinène	8.948	0.94
Camphene	9.512	0.13
1-Octen-3-ol	10.749	0.93
Amylethylketone	11.042	0.25
Myrcene	11.260	1.72
β-phellandrene	11.804	0.34
δ3-Carene	12.063	0.10
α-Terpinène	12.339	2.00
o-Cymene	12.711	11.29
Eucalyptol	12.873	1.09
β -Pinene	13.307	0.02
(E)-Ocimene	13.767	0.06
γ-Terpinène	14.253	6.37
(cis)-4-Thujanol	14.591	0.08
Cyclohexene, 1-methyl-4-(1-methylethylidene)-	15.588	0.46
Linalool	16.124	3.55
2,5-Dimethylhex-5-en-3-yn-2-ol	16.756	0.04
1,3,8-p-Menthatriene	17.949	0.01
Borneol	19.158	0.37
3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)-	19.707	0.91
α-Terpineol	20.568	0.09
Cyclohexanone, 2-methyl-5-(1-methylethenyl)-, trans-	20.870	0.03
Benzene, 1-methoxy-4-methyl-2-(1-methylethyl)-	22.774	0.06
Cyclohexanone, 5-methyl-2-(1-methylethylidene)-, (R)-	23.157	0.04
Duroquinone	23.243	0.03

2,3,5,6-Tetramethylphenol	24.706	0.11
Thymol	25.069	7.61
Carvacrol	25.818	56.97
Copaene	28.668	0.02
Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-	29.973	0.01
α-Gurjunene	30.094	0.01
Caryophyllene	30.533	3.18
Aromandendrene	31.305	0.02
(Z,Z,Z)-1,5,9,9-tetra- methyl-1,4,7-cycloundecatriene	31.909	0.18
γ-Muurolene	32.857	0.01
1H-Cycloprop[e]azulene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,7.alpha.,7a.beta.,7b.alpha.)]-	33.618	0.02
β-Bisabolene	34.136	0.35
γ-Cadinene	34.367	0.01
δ-Cadinene	34.732	0.03
Oxyde de caryophyllene	37.048	0.07

Table 2: Chemical composition of sage Eo.

Nom	tr (min)	Composition (%)
Myrcene	11.33	2.93
Limonène	12.88	0.17
α-Pinène	13.32	0.64
(E)-β-Ocimene	13.80	1.62
Linalool	16.17	18.79
Allo-ocimene	17.50	0.32
α-Terpinéol	20.29	1.66
Formate de linalyle	21.49	0.34
(Z)-géraniol	22.04	0.21
Acétate de linalyle	23.52	61.39
(Z)-Formate de néryle	25.39	0.08
γ-Elemene	26.95	0.24
Acétate de neryle	28.10	1.08
Copaene	28.63	1.17
Acétate de géranyle	28.92	1.88
Bicyclosesquiphellandrene	29.24	0.28

Germacrène A	29.31	0.17
Caryophyllene	30.47	2.52
γ-Cadinene	31.87	0.29
β-Copaen-4α-ol	33.02	3.37
Valencene	33.29	0.11
Lepidozene	33.66	0.35
δ-Cadinene	34.71	0.20

Microbiological analysis

Air packaging

In chilled circumstances, aerobic, Gram-negative psychotrophic bacteria flourish. Aerobic deterioration of chilled meat, poultry, and fish is caused by these microorganisms (Fung 2009). Turkey leg samples had an initial psychrotrophic count of 5.21 log CFU/g on day 0, indicating good product quality, as the ICMSF (1986) recommends a maximum of 10^7 CFU/g for poultry. Day 9 storage increased air-packaged sample psychrotrophic counts to 6.42 log CFU/g (Table 3).

According to Wages (2020), most psychrotrophic bacteria detected on poultry carcasses after processing originate not from the intestinal tract but from external sources such as feathers, feet, processing water, cooling tanks, and handling equipment. During the course of this investigation, the psychrotrophic population exhibited a noteworthy increase with the passage of time ($p < 0.05$). The control group exhibited a considerably higher quantity of bacteria compared to all of the treated groups ($p <= 0.05$). This indicates that in the absence of any antimicrobial action, the development of bacteria is occurring at a rapid pace. Among the treatments, the samples of oregano essential oil emulsion (OOE) and sage essential oil emulsion (SOE) that were treated with warm oregano and sages, respectively, had the lowest psychrotrophic counts while they were being stored. However, beginning on the ninth day, there was no discernible difference ($p > 0.05$) between the samples that were treated with OOE and those that were treated with SOE(Rafiq et al. 2016).

Most psychrotrophic bacteria that cause poultry spoiling in aerobic packages are *Pseudomonas spp*. (Wang et al. 2017). The load in this investigation was 5.04 log CFU/g at the start and 6.46 after nine days of air-packaged sample storage. Treatment with sage and oregano oils at 2 ± 0.5 °C resulted in significant differences ($p < 0.05$) compared to control samples, but not between air-packaged samples ($p > 0.05$) (Table 3). Under vacuum packaging (VP), warm SOE treatments had higher Pseudomonas counts during storage, indicating a significant difference ($p < 0.05$) from warm OOE treatments. Warm-temperature OOE inhibited *Pseudomonas spp*. growth more. According to Nychas et al. (2008), Pseudomonas spp. counts over 7.0-8.0 log CFU/g indicate potential fresh meat deterioration. Before the 16th day of storage, all samples were below 7 log CFU/g, and warm essential oil emulsion samples were below 6 log.

Refrigerated foods often include Gram-negative, facultatively anaerobic *Enterobacteriaceae* that aerobically degrade poultry flesh (Chen et al. 2014). Under VP circumstances, they grow slower (Chouliaraet al. 2007). The study found that Enterobacteriaceae levels in aerobically stored control samples increased from 5.14 ± 0.01 log CFU/g on day 1 to 6.38 log CFU/g on the last day of measurement (Table 3)(Zou et al. 2022). The treated samples had considerably lower colony counts than the control ($p \leq 0.05$), with heated OOE resulting in the lowest results. Oregano and sage oils had no significant influence ($p > 0.05$) on turkey legs' antimicrobial response after day 9, and they performed similarly during storage. The product's sanitary and microbiological quality is also shown (Mladenovic et al. 2021).

The yeast and molds which have the ability to grow at refrigeration temperature are also responsible for spoilage of poultry by producing undesirable aromas and flavors (Fung 2009; Jayasena et al. 2013). Air-packaged control samples had 5.36 log CFU/g yeast and mold at day 1, which increased to 6.35 log CFU/g, day 9. Compared to the control group, warm SOE had a greater inhibitory impact on fungus growth ($p < 0.05$). Warm SOE treatment resulted in substantially decreased bacteria populations (4.91 ± 0.01 log CFU/g) till day 9, indicating powerful antifungal effects. Raymondbaudi-Massilia et al. (2006) found that antibacterial efficacy varies by microbial species and essential oil. At the conclusion of storage (day 20), warm OOE-treated samples showed lower yeast and mold counts (5.73 ± 0.01 log CFU/g), indicating improved long-term protection.

Table 3: Effect of dipping a warmed and not warmed oregano and sage essential oils emulsion on the growth of spoilage bacteria in turkey legs stored aerobically at 2 ± 0.5°C

Microorganisms	Treatment	Storage days						
		J0	J3	J6	J9	J12	J16	J20
Psychrotrophics	Control	5.21 ±0.00a	5.44 ±0.00a	5.55 ±0.00 a	6.42 ±0.00 a			
	Oregano oil emulsion	5.21 ±0.00a	5.10 ±0.01b	5.08 ±0.00 b	5.93 ±0.00 b	6.09 ±0.00 a		
	Oregano warm oil emulsion	5.21 ±0.00a	4.83 ±0.00e	4.79 ±0.00 e	4.92 ±0.02 d	4.98 ±0.01 c	5.45 ±0.00 b	6.16 ±0.01b
	Sage oil emulsion	5.21 ±0.00a	5.00 ±0.01c	5.00 ±0.00 c	5.93 ±0.01 b	6.09 ±0.02 a		
	Sage warm oil emulsion	5.21 ±0.00a	4.86 ±0.01d	4.82 ±0.01 d	5.09 ±0.01 c	5.30 ±0.03 b	5.64 ±0.01 a	6.37 ±0.02a
Pseudomonas spp.	Control	5.04 ±0.00a	5.28 ±0.00a	5.69 ±0.01 a	6.46 ±0.00 a			
	Oregano oil	5.04	5.00	4.94	5.84	6.01		

PHYTON-ANNALES REI BOTANICAE
ISSN : 0079-2047
Volume 65 No.2 (2025)
https://phyton-annales.com

	emulsion	±0.00a	±0.00b	±0.03 b	±0.13 b	±0.01 b		
	Oregano warm oil emulsion	5.04 ±0.00a	4.35 ±0.01d	4.36 ±0.00 d	4.94 ±0.00 d	5.08 ±0.01 d	5.39 ±0.02 b	6.32 ±0.01b
	Sage oil emulsion	5.04 ±0.00a	5.00 ±0.00b	4.98 ±0.01 b	5.94 ±0.01 b	6.11 ±0.00 a		
	Sage warm oil emulsion	5.04 ±0.00a	4.64 ±0.04c	4.62 ±0.04 c	5.49 ±0.03 c	5.61 ±0.02 c	5.77 ±0.01 a	6.76 ±0.01a
Enterobacteriaceae	Control	5.14 ±0.01a	5.32 ±0.00a	5.34 ±0.00 a	6.38 ±0.00 a			
	Oregano oil emulsion	5.14 ±0.01a	5.07 ±0.00c	5.06 ±0.01 c	5.75 ±0.01 b	6.01 ±0.00 a		
	Oregano warm oil emulsion	5.14 ±0.01a	4.89 ±0.00e	4.75 ±0.00 d	5.02 ±0.00 d	5.09 ±0.01 c	5.19 ±0.00 b	5.85 ±0.03b
	Sage oil emulsion	5.14 ±0.01a	5.11 ±0.00b	5.08 ±0.00 b	5.76 ±0.00 b	6.01 ±0.00 a		
	Sage warm oil emulsion	5.14 ±0.01a	4.92 ±0.00d	4.75 ±0.01 d	5.17 ±0.01 c	5.22 ±0.00 b	5.23 ±0.00 a	5.96 ±0.01a
yeasts and molds	Control	5.36 ±0.00a	5.37 ±0.00a	5.45 ±0.00 a	6.35 ±0.00 a			
	Oregano oil emulsion	5.36 ±0.00a	5.08 ±0.00b	4.96 ±0.00 b	5.63 ±0.02 b	5.68 ±0.00 a		
	Oregano warm oil emulsion	5.36 ±0.00a	4.81 ±0.00d	4.64 ±0.01 c	4.96 ±0.00 d	4.98 ±0.00 c	5.08 ±0.00 b	5.73 ±0.01b
	Sage oil emulsion	5.36 ±0.00a	5.01 ±0.00c	5.00 ±0.00 b	5.52 ±0.01 c	5.69 ±0.01 a		
	Sage warm oil emulsion	5.36 ±0.00a	4.72 ±0.03e	4.64 ±0.04 c	4.91 ±0.01 e	5.04 ±0.01 b	5.18 ±0.01 a	6.42 ±0.01a

Values are expressed as average ± standard deviation (n =3).
a, b, c, d: Different lowercase letters in the same column indicate significant differences (p<0.05) between the different treatments on the same sampling days.

Vacuum packaging

As facultative anaerobic bacteria, *Lactobacillus spp.* tend to proliferate under conditions with limited oxygen, forming a major component of the natural microbiota in VP meat (Doulgerakiet al. 2011). This genus is one of the most resistant Gram-positive bacteria to EO antimicrobials. Lactic acid bacteria (LAB) can create ATP efficiently and resist osmotic stress (Kostakiet al. 2009; Frangos 2010). Table 4 shows that LAB counts in control samples maintained under VP increased from 5.16 log CFU/g on day 0 to 6.22 on day 12. In combination with EOs, VP significantly reduced LAB proliferation, with lower bacterial counts in treated groups compared to controls ($p < 0.05$). The treatment groups with the lowest LAB counts from samples handled with heated OOE during the experiment differed significantly. The sample treated with OOE and heated OOE under VP at 2 ± 1°C showed LAB cell counts of 5.16 log CFU/g at day 0 and 5.06 and 4.97 log CFU/g at day 16. The study found that VP, warm OOE, and chilled storage (2 ± 0.5°C) effectively suppressed LAB multiplication over 28 days.

In the control group stored under VP, *Enterobacteriaceae* population was 5.14 ± 0.01 log CFU/g on day 1 and 6.24 on day 12, while EO-treated samples took over 20 days to reach similar values, indicating a significant difference ($p < 0.05$). All therapy groups reduced *enterobacteriaceae* counts, but VP and OOE had the greatest decreases. The combination of VP with OOE reduced Enterobacteriaceae by 1.14 log CFU/g ($p < 0.05$) on day 12, while warm OOE and warm SOE had reductions of 1.22 and 1.23 log CFU/g, respectively.

It has been reported as a prominent spoiling organism of VP refrigerated meat (Nowak et al. 2013) and to be a reliable indicator for shelf life and meat decomposition (Gribble and Brightwell 2013; Stanborough 2018). *Brochothrixthermosphacta* is a Gram-positive facultative anaerobic bacterium because it grows in the absence of oxygen(Lu et al. 2023). Furthermore, in the present investigation, a statistically significant difference ($p < 0.05$) was discovered between the control group and the EO-treated group that was stored under VP. During the storage period of 24 days for warm soya bean oil (SOE) and 28 days for warm O&SEO, the number of *B. thermosphacta* in the control group increased from 5.20 ± 0.01 CFU/g on day 0 to 6.45 CFU/g on day 12. However, the values were comparable to those of EO-treated samples. This was stated in Table 4. Therefore, the shelf life of the turkey legs was expanded to approximately 28 days for the heated OOE and 20 days for the heated SOE as a result of the combined application of VP and heated EOs. This markedly prolonged the growth of *B. thermosphacta.*

O&SEO consistently exhibit potent and consistent antimicrobial activity against psychrotrophs, *Pseudomonas spp.*, *Enterobacteriaceae*, *B. thermosphacta*, *Lactobacillus spp.*, yeasts, and molds. Since EOs lack a protective membrane, they are more effective against

Gram-positive bacteria than Gram-negative bacteria(Jayasena et al. 2013). At low temperatures, VP showed anti-bacterial growth activity, which reduced spoiling and extended poultry shelf life (Can and Sahin 2019). In the present study, turkey legs packaged aerobically and treated with oregano or SOE had a shelf life of 12 days, but those treated with warm essential oil emulsions were stable for 20 days, with cold OOE having the lowest microbial loads.

The combined effect of VP and EOs, especially in their heated emulsion form, was found to be synergistic. Moreover, the shelf-life of legs treated with oregano or SOE under VP was 16 days, whereas warmed oregano or warmed SOE increased the shelf-life of legs to 20 days. This improved antimicrobial activity can be explained by volatile bioactive compounds that are found in the oils: Carv and Thy in oregano, and linalyl acetate and Lin in sage (Ramos et al. 2012), which exert their antimicrobial effect by damaging cytoplasmic membrane, by inactivating key enzymes, by disrupting proton gradients, and by depleting ATP levels, leading to cell death (Diao et al. 2014; Lee et al. 2019). Besides, the application of EO emulsions at 53° C, a temperature comparable to the one used in soft scalding, would have probably enhanced their effectiveness by opening pores in the skin, facilitating deeper penetration of volatile EO molecules without harming the external layers of the skin (Irshad and Arun 2013; Wages 2020).

Hence, the results of this study indicate that the integration of VP with warmed EO emulsions (53°C), particularly warmed oregano EO, was highly effective in controlling spoilage microorganisms and extending the storage life of turkey legs maintained at 2 ± 0.5°C.

Table 4: Effect of dipping a warmed and not warmed oregano and sage essential oils emulsion on the growth of spoilage bacteria in turkey legs stored under vacuum packaging at 2 ± 0.5 °C

Microorganisms	Treatment	Storage days								
		J0	J3	J6	J9	J12	J16	J20	J24	J28
Lactobacillus spp	Control	5.16 ±0.00a	5.30 ±0.00a	5.46 ±0.00a	6.10 ±0.00a	6.22 ±0.00a				
	Oregano oil emulsion	5.16 ±0.00a	5.11 ±0.00d	5.07 ±0.00d	5.06 ±0.00d	5.04 ±0.00c	5.06 ±0.00c	5.92 ±0.00b	6.25 ±0.00a	6.71 ±0.00a
	Oregano warm oil emulsion	5.16 ±0.00a	5.00 ±0.00e	4.99 ±0.00e	4.98 ±0.00e	4.98 ±0.00e	4.97 ±0.00d	5.61 ±0.03c	6.10 ±0.00b	6.51 ±0.00b
	Sage oil emulsion	5.16 ±0.00a	5.16 ±0.00b	5.11 ±0.00b	5.74 ±0.00b	5.87 ±0.00b	6.09 ±0.00a			
	Sage warm oil emulsion	5.16 ±0.0	5.14 ±0.0	5.09 ±0.0	5.08 ±0.0	5.01 ±0.0	5.13 ±0.0	6.21 ±0.0	6.25 ±0.0	

		0a	0c	0c	2c	0d	0b	1a	0a	
Enterobacteriaceae	Control	5.14 ±0.01a	5.41 ±0.00a	5.44 ±0.01a	6.16 ±0.02a	6.24 ±0.00a				
	Oregano oil emulsion	5.14 ±0.01a	5.29 ±0.00c	5.17 ±0.02c	5.12 ±0.00c	5.10 ±0.00c	5.18 ±0.01b	6.04 ±0.00b	6.57 ±0.02b	6.76 ±0.01a
	Oregano warm oil emulsion	5.14 ±0.01a	4.93 ±0.01e	4.89 ±0.00d	5.03 ±0.00d	5.02 ±0.01d	4.97 ±0.00d	5.78 ±0.00c	6.19 ±0.01c	6.43 ±0.01b
	Sage oil emulsion	5.14 ±0.01a	5.30 ±0.00b	5.24 ±0.01b	5.86 ±0.00b	6.05 ±0.00b	6.16 ±0.01a			
	Sage warm oil emulsion	5.14 ±0.01a	4.98 ±0.00d	4.91 ±0.01d	4.99 ±0.00e	5.01 ±0.01d	5.16 ±0.01c	6.34 ±0.02a	6.79 ±0.01a	
Brochothrixthermosphacta	Control	5.20 ±0.01a	5.30 ±0.00a	5.32 ±0.01a	6.35 ±0.00a	6.45 ±0.00a				
	Oregano oil emulsion	5.20 ±0.01a	5.29 ±0.00a	5.23 ±0.00b	5.22 ±0.01c	5.21 ±0.00c	5.17 ±0.00b	6.29 ±0.00a	6.53 ±0.00a	6.72 ±0.00a
	Oregano warm oil emulsion	5.20 ±0.01a	5.00 ±0.00d	4.95 ±0.00e	4.98 ±0.00e	4.98 ±0.00e	4.93 ±0.01d	5.50 ±0.04c	5.83 ±0.00c	6.09 ±0.00b
	Sage oil emulsion	5.20 ±0.01a	5.27 ±0.00b	5.21 ±0.00c	5.73 ±0.01b	5.77 ±0.01b	6.09 ±0.00a			
	Sage warm oil emulsion	5.20 ±0.01a	5.13 ±0.01c	5.08 ±0.00d	5.02 ±0.00d	5.00 ±0.00d	4.99 ±0.00c	5.91 ±0.03b	6.29 ±0.02b	

Values are expressed as average ± standard deviation (n =3).
a, b, c, d: Different lowercase letters in the same column indicate significant differences ($p<0.05$) between the different treatments on the same sampling days.

Sensory analysis

The sensory characteristics of both raw and cooked turkey legs stored under aerobic and VP conditions, with or without EO treatment, were assessed throughout the refrigeration period. The total demerit points for the raw and cooked samples are presented in Figures 1 and 2, respectively. At first all samples had a sensory score of zero, showing that the legs of turkeys had acceptable freshness and quality at the start of storage. Sensory scores decreased with storage in the treated and untreated groups, although this decrease was probably gradual due to the growth of SO. Nevertheless, the EO-treated samples always obtained better sensory scores due to the improved aroma and flavor characteristics.The study showed that the lower limit of shelf life (score of 5) for cooked turkey thighs stored under air at 2°C was reached after 3 days of storage for the control groups, at 12 and 16 days for the groups treated with oregano essential oil emulsion at room temperature or heated temperature, respectively, and after 9 and 12 days for the groups treated with sage essential oil emulsion at room temperature or heated temperature, respectively.In contrast, this limit was reached on the 6th day of storage for the control groups, on the 16th and 20th days of storage for the groups treated with sage essential oil emulsion at room temperature or heated temperature, respectively, and on the 12th and 16th days for the groups treated with sage essential oil emulsion at room temperature or heated temperature, respectively.Figure 2 shows the sensory scores of cooked turkey legs. At each of the sampling periods, significant differences ($p < 0.05$) were found between the control and treated groups with the treated groups receiving higher ratings by the panelists for taste and overall acceptability(López-Olvera et al. 2007). The observed decline in color and appearance scores may be attributed to the higher myoglobin content in turkey legs compared to breast meat (Ahn and Maurer 1990). Numerous studies have also associated spoilage-related sensory deterioration with microbial activity. According to Pooni and Mead (1984), the development of off-odors during cold storage is mainly due to the accumulation of metabolic byproducts from psychrotrophic bacteria utilizing available nutrients in carcasses. Likewise, the predominance of spoilage-associated microorganisms such as *Pseudomonas*, LAB, *Brochothrixthermosphacta*, and yeasts contributes to the formation of hydrogen sulfide and other volatile compounds responsible for undesirable greenish, sour, or cheesy odors (Zhang et al. 2016).

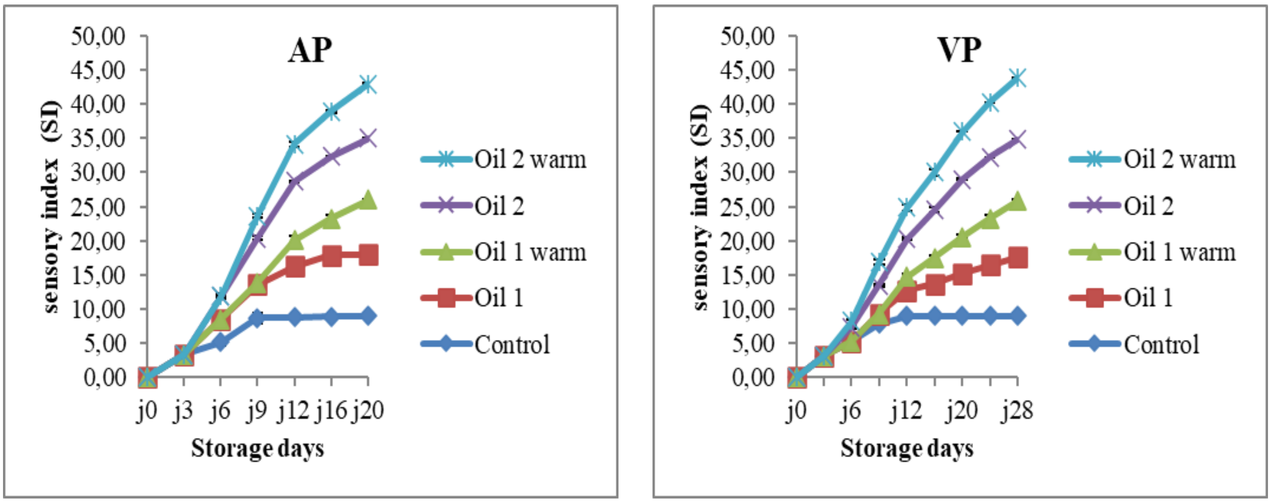
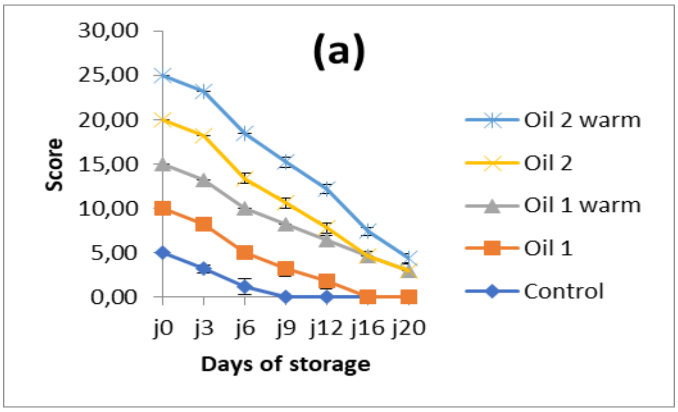
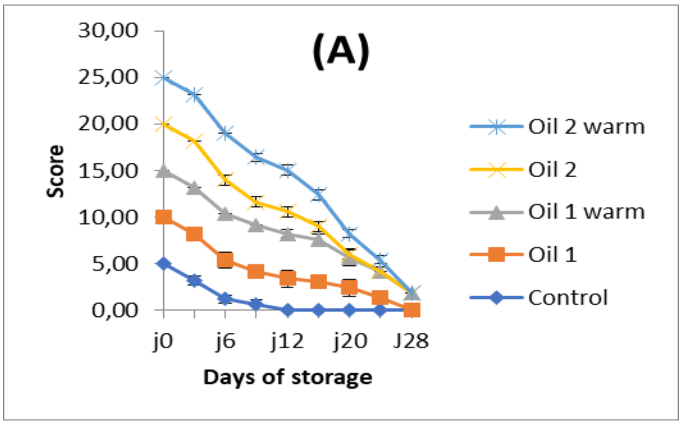
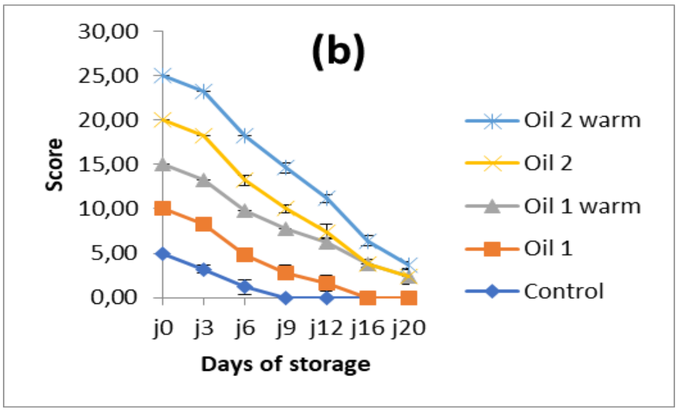
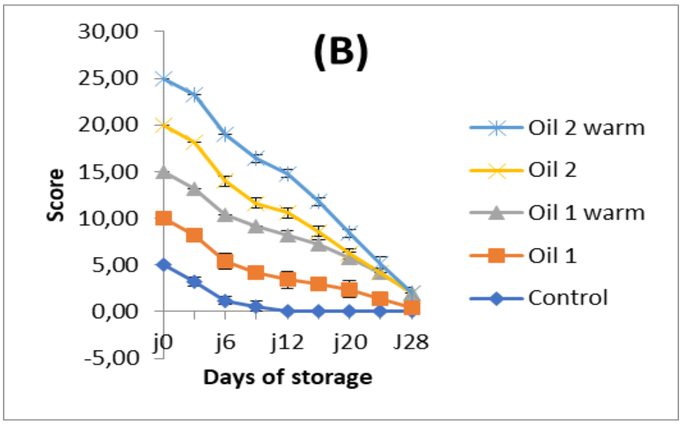


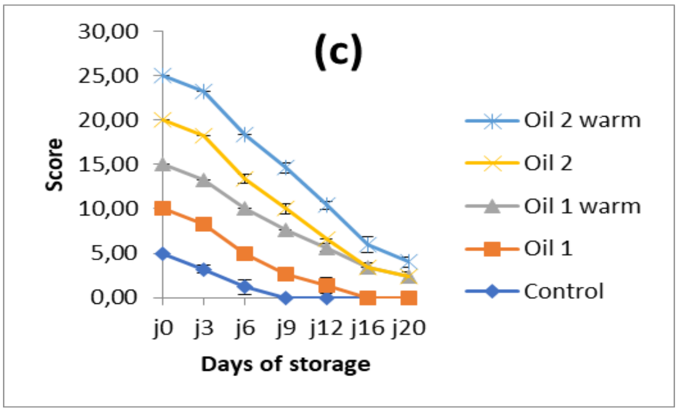
Figure.1. Change in sensory index (SI) of raw turkey legs stored at 2 ± 0.5 °Cin differently packaged methods under different treatments; AP: air-packaging, VP: VP, Oil 1: oregano, Oil 2: sage.

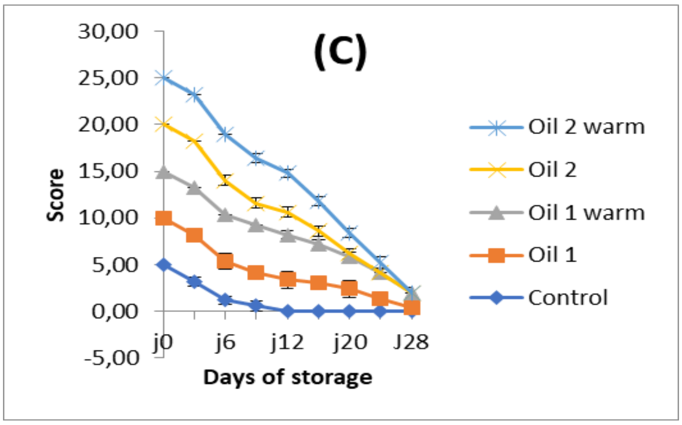

(a)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j3 j6 j9 j12 j16 j20
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control

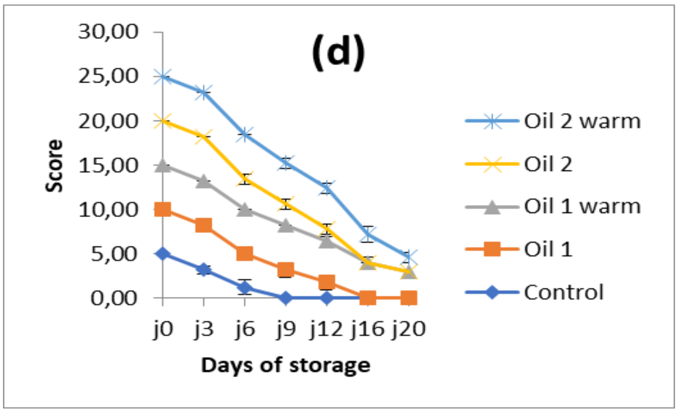

(A)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j6 j12 j20 J28
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control


(b)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j3 j6 j9 j12 j16 j20
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control


(B)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
-5,00
j0 j6 j12 j20 J28
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control


(c)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j3 j6 j9 j12 j16 j20
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control


(C)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
-5,00
j0 j6 j12 j20 J28
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control


(d)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j3 j6 j9 j12 j16 j20
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control

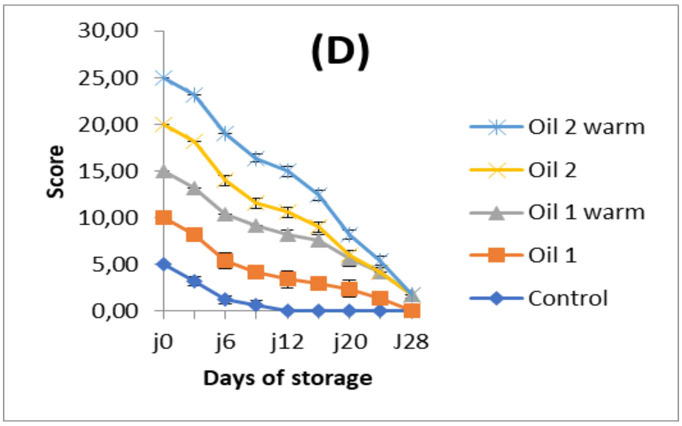

(D)
Score
30,00
25,00
20,00
15,00
10,00
5,00
0,00
j0 j6 j12 j20 J28
Days of storage
Oil 2 warm
Oil 2
Oil 1 warm
Oil 1
Control

Figure.2. Sensory analysis of cooked turkey legs stored at 2 ± 0.5 °C in differently packaged methods under different treatment. Sensory attributes: Air packaging a = Odor, b = Texture, c = Appearance, d = Taste intensities. VP A = Odor, B = Texture, C = Appearance, D = Taste intensities. Oil 1: oregano, Oil 2: sage.

Conclusion

The results of this investigation demonstrate that the EOs of oregano and sage possess a powerful antibacterial action against a wide range of SMs, including psychrotrophic bacteria, *Pseudomonas*, *Enterobacteriaceae*, *Lactobacillus spp*., *Brochothrixthermosphacta*, and a variety of yeasts and molds. According to the findings, the incorporation of heated oregano or SOE, which is heated to 53 °C, in conjunction with VP is an efficient method for enhancing the sensory qualities of turkey legs that are stored at a temperature of 2 °C± 0.5 °C. The use of warmed essential oil mixtures as a natural preservation strategy that is capable of demonstrating an additive effect in keeping the ecological stability and organoleptic quality of turkey meat while it is being stored in the refrigerator is therefore recommended.

Acknowledgments: We would like to thank Dr Bentoumi Yacine for their guidance and insightful feedback on research methodology. We also acknowledge Diproche Company for their help in providing the culture media. Finally, our gratitude goes to Pr Guendouz Abdelaziz to grant me a license to work in the biology laboratory in Djelfa- Algeria.

Disclosure statement: Conflict of Interest: The authors declare that there are no conflicts of interest. Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

REFERENCES

Acimovic, M. G., Loncar, B. L., Jeliazkov, V. D., Pezo, L. L., Ljujic, J. P., Miljkovic, A. R., &Vujisic, L. V. 2022. Comparison of volatile compounds from clary sage (Salvia sclarea L.) verticillasters essential oil and hydrolate. Journal of Essential Oil-Bearing Plants, 25(3), 555-570.

Ahn, DU, and AJ Maurer. 1990. Poultry meat color: Kinds of heme pigments and concentrations of the ligands. Poultry Sci. 69, pp. 157-65.

Bauer, P., & Buettner, A. (2018). Characterization of odorous and potentially harmful substances in artists' acrylic paint. Frontiers in Public Health, 6. https://doi.org/10.3389/fpubh.2018.00350.

Borucka, M., Mizera, K., Przybysz, J., Kozikowski, P., & Gajek, A. (2023). Analysis of flammability and smoke emission of plastic materials used in construction and transport. Materials, 16(6), 2444. https://doi.org/10.3390/ma16062444.

Boskovic, M., Zdravkovic, N., Ivanovic, J., Janjic, J., Djordjevic, J., Starcevic, M., & Baltic, M. Z. 2015. Antimicrobial activity of thyme (Tymus vulgaris) and oregano (Origanum vulgare) essential oils against some food-borne microorganisms. Procedia Food Science, 5, 18-21.

Cai, L., Cao, A., Li, T., Wu, X., Xu, Y., & Li, J. (2014). Effect of the Fumigating with

Essential Oils on the Microbiological Characteristics and Quality Changes of Refrigerated Turbot (Scophthalmus maximus) Fillets. Food and Bioprocess Technology, 8(4), 844–853. https://doi.org/10.1007/s11947-014-1453-0.

Can, Ö. P., & Şahin, S. 2019. Effect of Rosemary Essential Oil Coated Vacuum Packaging on the Quality of Chicken Meatballs at+ 4Â° C. Turkish Journal of Agriculture-Food Science and Technology, 7(12), 2165-2169.

Chen, Z.; Jiang, X. 2014. Microbiological Safety of Chicken Litter or Chicken Litter-Based Organic Fertilizers: A Review. Agriculture 4, 1–29.

Chouliara, E., Karatapanis, A., Savvaidis, I. N., &Kontominas, M. G. 2007. Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, stored at 4 °C. Food microbiology, 24(6), 607-617.

Diao, W. R., Hu, Q. P., Zhang, H., & Xu, J. G. (2014). Chemical composition, antibacterial activity and mechanism of action of essential oil from seeds of fennel (Foeniculum vulgare Mill.). Food control, 35(1), 109-116.

Dinesh D. Jayasena, Cheorun Jo. 2013. Essential oils as potential antimicrobial agents in meat and meat products: A review, Trends in Food Science & Technology, Volume 34, Issue 2. Pages 96-108, ISSN 0924-2244, https://doi.org/10.1016/j.tifs.2013.09.002.

Doulgeraki, A. I., Paramithiotis, S., Nychas, G. J. E. 2011. Characterization of the Enterobacteriaceae community that developed during storage of minced beef under aerobic or modified atmosphere packaging conditions. International Journal of Food Microbiology, vol. 145, no. 1, p. 77-83.

El-Shahat, A., Mounir, A. M., Hamza, R., & Al-Seeni, M. N. (2020). The Expected Beneficial Effects of Watermelon Juice against Damage Induced by Gamma Radiation in the Testis of Rats. Indian Journal of Animal Research, Of. https://doi.org/10.18805/ijar.b-1307

FAOSTAT. 2020. Available online at:http://www.fao.org/faostat/en/#data/QA.

Frangos, L., Pyrgotou, N., Giatrakou, V., Ntzimani, A., &Savvaidis, I. N. 2010. Combined effects of salting, oregano oil and vacuum-packaging on the shelf-life of refrigerated trout fillets. Food microbiology, 27(1), 115-121.

Fung, D. 2009. Food Spoilage, Preservation and Quality Control. M. Schaechter içinde, Encyclopedia of Microbiology (s. 54-79).

Gan, J., Mukaddas, M., Tao, Y., Liu, H., Ye, K., & Zhou, G. (2024). High-voltage electrostatic field with 35 kV-15 min could reduce Pseudomonas spp. to maintain the quality of pork during −1 °C storage. Innovative Food Science & Emerging Technologies, 94, 103700. https://doi.org/10.1016/j.ifset.2024.103700.

Govaris, A., Botsoglou, E., Sergelidis, D., &Chatzopoulou, P. S. 2011. Antibacterial activity of oregano and thyme essential oils against Listeria monocytogenes and Escherichia coli O157: H7 in feta cheese packaged under modified atmosphere. LWT-Food Science and Technology, 44(4), 1240-1244.

Gribble, A., & Brightwell, G. 2013. Spoilage characteristics of Brochothrixthermosphacta and campestris in chilled vacuum packaged lamb, and their detection and identification by real time PCR. Meat science, 94(3), 361-368.

Hossain, F., Follett, P., Vu, K. D., Harich, M., Salmieri, S., & Lacroix, M. (2016). Evidence for synergistic activity of plant-derived essential oils against fungal pathogens of food. Food microbiology, 53, 24-30.

Hristova, Y., Gochev, V., Wanner, J., Jirovetz, L., Schmidt, E., Girova, T., & Kuzmanov, A. 2013. Chemical composition and antifungal activity of essential oil of Salvia sclarea L. from Bulgaria against clinical isolates of Candida species. Journal of BioScience& Biotechnology, 2(1).

Huerta-Jimenez, M., Herrera-Gomez, B., Dominguez-Ayala, E. A., Chavez-Martinez, A., Juarez-Moya, J., Felix-Portillo, M., Alarcon-Rojo, A. D., & Carrillo-Lopez, L. M. (2022). Properties of Oaxaca Cheese Elaborated with Ultrasound-Treated Raw Milk: Physicochemical and Microbiological Parameters. Foods, 11(12), 1735. https://doi.org/10.3390/foods11121735.

ICMSF. 1986. International Commission on Microbiological Specifications for Foods. Sampling plans for fish and shellfish. In: ICMSF, Microorganisms in foods. Sampling for microbiological analysis: Principles and scientific applications, (2nd ed., vol. 2, pp. 181–196). University of Toronto Press: Toronto, Canada.

Irshad, A., & Arun, T. S. 2013. Scalding and its significance in livestock slaughter and whole some meat production. International Journal of Livestock Research, 3(2), 45-53.

Kostaki, M., Giatrakou, V., Savvaidis, I. N., &Kontominas, M. G. 2009. Combined effect of MAP and thyme essential oil on the microbiological, chemical and sensory attributes of organically aquacultured sea bass (Dicentrarchuslabrax) fillets. Food microbiology, 26(5), 475-482.

Kreyenschmidt, J. 2003. Modellierung des Frischeverlustes von Fleisch sowie des Entf¨arbeprozesses von Temperatur-Zeit-Integratoren zur Festlegung von Anforderungsprofilen für die produktbegleitende Temperaturüberwachung. PhD Thesis, Rheinische Friedrich-Wilhelms-Universität Bonn, Bergen/ Dumme, Germany. AgriMedia.

Lee, M. M., Zheng, L., Yu, B., Xu, W., Kwok, R. T., Lam, J. W., ... & Tang, B. Z. (2019). A highly efficient and AIE-active theranostic agent from natural herbs. Materials Chemistry Frontiers, 3(7), 1454-1461.

Linden, J. (2014). GLOBAL POULTRY TRENDS 2014: Poultry set to become No.1 meat in Asia. The Poultry Site. https://www.thepoultrysite.com/articles/global-poultry-trends-2014-poultry-set-to-become-no1-meat-in-asia.

López-Olvera, J. R., Marco, I., Montané, J., Casas-Díaz, E., &Lavín, S. (2007, January 1). Effects of acepromazine on the stress response in Southern chamois (Rupicapra pyrenaica) captured by means of drive-nets. PubMed. https://pubmed.ncbi.nlm.nih.gov/17193881/.

Lu, H., Zheng, S., Fang, J., & Zhu, J. (2023). Photodynamic inactivation of spoilers Pseudomonas lundensis and Brochothrixthermosphacta by food-grade curcumin and its application on ground beef. Innovative Food Science & Emerging

Technologies, 87, 103410. https://doi.org/10.1016/j.ifset.2023.103410.

Mladenović KG, Grujović MŽ, Kiš M, Furmeg S, Tkalec VJ, Stefanović OD, Kocić-Tanackov SD. 2021. Enterobacteriaceae in food safety with an emphasis on raw milk and meat. Appl MicrobiolBiotechnol. 2021 Dec;105(23):8615-8627. doi: 10.1007/s00253-021-11655-7. Epub Nov 3. PMID: 34731280.

Mojaddar Langroodi, A., Nematollahi, A., Sayadi, M. 2021. 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, 15, 2790-2804.

Nowak, A., Kalemba, D., Piotrowska, M., &Czyżowska, A. 2013. Effects of thyme (Thymus vulgaris L.) and rosemary (Rosmarinus officinalis L.) essential oils on growth of Brochothrixthermosphacta. Afr. J. Microbiol. Res, 7, 3396-3404.

Nychas, G. J. E., Skandamis, P. N., Tassou, C. C., &Koutsoumanis, K. P. 2008. Meat spoilage during distribution. Meat science, 78(1-2), 77-89.

OECD/FAO. 2023. "OECD and FAO Agricultural Outlook", OECD Agricultural Statistics (database). dx.doi.org/10.1787/ agr-outl-data-fr.

Patsias A, Chouliara I, Badeka A, Savvaidis IN, Kontominas MG. Shelf-life of a chilled precooked chicken product stored in air and under modified atmospheres: microbiological, chemical, sensory attributes. Food Microbiology. 2006; 23: 423–429. https://doi.org/10.1016/j.fm.2005.08.004.

Pavelková, A., Kačániová, M., Horská, E., Rovná, K., Hleba, L., & Petrová, J. 2014. The effect of vacuum packaging, EDTA, oregano and thyme oils on the microbiological quality of chicken's breast. Anaerobe, 29, 128-133.

Pooni, G S and Mead, G C. 1984. Prospective use of temperature function integration for predicting the shelf-life of non-frozen poultry-meat products, Food Microbiology 1, 67±78.

Rafiq, R., Hayek, S. A., Anyanwu, U., Hardy, B. I., Giddings, V. L., Ibrahim, S. A., Tahergorabi, R., & Kang, H. W. (2016). Antibacterial and Antioxidant Activities of Essential Oils from Artemisia herba-alba Asso., Pelargonium capitatum × radens and Laurus nobilis L. Foods, 5(2), 28. https://doi.org/10.3390/foods5020028.

Ramos, C., Teixeira, B., Batista, I., Matos, O., Serrano, C., Neng, N. R., & Marques, A. 2012. Antioxidant and antibacterial activity of essential oil and extracts of bay laurel Laurus nobilis Linnaeus (Lauraceae) from Portugal. Natural Product Research, 26(6), 518-529.

Raybaudi-Massilia, R. M., Mosqueda-Melgar, J., & Martin-Belloso, O. 2006. Antimicrobial activity of essential oils on Salmonella enteritidis, Escherichia coli, and Listeria innocua in fruit juices. Journal of food protection, 69(7), 1579-1586.

Reale, A., Sorrentino, E., Iaffaldano, N., Rosato, M. P., Ragni, P., Coppola, R., Capitani, D., Sobolev, A. P., Tremonte, P., Succi, M., & Mannina, L. (2008). Effects of ionizing radiation and modified atmosphere packaging on the shelf life of aqua-cultured sea bass (Dicentrarchuslabrax). World Journal of Microbiology and Biotechnology, 24(12), 2757–2765. https://doi.org/10.1007/s11274-008-9802-7.

Ribarski, S., Oblakova, M., Oblakov, N., & Hristakieva, P. 2016. Chemical composition and quality of turkey-broiler meat from crosses of layer light (LL) and meat heavy (MH) turkey. Trakia J. Sci, 2, 142-147.

Stanborough, T., Suryadinata, R., Fegan, N., Powell, S. M., Tamplin, M., Nuttall, S. D., & Chandry, P. S. 2018. Characterisation of the Brochothrixthermosphactasortase A enzyme. FEMS microbiology letters, 365(17), fny184.

Wages, J. A. (2020). Microbiota Characterization of Poultry Processing Systems and Associated Microbiological Sampling Materials Collected at Commercial Processing Facilities. Graduate Theses and Dissertations Retrieved from https://scholarworks.uark.edu/etd/3709.

Wang, J., Han, R., Liao, X., & Ding, T. (2020). Application of plasma-activated water (PAW) for mitigating methicillin-resistant Staphylococcus aureus (MRSA) on cooked chicken surface. LWT, 137, 110465. https://doi.org/10.1016/j.lwt.2020.110465

Wang, G., Wang, H., Han, Y., Xing, T., Ye, K., Xu, X., Zhou, G. 2017. Evaluation of the spoilage potential of bacteria isolated from chilled chicken in vitro and in situ. Food Microbiol. 63, 139–146.

Wang, G., Wang, H., Han, Y., Xing, T., Ye, K., Xu, X., Zhou, G. 2017. Evaluation of the spoilage potential of bacteria isolated from chilled chicken in vitro and in situ. Food Microbiol. 63, 139–146.

Yaseen, M., Kumar, B., Ram, D., Singh, M., Anand, S., Yadav, H. K., & Samad, A. 2015. Agro morphological, chemical and genetic variability studies for yield assessment in clary sage (Salvia sclarea L.). Industrial Crops and Products, 77, 640-647.

Yuan, W., Yuk, H. 2017. Antimicrobial efficacy of Syzygiumantisepticum plant extract against Staphylococcus aureus and methicillin-resistant S. aureus and its application potential with cooked chicken. Food Microbiology, 72, 176-184.

Zhang H, Wu J, Guo X. 2016. Effects of antimicrobial and antioxidant activities of spice extracts on raw chicken meat quality. Food Sci Hum Wellness; 5:39–48.

Zou, J., Liu, X., Wang, X., Yang, H., Cheng, J., Lin, Y., & Tang, D. (2022. Influence of Gelatin-Chitosan-