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

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 (approx. 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 (OJ. 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×10⁶) 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 meal 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>
<thead>
<tr>
<th>TRT*</th>
<th>upH</th>
<th>Cooking loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.46*</td>
<td>0.164*</td>
</tr>
<tr>
<td>RE</td>
<td>5.48*</td>
<td>0.168*</td>
</tr>
<tr>
<td>OE</td>
<td>5.49*</td>
<td>0.164*</td>
</tr>
<tr>
<td>CM</td>
<td>5.49*</td>
<td>0.169*</td>
</tr>
<tr>
<td>E-250</td>
<td>5.48*</td>
<td>0.168*</td>
</tr>
<tr>
<td>SEM**</td>
<td>0.039</td>
<td>0.014</td>
</tr>
</tbody>
</table>

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

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; Heş 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 4°C.

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>RE</th>
<th>OE</th>
<th>CM</th>
<th>E-250</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>1.268**</td>
<td>1.275**</td>
<td>1.264**</td>
<td>1.275**</td>
<td>1.289**</td>
<td>0.048</td>
</tr>
<tr>
<td>Day 4</td>
<td>3.550**</td>
<td>2.515**</td>
<td>1.504**</td>
<td>1.281**</td>
<td>2.258**</td>
<td>0.076</td>
</tr>
<tr>
<td>Day 8</td>
<td>7.041**</td>
<td>3.993**</td>
<td>2.538**</td>
<td>2.176**</td>
<td>3.534**</td>
<td>0.144</td>
</tr>
<tr>
<td>SEM**</td>
<td>0.127</td>
<td>0.131</td>
<td>0.074</td>
<td>0.061</td>
<td>0.074</td>
<td></td>
</tr>
</tbody>
</table>

**Values with different letters within a row are significantly different (p<0.05).
**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).
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 formation as compared to the other additives at day 4. In addition, the CM 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 3 – Effect of OE and RE on protein oxidation of incorporated cooked meat.**

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>RE</th>
<th>OE</th>
<th>CM</th>
<th>E-250</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>1.313a</td>
<td>1.337a</td>
<td>1.307a</td>
<td>1.323a</td>
<td>1.310a</td>
<td>0.058</td>
</tr>
<tr>
<td>Day 4</td>
<td>3.074bc</td>
<td>2.884bc</td>
<td>2.309abc</td>
<td>1.912bc</td>
<td>2.629abc</td>
<td>0.077</td>
</tr>
<tr>
<td>Day 8</td>
<td>3.908abc</td>
<td>3.176abc</td>
<td>2.573abc</td>
<td>2.195abc</td>
<td>2.978abc</td>
<td>0.044</td>
</tr>
<tr>
<td>SEM**</td>
<td>0.056</td>
<td>0.071</td>
<td>0.080</td>
<td>0.055</td>
<td>0.034</td>
<td></td>
</tr>
</tbody>
</table>

**SEM:** Standard error of the means.

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

<table>
<thead>
<tr>
<th>TRT*</th>
<th>Color</th>
<th>Spice</th>
<th>Oxidation</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odor</td>
<td>Odor</td>
<td>Acceptability</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.91*</td>
<td>0.69*</td>
<td>7.07*</td>
<td>4.37*</td>
</tr>
<tr>
<td>RE</td>
<td>6.09*</td>
<td>5.52*</td>
<td>5.14*</td>
<td>5.56*</td>
</tr>
<tr>
<td>OE</td>
<td>6.61*</td>
<td>6.08*</td>
<td>3.93*</td>
<td>6.82*</td>
</tr>
<tr>
<td>CM</td>
<td>6.79*</td>
<td>7.06*</td>
<td>3.05*</td>
<td>7.21*</td>
</tr>
<tr>
<td>E-250</td>
<td>6.30*</td>
<td>0.68*</td>
<td>4.62*</td>
<td>5.97*</td>
</tr>
<tr>
<td>SEM**</td>
<td>0.314</td>
<td>0.239</td>
<td>0.285</td>
<td>0.296</td>
</tr>
</tbody>
</table>

*SEM:** Standard error of the means.

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

<table>
<thead>
<tr>
<th>Time</th>
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<th>RE</th>
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<th>CM</th>
<th>E-250</th>
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</tr>
<tr>
<td>SEM**</td>
<td>0.056</td>
<td>0.071</td>
<td>0.080</td>
<td>0.055</td>
<td>0.034</td>
</tr>
</tbody>
</table>

*SEM:* Standard error of the means.

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<thead>
<tr>
<th>TRT*</th>
<th>Color</th>
<th>Spice</th>
<th>Oxidation</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odor</td>
<td>Odor</td>
<td>Acceptability</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.91*</td>
<td>0.69*</td>
<td>7.07*</td>
<td>4.37*</td>
</tr>
<tr>
<td>RE</td>
<td>6.09*</td>
<td>5.52*</td>
<td>5.14*</td>
<td>5.56*</td>
</tr>
<tr>
<td>OE</td>
<td>6.61*</td>
<td>6.08*</td>
<td>3.93*</td>
<td>6.82*</td>
</tr>
<tr>
<td>CM</td>
<td>6.79*</td>
<td>7.06*</td>
<td>3.05*</td>
<td>7.21*</td>
</tr>
<tr>
<td>E-250</td>
<td>6.30*</td>
<td>0.68*</td>
<td>4.62*</td>
<td>5.97*</td>
</tr>
<tr>
<td>SEM**</td>
<td>0.314</td>
<td>0.239</td>
<td>0.285</td>
<td>0.296</td>
</tr>
</tbody>
</table>
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.

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CONFLICTS OF INTEREST

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

REFERENCES


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