Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

e-ISSN: 1806-9061 2024 / v.26 / n.1 / 001-010

http://dx.doi.org/10.1590/1806-9061-2023-1835

Original Article

Effect of Oregano Essential Oil and Rosemary Extract Inclusion with Aloe vera Gel on the Quality and Storage Stability of Cooked Chicken Meat

■Author(s)

Al-Hijazeen MA[I] https://orcid.org/0000-0002-7717-7977
Ibrahim RW[II] https://orcid.org/0000-0001-7369-3272

[I] Department of Animal Production, Faculty of Agriculture, Mutah University, Karak 61710, Jordan.
[II] Rania Wajdi Ibrahim, Research Associate, Amman-Jordan; Ph.D.

■Mail Address

Corresponding author e-mail address
Marwan Abdullah Al-Hijazeen
Mutah University, Agriculture Collage, Department of Animal Production, Karak, Mutah (61710), Jordan P.O. Box (7).
Phone: +00962 772665287
Email: marwana@mutah.edu.jo

■Keywords

Oregano; rosemary extract; lipid oxidation; sensory panel; Aloe vera; ground meat.

CC BY

Submitted: 13/August/2023
Approved: 15/March/2024

ABSTRACT

This study investigated the effect of adding *Origanum syriacum* L. essential oil and *Rosmarinus officinalis* L. extract incorporated with 5 % of *Aloe barbadensis* miller gel on the quality and storage stability of cooked chicken meat. The experiment included five treatments: 1) Control (*No additives*); 2) 600 ppm of Rosemary Extract (RE); 3) 500 ppm of Oregano essential oil (OE); 4) Combination of 600 RE and 500 ppm OE (CM); and 5) 200 ppm Sodium nitrite (E-250). Lipid and protein oxidation, sensory panel assessment, and other related parameters were evaluated at different storage times. No significant differences (p>0.05) were found among treatments regarding both *ultimate* pH and cooking loss %. All additives showed significant (p<0.05) effect at decreasing both TBARS and total carbonyl values. However, the combination of RE and OE showed the highest significant (p<0.05) preservative effect compared to the other treatments. Moreover, the CM treatment showed the highest antioxidant effect, decreasing total aldehydes (TA) formation. The sensory panel also showed that the CM treatment was the most effective additive at improving meat shelf life regarding the selected sensorial attributes. The OE effect was higher than the RE during storage time, and comparable to the E-250 regarding TBARS, DNPH, TA values, and current sensory attributes. The combination OE and RE incorporated with *Aloe* carrier gel was a successful replacement that could be used in the meat industry. In addition, the gel was a promising natural carrier for both OE and RE during storage.

INTRODUCTION

The effect of adding plant-derived natural antioxidants is a promising alternative to currently used synthetic ones, and has been intensively studied in various meat formulations (Al-Hijazeen *et al.*, 2018; Manessis *et al.*, 2020; Estévez, 2021). This is due to the negative effect of using synthetic antioxidants on human health. Sodium nitrite (E-250), for example, is considered one of the most synthetic curing additives used in the meat industry, and may have carcinogenic (nitrosamine formed in the finished meat products) and toxicological effects (Honikel, 2008; Oostindjer *et al.*, 2014). On the other hand, many previous studies have found positive effects on both meat quality and its storage stability by adding natural antioxidants (Estévez, 2021; Al-Hijazeen, 2022, a, b, c). Several medicinal plants (such as oregano, sage, rosemary, mint, garlic, thyme, etc.) have been used as dried ingredients, extracts, and essential oils, showing significant positive effects at improving freshness, shelf life, storage stability, and overall meat quality (Kahraman *et al.*, 2015; Al-Hijazeen & Al-Rawashdeh, 2019; Liu *et al.*, 2020; Manessis *et al.*, 2020; Estévez, 2021). In spite of that, very little research studies have been conducted to investigate their effect when mixing/incorporating them with a natural edible carrier (Eça *et al.*, 2014; Soni *et al.*, 2018;

Yeddes *et al.*, 2021). Furthermore, there is the problem of how to stabilize or prolong antioxidant activity during storage. Researchers have recently been focusing on using natural carriers (edible coating or carriers) which have positive effect on food quality and safety and prevent these phenols (antioxidants compounds) from being oxidized (Eça *et al.*, 2014; Jairath *et al.*, 2015; Kumar *et al.*, 2022). Oregano essential oil (OE) and rosemary extract (RE) showed very effective and positive results regarding meat quality, safety, and storage stability (Al-Hijazeen, 2022a, b, c). Their antioxidant activity was due to the presence of phenolic compounds such as thymol, carvacrol, carnosic acid and carnosol, that represent their major antioxidant constituents (Erkan *et al.*, 2008; Mena *et al.*, 2016; Kaur *et al.*, 2021; Al-Hijazeen, 2022, a, c). In addition, wild oregano (Origanum syriacum L.) and cultivated rosemary (Rosmarinus officinalis L.) have been shown to be the bets antioxidant-additives among other natural replacements found in Jordan (Al-Hijazeen, 2022a, b, c). However, scientists are trying to find a practical natural edible-carrier that can hold and prolong their antioxidant effect. This carrier must also protect the main polyphenols and make a barrier that avoid external oxidized conditions. One of the most popular edible preservative barriers studied recently is Aloe vera gel (Eça *et al.*, 2014; Rajkumar *et al.*, 2016; Hęś *et al.*, 2019). This gel is generally obtained from the leaves of the Aloe vera (Aloe barbadensis Miller) plant, a member of the Liliaceae family consisting of over 400 different species that is cultivated in several dry regions around the world, such as Africa, Asia, Europe, and America (Rajkumar *et al.*, 2016; Sánchez-Machado *et al.*, 2017; Nicolau-Lapeña *et al.*, 2021). In addition, Aloe vera is the most common Aloe variety distributed around the world. This perennial succulent xerophyte herb has several medicinal and pharmacological benefits for human health, such as skin care characteristics, immune modulation, anticancer, and gastroprotective properties, as well as wound healing properties (Hamman, *et al.*, 2008; Lucini *et al.*, 2015; Massoud *et al.*, 2022). The Jordanian Ministry of Agriculture (MOA) encourages local framers to increase cultivation of this plant due to its medicinal and health benefits and its ability to grow in a dry condition, given recent challenges with water shortage and climate change in the country. Aloe vera gel (US-FDA approved as a food flavoring agent) contains several compounds with antioxidant properties that could improve meat quality, sensorial characteristics, and storage stability (Rajkumar *et al.*, 2016; Chin *et al.*, 2017; Hęś *et al.*, 2019; Usan *et al.*, 2022; Kumar *et al.*, 2022). The crude gel of Aloe vera was analyzed, and it contains compounds such as acids, enzymes (Superoxide dismutase, alkaline phosphatase, amylase, carboxypeptidase, catalase), vitamins (B1, B2, B6, C, β-carotene, choline, folic acid, α-tocopherol), lipids, proteins, inorganic compounds (Calcium, chlorine, chromium, copper, iron, magnesium, etc.), and carbohydrates (Hamman, *et al.*, 2008; Liu *et al.*, 2013; Hęś *et al.*, 2019). These compounds have shown positive effects on food quality and stability in different products, as reported in previous research (Hu *et al.*, 2003; Kahramanoğlu *et al.*, 2019; Nicolau-Lapeña *et al.*, 2021; Hasan *et al.*, 2021; Kumar *et al.*, 2022). There are no previous studies on the effect of incorporating OE and RE with Aloe vera gel as a meat preservative. In the current study, the use Aloe vera gel may enhance the synergistic/or additive effect of these NA through its antioxidant constituents. The activity of these antioxidants through the meat system needs to be evaluated, since there is no data on how these phenols interact with this unique gel. Finally, this research may contribute to solving the problem of finding natural edible carriers that could be used in the meat industry.

The objectives of this study were: 1) to evaluate the antioxidant effect of adding RE and OE incorporated with *Aloe vera* gel; 2) compare this effect with commonly used synthetic antioxidants; and 3) find good natural carriers of antioxidants which potential for use in the meat industry.

MATERIALS AND METHODS

Meat Samples Preparation

All chicken (50 healthy and qualified birds) were slaughtered at the National Poultry Company (Al-Qatarna; Al Karak, Jordan), under the standard regulations and guidelines of poultry slaughtering, following the meat safety recommendations of the Food and Drug Administration (FDA) and the Ministry of Agriculture (MOA) of Jordan. The refrigerated carcasses were transported to the meat laboratory located at the Department of Animal Production of the Agriculture College of Mutah University. All birds' carcasses were dipped in ice water for 1 hour, drained in a cold room, and then the thigh meat muscles were deboned, cleaned from hard connective tissues, skins, and its visual fat. Subsequently, all muscles were vacuum packaged in oxygen impermeable bags and stored at -18 °C until further use.

At the first day of the experiment, the frozen meat was thawed, cut into small pieces, and then double ground through 8-mm and a 3-mm plates (*Moulinex*, Type *DKA1*, France) before patties preparation. Five treatments were included: 1) Control (*No additives*); 2) 600 ppm of Rosemary Extract (RE); 3) 500 ppm of Oregano essential oil (OE); 4) Combination of 600 and 500 ppm of RE and OE, respectively; and 5) 200 ppm Sodium nitrite (E-250). Similarly to Al-Hijazeen & Al-Rawasheh (2019), RE was purchased from a local company (Green Fields Factory for Oils, Amman, Jordan) and the HPLC analysis of the RE was conducted by the method of Okamura *et al.* (1994) at the Royal Scientific Society, Jordan, Amman (RSS). The RE contained 26 ± 3% average phenolic diterpenes (carnosol (4%), carnosic acid (6%), rosmanol (8%), and rosmarinic acid (8%)). Furthermore, the oregano essential oil (OE) was obtained from same company and its HPLC analysis (also by Royal Scientific Society, Jordan, Amman) indicated that 76.39% of the essential oil was carvacrol.

Sodium nitrite (Gainland Chemical Company - GCC, factory road; UK) powder was first dissolved in and mixed with crude *Aloe vera* gel (appx. 98.5 % water (Raw pulp)), ant then prepared to make an aqueous stock solution. Both RE and OE were manufactured and stored in 5 % organic oil, then mixed with *Aloe vera* gel to make a homogenous mixture (oil in water) before use. Fresh *Aloe vera* plants leaves were obtained from different local farmers in south Jordan. In the meat laboratory, *Aloe vera* gel (*Parenchymatous* inner colorless gel) was manually collected, washed, cleaned with cold distilled water, and finally stored in oxygen impermeable bags until use. All additives were mixed with the ground meat for 3 min in a bowl mixer (Model KM-331; Kenwood Limited, New Lane, Havant, PO9 2NH, UK). The same amount of *Aloe vera* gel at a level of 5% was mixed to all treatment's meat batches, including control. After the preparation of meat patties, raw meat samples were packaged in oxygen impermeable vacuum bags (Ehsan & Tahssin Baalbaki Co, Bayader Wadi Al-Seer, Amman, Jordan), then cooked in-bag in a 90 °C water bath (Memmert, WNB 14; GMbH + Co. KH, D-91107 Schwabach, Germany) until the internal temperature of the meat reached 75 °C. After cooling, the cooked meat samples (50 g) were transferred to a new oxygen-permeable bag (polyethylene, Size: 11 × 25 cm, Future for Plastic Industry, Al-Moumtaz bags, Co. L.T.D, Amman, Jordan), and stored at 4 °C for up to 8 days, and analyzed for TBARS and total carbonyl at 0, 4, and 8 days of storage. Separate samples of raw meat from each treatment were used to measure their *ultimate* pH. In addition, cooked meat sub-samples were used to evaluate any significant differences in total aldehydes (TA) among treatments on day 8. The same preparation method was conducted for all cooking loss and sensory analysis treatments samples. The ground chicken (raw thigh) meat patties were stored at 4 °C for up to 4 days before cooking and for each sensory evaluation session.

Cooking loss %

All cooking loss values were determined and calculated according to the method described by Al-Hijazeen & Al-Rawashdeh, (2019).

Acidity of the raw meat

The ultimate pH values of the thigh ground meat samples were determined using a pH meter (PL-600, pH/mV/Temp Meter, Taiwan) after homogenizing the 1.0g samples with 9 ml deionized distilled water (DDW) (Sebranek *et al.,* 2001).

Thiobarbituric acid-reactive substances (TBARS) measurement

Cooked meat samples were tested for lipid oxidation using the TBARS method (Ahn *et al.,* 1998). The amounts of TBARS were reported as mg of malondialdehyde (MDA) per kg of meat.

Total aldehydes

GC-MS (QP2010nc System, Shimadzu Corporation, Japan) apparatuses connected with purge and trap concentrator (O.I.Analytical, Eclipse; Model 4660) were used to determine total aldehydes according to the procedure of Ahn *et al.* (2001). The total aldehydes of cooked (thigh meat) samples were estimated as the sum of pentanal, propanal, hexanal, and heptanal formation at day 8 of storage time, as described by Al-Hijazeen & Al-Rawashdeh (2019). Volatile analysis was done at the RSS (*Royal Scientific Society, Jordan, Amman*/ Department of Gas Laboratory) by specialist staff. Samples for the five treatments were prepared similarly to the previous section, then cooked meat samples (3 g/ each) were placed in small vials and analyzed by GC-MS. The identification of each peak was attained by Wiley Library, and the area of each peak was integrated. The total peak area (total ion counts× 10^4) was reported as an indicator of volatiles generated from meat samples.

Protein oxidation (Total carbonyl)

Protein oxidation was determined using the general procedure of total carbonyl value described by Lund *et al.* (2008), with minor modifications. The carbonyl content was reported as nmol/mg protein, using the absorption coefficient of 22,000/M/cm, as reported by Levine *et al.* (1994).

Sensory panel evaluation

A highly trained panelist evaluated the selected sensory attributes of the cooked ground (thigh) meat, as described by Al-Hijazeen & Al-Rawashdeh (2019). The evaluation included the attributes of cooked meat color, spice odor (RE & OE odor), oxidation odor, and overall acceptability. Meat patties from the five treatments were prepared as described in the oxidation analysis part, in order to evaluate the effect of these additives (mixed with 5 % *Aloe gel*) on chicken meat quality and its stability.

The meat was refrigerated at 4°C for four days before starting the cooking process for each evaluation session. Ten trained panelists (Students, and staff from Mutah University) participated in each session. The evaluations were conducted twice after cooling the cooked meat patties to room temperature (25°C) for all samples. For training, 3 one-hour sessions were held using commercial and experimental products to develop descriptive terms for the desired attributes.

All attributes were measured using a line scale without numbers (numerical value 9 units) with graduation from 0 to 9. Evaluation sessions for cooked meat samples were done in separate days to decrease any variability.

The cooked meat samples (10g/each) were evaluated by the panelists for each treatment after cooling to a room temperature of 25°C. The panelists were served 1 glass vial with 20 ml from each treatment to evaluate the odor of cooked thigh meat samples. All sample vials were labeled with a three-digit number selected randomly. After finishing color attributes, panelists were asked to smell samples in a random order and record the intensity of the odor or overall acceptability on the scale line.

Statistical analysis

In the current study, data analysis was done using a generalized linear model (Proc. GLM, SAS program, version 9.3, 2012). In addition, mean values and standard error of the means (SEM) were reported. The significance was described at $p<0.05$, and Tukey test or Tukey's Multiple Range test were used to determine the significant differences among the mean values.

RESULTS AND DISCUSSION

Cooking loss % and *Ultimate* pH

The ability of processed meat to hold or retain water is considered an important factor that is highly affected by the pH values in finished products. In the current study, there were no significant differences (*p>0.05*) in cooking loss % among all treatments. However, *Aloe vera* gel could improve cooking yield when added to ground meat. For instance, Rajkumar *et al.* (2016) reported that adding *Aloe vera* gel at level 2.5 % improved the cooking yield of goat meat nuggets during storage (Table 1).

Table 1 – Ultimate pH[1], cooking loss %, and TA[2] of incorporated cooked meat at day 8.

TRT*	$_u$pH	Cooking loss %	Total ion counts × 10^4
Control	5.46^a	0.164^a	14082^a
RE	5.48^a	0.168^a	8955^b
OE	5.49^a	0.164^a	8249^{bc}
CM	5.49^a	0.169^a	6782^c
E-250	5.48^a	0.168^a	8279^{bc}
SEM**	0.039	0.014	366

a-c Values with different letters within a row are significantly different ($p<0.05$). n=4.

**SEM: Standard error of the means.

[1] $_u$pH: Ultimate pH after 24 hours of chicken slaughtering.

[2] TA: Total Aldehydes: Sum of Hexanal, Pentanal, Propanal, and Heptanal formation at day 8.

*Treatments: Control; RE; OE; CM: Combination of RE and OE; E-250. N=4.

Soltanizadeh & Ghiasi-Esfahani (2015) indicated that *Aloe vera* contributed to some extent to decreased cooking loss of low meat beef burgers. In addition, no significant differences (*p>0.05*) were found among all treatments regarding their ultimate pH values (raw meat before cooking). So, all treatments had similar acidity, which was statistically considered a suitable result, proving that any significant differences were due to treatments effect. Moreover, adding *Aloe vera* gel decreases the pH values of all treatments, as previously reported in the literature (Soltanizadeh & Ghiasi-Esfahani, 2015; Rajkumar *et al.,* 2016; Usan *et al.,* 2022) and analyzed in a preliminary study (*data not shown*).

Lipid Oxidation and Total Aldehyde

Although researchers intensively study rancidity development using different food systems by adding a variety of natural antioxidants (Beya *et al.,* 2021; Al-Hijazeen *et al.,* 2022a, b; Awad *et al.,* 2022), there have been few studies evaluating this effect by mixing these additives with a natural carrier (edible coating gel) such as Aloe *vera* gel (Kahramanoğlu *et al.,* 2019;

Farina *et al.,* 2020). Some studies have reported that adding or mixing *Aloe* gel with different meat types improves their shelf life and its oxidative stability during storage (Soltanizadeh & Ghiasi-Esfahani, 2015; Rajkumar *et al.,* 2016; Kumar *et al.,* 2017). For example, Usan *et al.* (2022) reported that the combination of *Aloe vera* extract and nitrite in sausage formulation is a useful approach to control lipid oxidation in the product. This effect is due to the composition of *Aloe vera* gel, in which these ingredients participate or react as natural antioxidants, as previously discussed (Rajkumar *et al.,* 2016; Hęś *et al.,* 2019). In the current study, there were no significant differences (*p>0.05*) in TBARS values among all treatments at day 0 (Table 2).

Table 2 – TBARS* values of incorporated cooked ground meat at different storage times at 4ºC.

Time	Control	RE	OE	CM	E-250	SEM
			---------- TBARS (mg/Kg) meat ----------			
Day 0	1.268^{ax}	1.275^{ax}	1.264^{ax}	1.275^{ax}	1.289^{ax}	0.048
Day 4	3.550^{ay}	2.515^{by}	1.504^{cx}	1.281^{cx}	2.258^{by}	0.076
Day 8	7.041^{az}	3.993^{bz}	2.538^{cy}	2.176^{cy}	3.534^{bz}	0.144
SEM**	0.127	0.131	0.074	0.061	0.074	

$^{a-c}$Values with different letters within a row are significantly different (*p*<0.05).

$^{x-z}$Values with different letters within a column are significantly different (*p*<0.05).

**SEM: Standard error of the means.

*TBARS value in mg malonaldehyde/kg meat.

Treatments: Control; RE; OE; CM: Combination of RE and OE; E-250. N=4.

However, all treatments additives showed significant (*p<0.05*) antioxidant effects by decreasing TBARS values at day 4. In addition, there was no significant difference (*p>0.05*) between the CM and OE treatments at day 4. Furthermore, OE and CM treatments exhibited the highest significant (*p<0.05*) antioxidant effect until day 8. However, no significant differences (*p>0.05*) were found between the RE and E-250 treatments at day 8 of storage. Antioxidant activity depends on many internal factors, such as phenol interactions, meat formulation, and possibility of synergistic or additive effects (Al-Hijazeen, 2022a, c). Based on the current results, OE showed higher oxidative stability, which may be due to its phenolic contents, anti-*malonaldehyde formation* compared to RE treatments. The interaction of OE ingredients with *Aloe vera* gel could be another reason for this finding. Finally, based on lipid oxidation data, the antioxidant effect of *Aloe* gel could enhance the oxidative stability of these natural additives, making it a suitable carrier for the future of processed meat.

Lipid oxidation secondary compounds (e.g. aldehydes, ketones, hydrocarbons, carboxylic acids, and esters) are the most important elements affecting meat odor and freshness (Du *et al.*, 2003; Ahn *et al.*, 2009; Kosowska *et al.*, 2017; Domínguez *et al.*, 2019; Al-Hijazeen, 2022b). These secondary compounds consist of several volatiles compounds that cause off-odors and meat rancidity (Ahn *et al.*, 2009; Al-Hijazeen, 2022a, b, c). Aldehydes are considered the most important compounds indicating off-odor and fat rancidity (Al-Hijazeen, 2022c). An example is hexanal, which has been reported as a good indicator that correlates well with lipid oxidation (TBARS) (Jo *et al.*, 2006; Ahn *et al.*, 2009; Domínguez *et al.*, 2019; Al-Hijazeen, 2022b). In the current study, the total aldehydes (TA) formation was significantly (*p<0.05*) higher in the control treatment as compared to the others. Overall, the CM treatment showed the highest effect decreasing the TA values compared to the other treatments (Table 1). In addition, no significant difference (*p>0.05*) was found between the CM, OE, and E-250 treatments' mean values. These results also agreed with the lipid, protein, and sensory evaluation tables, where the CM treatment showed the highest effect. So, using Aloe gel combined with RE and OE should give a suitable natural replacement to the synthetic alternative.

Protein Oxidation

Meat protein chemical status affects many internal and external quality characteristics of meat products (Lund *et al.,* 2011; Li *et al.,* 2023). Protein properties (e.g. protein solubility, emulsification properties, and water holding capacity) are well documented to be highly affected by oxidation development (Lund *et al.,* 2011; Al-Hijazeen, 2018; Al-Hijazeen & Al-Rawashdeh, 2019; Li *et al.,* 2023). 2,4-dinitrophenylhydrazine (DNPH) is a general method employed to estimate protein oxidation progress in meat systems (Domínguez *et al.,* 2021). So, it is valuable to evaluate the antioxidant effect of RE and OE incorporated in *Aloe vera* gel on total carbonyl (TC) formation using the DNPH method. Similarly, as observed in the lipid oxidation part, there were no significant differences (*p>0.05*) in the means value of TC among all treatments at day 0 (Table 3).

Table 3 – Effect of OE and RE on protein oxidation of incorporated cooked meat.

Time	Control	RE	OE	CM	E-250	SEM
			------------------ Carbonyl (nmol/ mg of protein) ----------------------			
Day 0	1.313^{ax}	1.337^{ax}	1.307^{ax}	1.323^{ax}	1.310^{ax}	0.058
Day 4	3.074^{ay}	2.884^{aby}	2.309^{cy}	1.912^{dy}	2.629^{bcy}	0.077
Day 8	3.908^{az}	3.176^{bz}	2.573^{dy}	2.195^{ez}	2.978^{cz}	0.044
SEM**	0.056	0.071	0.080	0.055	0.034	

a-c Values with different letters within a row are significantly different (p<0.05).

x-z Values with different letters within a column are significantly different (p<0.05).

**SEM: Standard error of the means.

Treatments: Control; RE; OE; CM: Combination of RE and OE; E-250. N=4.

However, the OE and CM treatments showed the highest significant effects (*p<0.05*) in delaying carbonyl formation as compared to the other additives at day 4. Moreover, the trend of TC changes was reported to have a good correlation with TBARS during the storage period (Ahn *et al.,* 2009; Al-Hijazeen, 2022a, b, c). No significant differences (*p>0.05*) were found between the RE and E-250 treatments at day 4. In addition, the CM treatment showed the highest significant (*p<0.05*) anti-carbonyl formation effect during the storage period (day 4-8). These TC value results were in line with previous studies that evaluated various meat products, which ranged from 1-3 nmol/mg, and up to 5 nmol/mg protein for both raw and cooked meat, respectively (Sun *et al.,* 2010; Estévez, 2011; Al-Hijazeen *et al.,* 2022). It is also interesting to note that the OE and E-250 antioxidant effects were significantly (*p<0.05*) higher than the effect of RE at day 8 of storage. The CM treatment was the superior additive, decreasing TC formation in comparison to the other treatments. However, no synergistic effect was found by incorporating these additives (RE and OE) using *Aloe vera* gel. *Aloe vera* gel has antioxidant properties that may improve the effect of these additives by reducing TC values, as reported by Mubarik *et al.* (2023). This antioxidant activity is well documented (Rajkumar *et al.,* 2016; Hęś *et al.,* 2019), and there is no need to compare it with a control sample without *Aloe Gel*. The OE treatment showed higher anti-carbonyl effect as compared to the other additives in isolation. This may be due to the interaction of its phenols inside *Aloe vera* gel with the meat system in comparison with other additives.

Sensory Evaluation

Aloe vera gel is generally recognized as a safe (GRAS/USA) substance for application in food, and dietary supplements (Kumar *et al.,* 2022). Therefore, this enriched *Aloe gel* needs more investigation to be industrialized in the future, especially regarding its sensorial effect. There were no significant differences (*p>0.05*) among the color attribute means of all treatments' additives (Table 4). This indicates that adding these plant extract additives had no effect or interaction with finished meat colors. This is in line with a previous research study conducted by Al-Hijazeen. (2022a), who observed that the inclusion of 150 ppm OE and 350 ppm RE showed the highest antioxidant effects, with no significant differences (*p>0.05*) being observed in cooked meat color as compared to the control. However, high intensity of spice odor was clearly detected by the panelists on the RE, OE, and CM samples as compared to the other treatments.

Table 4 – Sensory attributes means values of incorporated cooked chicken meat patties.

TRT*	Sensory attributes b			
	Color	Spice Odor	Oxidation Odor	Overall Acceptability
Control	5.91^{a}	0.69^{c}	7.07^{a}	4.37^{d}
RE	6.09^{a}	5.52^{b}	5.14^{b}	5.56^{c}
OE	6.61^{a}	6.08^{b}	3.93^{cd}	6.82^{ab}
CM	6.79^{a}	7.06^{a}	3.05^{d}	7.21^{a}
E-250	6.30^{a}	0.68^{c}	4.62^{bc}	5.97^{bc}
SEM**	0.314	0.239	0.285	0.296

b Sensory attributes: Samples were evaluated on day 4.

**SEM: Standard error of the means.

a-f Means within the same column with different superscripts are different (p<0.05).

*Treatments: Control; RE; OE; CM: Combination of RE and OE; E-250. N=4.

Furthermore, the highest significant spice odor appeared in the CM treatment, which was reflected in the overall meat acceptability estimation. CM and OE showed the highest significant antioxidant effects by decreasing the oxidation attribute values. Similar effects were found in previous studies that used lower levels of OE and RE on chicken meat (Al-Hijazeen, 2022a, b, c; Al-Hijazeen & Al-Rawashdeh, 2019). The positive effect of RE on meat sensorial characteristics is also documented in several studies (Feng *et al.*, 2016; Manhani *et al.*, 2018; Szymandera-Buszka *et al.*, 2020). In addition, there were no significant differences for the same attributes among both RE and E-250 treatments. These results indicated that OE antioxidant performance was better than rosemary and nitrite additives, which may be due to their unique composition of polyphenols. This effect is also enhanced by the incorporation of *Aloe vera* gel. The unique polyphenols constituents of these additives usually enhance meat stability and decrease off-odor volatiles, rancidity development, TA, hydrocarbons, and sulfuric compound formation (Keokamnerd *et al.,* 2008; Ahn *et al.,* 2009; Kumar *et al.,* 2015; Al-Hijazeen, 2022a, c). CM and OE also showed the highest significant ($p<0.05$) values of overall acceptability attributes compared to the other treatments. Similarly, there were no significant differences ($p>0.05$) between RE and E-250 regarding overall meat acceptability. Finally, the CM treatment showed the best antioxidant effect, improving most of the sensorial attributes. These results were also correlated (A-Hijazeen, 2022a; b, c) with the lipid and protein oxidation trend during storage, which were stabilized by adding *Aloe vera* gel. In addition, *Aloe vera* gel has been reported to have positive effect on most sensorial attributes (slicing properties, odor, appearance, flavor, juiciness, texture profile analysis) of meat products if used in suitable amounts (Rajkumar *et al.*, 2016; Kumar *et al.,* 2017; Kianiani *et al.* 2019; Usan *et al.*, 2022). However, high doses may cause a bitter taste due to the aloin compounds present in the gel (Tumlinson, 1985). Furthermore, higher levels of RE and OE combined with *Aloe* gel worked well, with similar results to those of previous studies using different or synthetic carriers (Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen; 2022a; b, c). Finally, more research is needed to evaluate the suitable amount of *Aloe* gel, which depends on meat product formulations.

CONCLUSIONS

Based on our results, all treatments additives showed significant ($p<0.05$) antioxidant activities as compared to the control treatment in regards to lipid and protein oxidation, total aldehydes, and most sensorial characteristics. No significant differences ($p>0.05$) were found among treatments regarding *ultimate* pH and cooking loss percentage. The effect of RE and E-250 was comparable for these parameters during storage time. However, CM and OE exhibited the highest antioxidant effects, decreasing off-odor volatiles (such as TA), TBARS, and DNPH values. Furthermore, the CM treatment was superior depending on the data analysis. This study indicated that *Aloe vera* gel was a successful carrier for OE and RE, suggesting it can be used in the meat industry in the future.

ACKNOWLEDGEMENTS

The authors would like to thank the Deanship of Academic Research at Mutah University for their support. Furthermore, they thank the great help and support from the National Poultry Company (Amman-Jordan) and the NARC at Al Raba-karak (Dr. Hanna Madanat) for his help and assistance.

CONFLICTS OF INTEREST

We declare that there is no conflict of interest with any financial organization regarding this manuscript.

REFERENCES

Ahn DU, Nam KC, Lee EJ. Lipid oxidation and flavor. In: Du M, McCormick RJ, editors. Applied muscle biology and meat science. Boca Raton: CRC Press; 2009. p.227-246. ISBN 9780429112072.

Ahn DU, Olson DG, Jo C, *et al.* Effect of muscle type, packaging, and irradiation on lipid oxidation, volatile production and color in raw pork patties. Meat Science 1998;49:27-39. https://doi.org/10.1016/s0309-1740(97)00101-0.

Al-Hijazeen M, Al-Rawashdeh M. Preservative effects of rosemary extract (Rosmarinus officinalis L.) on quality and storage stability of chicken meat patties. Food Science and Technology 2019;39(1):27–34. https://doi.org/10.1590/1678-457x.24817.

Al-Hijazeen M, Al-Rawashdeh MS, Al-Rabadi GJ. Cooked broiler meat quality affected by different Mediterranean medicinal plants in the diet. Animal Bioscience 2022;35:290-8. https://doi.org/10.5713/ab.21.0264.

Al-Hijazeen M, Al-Rawasheh M. Preservative effects of rosemary extract (Rosmarinus officinalis L.) on quality and storage stability of chicken meat patties. Food Science and Technology 2019; 39:27–34. https://doi.org/10.1590/1678-457X.24817.

AL-Hijazeen M, Mendonca A, Lee EJ, *et al.* Effect of oregano oil and tannic acid combinations on the quality and sensory characteristics of cooked chicken meat. Poultry Science 2018;97:676-83. https://doi.org/10.3382/ps/pex285.

Al-Hijazeen M. Effect of direct adding oregano essential oil (Origanum syriacum L.) on quality and stability of chicken meat patties. Food Science and Technology 2018;38(1):123–130. https://doi.org/10.1590/1678-457x.17117.

Al-Hijazeen M. Lipid oxidation, total volatiles, and sensory evaluation of cooked chicken meat treated with Origanum syriacum L. essential oil. Food Science and Technology Research 2022c;28(3):257-66. https://doi.org/10.3136/fstr.FSTR-D-21-00300.00

Al-Hijazeen M. Recommended level of rosemary extract (Rosmarinus officinalis L.) based on lipid oxidation, total volatiles, and sensory evaluation of treated cooked chicken meat. Food Science and Technology Research 2022b;28(5):391-401. https://doi.org/10.3136/fstr. FSTR-D-22-00034.

Al-Hijazeen M. The combination effect of adding rosemary extract and oregano essential oil on ground chicken meat quality. Food Science and Technology 2022a;42:e57120. https://doi.org/10.1590/fst.57120.

Awad AM, Kumar P, Ismail-Fitry MR, *et al.* Overview of plant extracts as natural preservatives in meat. Journal of Food Processing and Preservation 2022;46(8):e16796. https://doi.org/10.1111/jfpp.16796.

Beya MM, Ntzel ME, Sultanbawa Y, *et al.* Plant-based phenolic molecules as natural preservatives in comminuted meats; a review. Antioxidants 2021;10(2):263. https://doi.org/10.3390%2Fantiox10020263.

Chin SS, Lyn FH, Hanani ZN. Effect of Aloe vera (Aloe barbadensis Miller) gel on the physical and functional properties of fish gelatin films as active packaging, Food Packaging and Shelf Life 2017;12:128-34. https://doi.org/10.1016/j.fpsl. 2017.04.008.

Domínguez R, Pateiro M, Gagaoua M, *et al.* A Comprehensive review on lipid oxidation in meat and meat products. Antioxidants (Basel) 2019;8(10):429. https://doi.org/10.3390/a ntiox8100429.

Domínguez R, Pateiro M, Munekata PES, *et al.* Protein oxidation in muscle foods; a comprehensive review. Antioxidants (Basel) 2021;11(1):60. https://doi.org/10.3390/an tiox11010060.

Du M, Nam KC, Hur SJ, *et al.* Quality characteristics of irradiated chicken breast rolls from broiler fed different level of conjugated linoleic acid. Meat Science 2003;63:249-55. https://doi.org/10.1016/s0309-1740(02) 00077-3.

Eça KS, Sartori T, Menegalli FC. Films and edible coatings containing antioxidant s;a review, Brazilian Journal of Food Technology 2014;17(2):98–112. https:// doi.org/10.1590/b jft.2014.017.

Erkan N, Ayranci G, Ayranci E. Antioxidant activities of rosemary (Rosmarinus Officinalis L.) extract, blackseed (Nigella sativia L.) essential oil, carnosic acid, rosmarinic acid and sesamol. Food Chemistry 2008;110:76-82. https://doi.org/10.1016/j. food chem.2008.01. 058.

Estévez M. Critical overview of the use of plant antioxidants in the meat industry; opportunities, innovative applications and future perspectives. Meat Science 2021;181:108610. https://doi.org/10.1016/j. meatsci.2021.108610.

Estévez M. Protein carbonyls in meat system: a review. Meat Science 2011;89(3):259-79. https://doi.org/10.1016/j.meatsci.2011.04.025.

Farina V, Passafiume R, Tinebra I, *et al.* Use of Aloe Vera Gel-Based Edible Coating with Natural Anti-Browning and Anti-Oxidant additives to improve post-harvest quality of fresh-cut 'Fuji' apple. Agronomy 2020;10(4):515. https://doi.org/10.3390/agronomy1 0040515.

Feng L, Shi C, Bei Z, *et al.* Rosemary extract in combination with Polylysine enhance the quality of chicken breast muscle during refrigerated storage. International Journal of Food Properties 2016;19:2338–2348. https://doi.org/10.1080/10942912. 2015.1130053.

Hamman JH. Composition and applications of Aloe vera leaf gel. Molecules 2008;13:1599-616. https://doi.org/10.3390%2Fmolecules13081599.

Hasan MU, Riaz R, Malik AU, *et al.* Potential of Aloe vera gel coating for storage life extension and quality conservation of fruits and vegetables;An overview. Journal of Food Biochemistry 2021;45(4):e13640. https://doi.org/10. 1111/jfbc.13640.

Hęś M, Dziedzic K, Górecka D, *et al.* Aloe vera (L.) Webb: natural sources of antioxidants - areview. Plant Foods and Human Nutrition. 2019;74(3):255-65. https://doi.org/10.1007/s11130-019-00747-5.

Honikel KO. The use and control of nitrate and nitrite for the processing of meat products. Meat Science 2008;78:68–76. https://doi.org/10.1016/j.meatsci.2007.05.030.

Hu Y, Xu J, Hu Q. Evaluation of antioxidant potential of aloe vera (Aloe barbadensis Miller) extracts. Journal of Agricultural and Food Chemistry 2003;51(26):7788-91. https://doi.org/10.1021/jf03425 5i.

Jairath G, Chatli MK, Sahoo J, *et al.* Effect of packaging methods and crude aloe vera gel (Aloe vera barbadensis miller) on the storage quality of enrobed goat meat bites. Journal of Food Science and Technology 2015;52(6):3730–8. https://doi.org/10.1007%2F s131 97-014-1433-4.

Jo SC, Nam KC, Min BR, *et al.* Antioxidant activity of prunusmume extract in cooked chicken breast meat. International Journal of Food Science and Technology 2006;41:15-9. https://doi.org/10.1111/j.1365-2621.2006.01234.x.

Kahraman T, Issa G, Bingol EB, *et al.* Effect of rosemary essential oil and modified-atmosphere packaging (MAP) on meat quality and survival of pathogens in poultry fillets. Brazilian Journal of Microbiology 2015;46:591-9. https://doi.org/10.1590%2FS1 517-838246220131201.

Kahramanoğlu I, Chen C, Chen J, *et al.* Chemical constituents, antimicrobial activity, and food preservative characteristics of aloe vera gel. Agronomy 2019;9:831. https://doi.org/10.3390/agronomy9120831.

Kahramanoğlu I, Chen C, Chen J, *et al.* Chemical constituents, antimicrobial activity, and food preservative characteristics of Aloe vera gel. Agronomy 2019;9(12):831. https://doi.org/10.3390/agronomy9120831.

Kaur R, Gupta TB, Bronlund J, *et al.* The potential of rosemary as a functional ingredient for meat products - a review. Food Reviews International 2021;16:1-21. https://doi.org/10.1080/87559129.2021.1950173.

Keokamnerd T, Acton JC, Han IY, *et al.* Effect of commercial rosemary oleoresin preparations on ground chicken thigh meat quality packaged in a high-oxygen atmosphere. Poultry Science 2008;87(1):170–9. https://doi.org/10.3382/ps.2007-00066.

Kianiani S, Varidi MJ, Varidi M. The effect of fat replacement by aloe vera gel on physicochemical, technological and sensory properties of sausage containing 40% red meat. Iranian Food Science and Technology Research Journal 2019;15(1):1–11. https;//doi.org/10.22067/ifstrj.v0i 0.60437.

Kosowska M, Majcher MA, Fortuna T. Volatile compounds in meat and meat products. Food Science and Technology 2017;37:1–7. http://doi.org/10.1590/1678-457X.08416.

Kumar S, Kalita S, Das A, *et al.* Aloe vera: a contemporary overview on scope and prospects in food preservation and packaging, Progress in Organic Coatings 2022;166:106799. https://doi.org/10.1016/j.porgcoat. 2022.106799.

Kumar Y, Tyagi SK, Vishwakarma RK, *et al.* Textural, microstructural, and dynamic rheological properties of low-fat meat emulsion containing aloe gel as potential fat replacer. International Journal of Food Properties 2017;20(1);S1132–S1144. https://doi.org/10.1080/109429 12.2017.1336721.

Kumar Y, Yadav DN, Ahmad T, *et al.* Recent trend in the use of natural antioxidants for meat and meat products. Comprehensive Reviews in Food Science and Food Safety 2015;14(6):796–812. https://doi.org/10.1111/1541–4337.12156.

Levine RL, Williams JA., Stadtman ER, *et al.* Carbonyl assays for determination of oxidatively modified proteins. Methods in Enzymology 1994;233:346-57. https://doi.org/10.1016/S0076-6879(94)33040-9.

Li C, Bassey AP, Zhou G. Molecular changes of meat proteins during processing and their impact on quality and Nutritional values. Annual Review of Food Science and Technology 2023;14(1):85-111. https://doi.org/10.1146/annurev-food-052720-124932.

Liu P, Chen D, Shi J. Chemical constituents, biological activity and agricultural cultivation of Aloe vera. Asian Journal of Chemistry 2013;25(12);6477-85. https://doi.org/10.14233/ajchem.2013.14418.

Liu S, Zhang R, Fan L, *et al.* Effect of rosemary extract on lipid oxidation of cooked pork during simulated gastric digestion. Journal of the Science of Food and Agriculture 2020;100:1735-40. https://doi.org/10.1002/jsfa.10194.

Lucini L, Pellizzoni M, Pellegrino R, *et al.* Phytochemical constituents and in vitro radical scavenging activity of different Aloe species. Food Chemistry 2015;170:501-7. https://doi.org/10.1016/j.foodchem.2014.08.034.

Lund MN, Heinonen M, Baron CP, *et al.* Protein oxidation in muscle food: a review. Molecular Nutrition & Food Research 2011;55(1):83–95. https://doi.org/10.1002/mnfr.2010004 53.

Lund MN, Hviid MS, Claudi-Magnussen C, *et al.* Effects of dietary soybean oil on lipid and protein oxidation in pork patties during chill storage. Meat Science 2008;79(4):727-33. https://doi.org/10.1016/j.meatsci.2007.11.008.

Manessis G, Kalogianni AI, Lazou T, *et al.* Plant-Derived natural antioxidants in meat and meat products. Antioxidants (Basel) 2020;9(12):1215. https://doi.org/10.3390/antiox 9121215.

Manhani M, Nicoletti M, Barretto A, *et al.* Antioxidant action of Rosemary and oregano extract in pre-cooked meat hamburger. Food and Nutrition Sciences 2018;9:806–817. https://doi.org/10.4236/fns.2018.97060.

Massoud D, Alrashdi BM, Fouda MM., *et al.* Aloe vera and wound healing;a brief review. Brazilian Journal of Pharmaceutical Sciences 2022;58:e20837. https://doi.org/10.1590/s2175-97902022e20837.

Mena P, Cirlini M, Tassotti M, *et al.* Phytochemical profiling of flavonoids, phenolic acids, terpenoids, and volatile fraction of a Rosemary (Rosemarinus officinalis L.) extract. Molecules 2016;21:1576. https://doi.org/10.3390%2Fmolecules21111576.

Mubarik U, Asif U, Mehwish. Inhibition of creatine using different concentrations of aloe vera extract in chicken nuggets. Agrobiological Records 2023;12:46–52. https://doi.org/10.47278/journal.abr/2023.013.

Nicolau-Lapeña I, Colàs-Medà P, Alegre I, *et al.* Aloe vera gel: an update on its use as a functional edible coating to preserve fruits and vegetables. Progress in Organic Coatings 2021;151:106007, https://doi.org/10.1016/j.porgcoat.2020.106007.

Okamura N, Fujimoto Y, Kuwabara S, *et al.* High-performance liquid chromatographic determination of carnosic acid and carnosol in Rosmarinus officinalis and Salvia officinalis, Journal of Chromatography A 1994;679:381-6. https://doi.org/10.1016/0021-9673(94)80582-2.

Oostindjer M, Alexander J, Amdam GV, *et al.* The role of red and processed meat in colorectal cancer development: a perspective. Meat Science 2014;97:583–596. https://doi.org/10.1016/j.meatsci.2014.02.011

Rajkumar V, Verma AK, Patra G, *et al.* Quality and Acceptability of Meat Nuggets with Fresh Aloe vera Gel. Asian-Australas Journal of Animal Sciences 2016;29(5):702-8. https://doi.org/10.5713%2Fajas.15.0454.

Sánchez-Machado DI, López-Cervantes J, Sendón R, *et al.* Aloe vera;Ancient knowledge with new frontiers. Trends in Food Science & Technology 2017;61:94–102. https://doi.org/10.1016/j.tifs.2016.12.005.

Sebranek JG, Lonergan SM, King-Brink M, *et al.* Meat science and processing. 3rd ed. Zenda: WI Peerage Press ;2001. p.141.

Soltanizadeh N, Ghiasi-Esfahani H. Qualitative improvement of low meat beef burger using Aloe vera. Meat Science 2015;99:75-80. https://doi.org/10.1016/j.meatsci.2014.09.002.

Soni A, Gurunathan K, Mendiratta SK, *et al.* Effect of essential oils incorporated edible film on quality and storage stability of chicken patties at refrigeration temperature (4 ± 1 °C). Journal of Food Science and Technology 2018;55(9):3538–3546. https://doi.org/10.1007/s13197-018-3279-7.

Sun WQ, Zhang YJ, Zhou GH, *et al.* Effect of apple polyphenol on oxidative stability of sliced cooked cured beef and pork hams during chilled storage. Journal of Muscle Foods 2010;21(4):722-37. https://doi.org/10.1111/j.1745-4573.2010.00215.x.

Szymandera-Buszka K, Waszkowiak K, Jędrusek-Golińska A, *et al.* Sensory analysis in assessing the possibility of using ethanol extracts of spices to develop new meat products. Foods 2020;9:209. https://doi.org/10.3390%2Ffoods9020209.

Tumlinson LN. Method and apparatus for extraction of Aloe Vera gel [US Patents 4555987A]. 1985.

Usan E, Kılıc GB, Kılıc B. Effects of Aloe vera utilization on physicochemical and microbiological properties of Turkish dry fermented sausage. Journal of Food Science and Technology 2022;59(5):1727-38. https://doi.org/10.1007/s13197-021-05183-5.

Yeddes W, Nowacka M, Rybak K, *et al.* Effect of rosemary essential oil and ethanol extract on physicochemical and antibacterial properties of optimized gelatin–chitosan film using mixture design. Journal of Food Processing and Preservation 2022;46:e16059. https://doi.org/10.1111/jfpp.16059.