Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Jan - Mar 2019 / v.21 / n.1 / 001-010

http://dx.doi.org/10.1590/1806-9061-2017-0719

Original Articles

Effect of Origanum syriacum L. Essential Oil on the Storage Stability of Cooked Chicken Meat

■Author(s)

Al-Hijazeen M[I] https://orcid.org/0000-0002-7717-7977

[I] Mutah University, Agriculture College, Department of Animal Production, Karak, Mutah (61710), Jordan P.O. Box (7).

■Mail Address

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

■Keywords

Chicken meat, lipid oxidation, oregano essential oil, sensory attributes.

Submitted: 28/December/2017
Approved: 16/July/2018

ABSTRACT

The effects of the addition of *Origanum syriacum L.* essential oil (OE) on the lipid and protein oxidation, and sensory attributes of cooked chicken meat were compared with those of synthetic commercial meat preservatives. Ground deboned and skinless chicken breast and thigh meat were distributed according to six treatments: (T1) control (no addition of meat preservative); or the addition of (T2) 100 ppm OE; (T3) 150 ppm OE; (T4) 300 ppm L-ascorbic acid (E-300); (T5) 5 and 14 ppm butylated hydroxyanisoleadded to breast and thigh meat, respectively, (BHA/E-320); and (T6) 150 ppm sodium nitrite (E-250). Meat samples were cooked and analyzed for lipid oxidation (TBARS levels) and protein oxidation (carbonyl levels) on days 0, 4, and 7 days of storage. In addition, cooked meat thigh patties were evaluated for cooking loss and sensory attributes. All additives were showed significant lipid and protein antioxidant effects ($p<0.05$) compared with the control treatment during storage, with the strongest effects obtained with OEat 150 ppm and E-250. Cooking loss was not influenced ($p>0.05$) by the treatments. The best sensory attribute scores were obtained with OEat 150 ppm and E-250 treatments. L-ascorbic acid and BHA also showed significant effect ($p<0.05$) on both lipid and protein oxidation values, and sensory attributes. Based on the results study, it concluded that OEat 150 ppm may be used in replacement of synthetic antioxidants to improve the storage stability of chicken meat.

INTRODUCTION

Synthetic antioxidants, such as butylatedhydroxyanisole (BHA), butylatedhydroxytoluene (BHT) and tertiary butyl-hydroquinone (TBHQ) were widely used in several countries such as United States of America (USA) as an effective antioxidant in poultry meat products (US-FDA, 2016a). On the other hand, in the Middle East, countries such as Jordan, which follow the European Commission regulations (*Codex Alimentarius*) have limitations on the use of synthetic antioxidants (SA) in their food (JSMO, 2016). However, all over the world, there is a negative impression on the use of SA due to their possible toxicological and carcinogenic effects (Kumar *et al*., 2015; Altmann *et al*., 1986). Therefore, natural antioxidants (NA) have been increasingly replaced SA by the meat processing industry, and are preferred due to recent changes in consumers' demand (Taghvaei & Jafari, 2015; Abdel-Hamied *et al*., 2009).

In addition to SA, sodium nitrite (E-250) has been used as meat preservative and curing ingredient to improve meat storage stability (Al-Shuibi & Al-Abdullah, 2002). Meat processing companies extensively usedE-250 as a curing agent, as labeled in their food products. E-250 is also a very important meat additive as it improves cooked-meat color, flavor, and storage stability (Honikel, 2008; Sindelar & Milkowski,

2011). However, it may negatively affect human health when present in meat due to the formation of nitrosamines. Previous research and epidemiological studies (Sebranek & Bacus, 2007; Oostindjer *et al*., 2014) indicated that these N-Nitroso compounds maybe carcinogenic, causing colorectal cancer in humans. Meat processers have changed their curing formulations to reduce the use of E-250 by increasing sodium nitrate levels and mixing it with ascorbate or erythorbate to maximize curing reaction (Oostindjer *et al*., 2014; Nunez De Gonzalez *et al*., 2012). The addition of these accelerators (reducers) also may inhibit the formation of nitrosamines (Tannenbaum & Leaf, 1991). Therefore, in order to increase the antioxidant capacity of processed meat, E-250is combined with E-300or other SA (Al-Shuibi & Al-Abdullah, 2002). Furthermore, E-300 is permitted by the European Commission to be used as an antioxidant in different meat products to extend their shelf life and improve their stability (Velasco & Williams, 2011).

According to the recent publications (Kumar *et al*., 2015; Abdel-Hamied *et al*., 2009), a novel approach is to find NA for the complete or partial substitution of SA. For instance, the direct inclusion of herbs and their essential oil extracts, including sage, rosemary, and green tea, in meat products have shown positive overall effects on meat quality and their storage stability (Abdel-Hamied *et al*., 2009). Oregano essential oil (OE) is one of the most promising (ranks the highest) herbal extracts evaluated to improve meat storage stability (Zheng & Wang, 2001). The essential oil of *Origanum syriacum L*. (commonly known as Za'atar) is characterized by its high thymol and carvacrol contents (Daouk *et al*., 1995; Tepe *et al*., 2004; Ibrahim *et al*., 2012a).In Jordan and the Middle Eastin general, *Origanum syriacum L.* ground leaves are dried and consumed in many different traditional ways. In addition, *Origanum syriacum* leaves are used to cure eye ailments, burns, and stomach conditions, whereas its seeds are used as a sedative (Oran & Al-Eisawi, 1998; Ibrahim *et al*., 2012a).

Origanum syriacum essential oil provides a pleasant flavor to meat, reduces off-odor, and prevents rancidity development. These properties called the attention of researchers on meat preservation technology. Studies showed that *Origanum syriacum L.* has very strong antioxidant effect due to the high levels of thymol and carvacrol in their composition (Adam *et al*., 1998; Yanishlieva *et al*., 1999; Tepe *et al*., 2004; Al-Bandak, 2007) compared with the other *Origanum* species, such as *Origanum vulgare*, *Origanumonties*, and *Origanummajorana* L. (Daouk *et al*., 1995; Berna'th, 1997; Baser, 2002; Sahin *et al*., 2004). The antioxidant activity of OE is affected by several factors, including genetics, season, temperature, moisture, soil, and daylight length (Ibrahim *et al*., 2012b; Farooqi *et al*., 1999; Gonuz & Ozorgucu, 1999; Ceylan *et al*., 2003;Viuda-Martos *et al*., 2010). The genetic variation among *Origanum* species is considered most important factor of variation of essential oil percentage and composition (Akeel *et al*., 2009). However, the food preservation properties of wild Jordanian OE need to be further investigated. In addition, studies comparing essential oils extracted from different *Origanum* species, which are characterized by different phenolic compound contents, are needed. For instance, *Origanum syriacum var. bevanii* collected in Turkey contains 43-79% carvacrol (Baser, 2002). Also, the inclusion levels OE as an alternative to the most popular meat preservatives still need evaluated.

The hypothesis of this study was that wild *Origanum syriacum L.* found In Jordan may have strong antioxidant effect, allowing it to be applied as a natural alternative to synthetic antioxidants.

The objectives of this study were: 1) to investigate of two different *Origanum syriacum L.* essential oil levels on the storage stability and quality characteristics of ground and cooked during storage, and 2) to compare the antioxidant effect of *Origanum syriacum L.* with the most common antioxidants used in the meat industry.

MATERIALS AND METHODS

Sample preparation

The experimental procedures were reviewed and approved by the Department of Animal Production, Agriculture College, Mu'tah University, Jordan. The health and welfare of the experimental birds were checked by a veterinarian.

One hundred and forty, 6-wk-old broilers fed a corn-soybean meal diet were slaughtered at the experimental facilities of Mu'tah University, according to using the standard guidelines for poultry slaughter of Jordan (Jordanian Ministry of Agriculture Guidelines). Carcasses were chilled in iced water for 2 h, and drained in a cold chamber. The muscles (breast and thigh) were separated from the carcasses 24h after slaughter. Boneless breast and thigh muscles were cleaned, skins removed, external fats trimmed off, vacuum packed in oxygen-impermeable bags, and stored at -18°C freezer until used.

The frozen meats were thawed in a cooler (4°C), and ground twice using a 10-mm and a 3-mm

plates (Moulinex, Type DKA1, France) before use. Meat samples were submitted to the following six treatments:1) no additive inclusion, 2) addition of 100 ppm OE (OE-100), 3) addition of 150 ppm OE (OE-150), 4) addition of 300 ppm E-300, 5) addition of 5 and 14ppm BHA to the breast and thigh meat, respectively, and 6) addition of 150 ppm E-250.

Oregano essential oil (pure extract) was obtained from a certified company in Jordan (Green Fields Factory for oils, Amman, Jordan) using the most efficient purification, extraction, and steam distillation methods. This essential oil was extracted from the wild *Origanum syriacum L.* collected from different regions in Jordan. The HPLC analysis of the OE (Royal Scientific Society, Jordan, Amman), using the method of Zekovic *et al*. (2000), indicated that the essential oil consisted of 76.39% of carvacrol, and 13.06%of thymol. L-ascorbic acid (Fisher Scientific, fair Lawn, N.J., USA), and E-250 (Gainland Chemical Company, UK) powder were first dissolved in de-ionized distilled water (DDW), then the oil emulsion a (water in oil), using mineral oil, were prepared to make their aqueous solution. BHA and OE were dissolved in 100% ethanol, and then mixed with mineral oil to make their stock solutions. The added ethanol was removed in a rotary evaporator (model Laborota 4001-efficient, Heidolph, Germany) at 70°C, 175 mbar vacuum pressure, before adding the stock solution to meat samples. Each additive was added to the ground breast or thigh meat and then mixed for 3 min in a bowl mixer. All additives contained the same amounts of mineral oil and water (oil emulsion) to provide the same conditions.

The raw meat samples were packed in oxygen-impermeable vacuum bags (Albalabki-Jordan, Malcom SRL, Italy), and were cooked in-bag in 90°C water bath (WNB 14, Memmert, Germany) until the internal temperature of the meat patties reached 75°C. After cooling to room temperature, the cooked meat samples (approximately 50g) were transferred to oxygen-permeable bag (polyethylene, 11 x 25 cm, Future for Plastic Industry, Al-Moumtaz bags, Co. L.T.D, Amman, Jordan), and stored at 4°C for up to 7 days, when lipid and protein oxidation, cooking loss, and sensory analyses were carried out. The ground chicken (raw thigh)meat patties stored at 4°C up to 4 days before cooking and for each evaluation session.

Thiobarbituric acid-reactive substances (TBARS) measurement

Lipid oxidation of the meat samples was determined using the TBARS method (Ahn *et al*., 1998) with minor modifications. Five grams of ground chicken meat were weighed, placed in a 50-mL test tube, 50 µL BHT (7.2%) and 15 mL deionized distilled water (DDW) were added, and homogenized in a Heidloph (DIAX-900, Germany) for 25s at high speed. One milliliter of the meat homogenate was then transferred to a disposable test tube (13 × 100 mm), to which thiobarbituric acid/trichloroacetic acid solution (15 mM TBA/15% TCA, 2 mL) was added. The mixture was vortexed and incubated in water bath (90°C) for 15 min when the pink color was developed. Test tubes were then cooled in iced water for 10 min, mixed again, and centrifuged for 15 min at 2,500 x g at 4°C. The absorbance of the resulting supernatant solution was confirmed at 532 nm against a blank containing 1 mL of DDW and 2 mL of TBA/TCA solution. The TBARS number was expressed as mg of malondialdehyde (MDA) per kg of meat.

Protein oxidation

Protein oxidation was determined by the general method of total carbonyl value proposed by Lund *et al*. (2008). In a test tube, 10 mL pyrophosphate buffer (2.0 mM $Na_4P_2O_7$, 10 mM Trizma-maleate), 100 mM KCL, 2.0 mM $MgCl_2$, and 2.0 mM ethylene glycol tetraacetic acid, pH 7.4) were added meat sample (1g), which was then homogenized in a Heidloph (DIAX-900,Germany). Two equal aliquots of meat homogenate (2 mL) were taken from a sample, precipitated with 2 mL of 20% trichloroacetic acid (TCA), and centrifuged at 12,000 × g for 5 min at room temperature. After centrifugation, one of the pellets was dissolved with 2 mL of 10 mM 2,4-dinitrophenylhydrazine in 2 M HCl and the other with 2 M HCl (blank), and incubated for 30 min in the dark. During incubation, samples were vortexed for 10 s every 3 min. The protein was further precipitated with 2 mL of 20% TCA and centrifuged at 12,000 xg for 5 min. The 2,4-dinitrophenylhydrazine was removed by washing the pellets 3 times with 4 mL of 10 mM HCl in 1:1 (vol/vol) ethanol:ethyl acetate, followed by centrifugation at 12,000 × g for 5 min. The pellets were finally solubilized in 2 mL of 6.0 mM guanidine hydrochloride dissolved in 20 mM potassium dihydrogen phosphate (pH = 2.3). The samples were kept at 5 °C overnight, centrifuged and their supernatant absorbance was read at 370 nm. The value of blank sample was subtracted from their corresponding sample values. The carbonyl content was calculated as nmol/mg protein using absorption coefficient of 22,000/M/cm, as described by Levine *et al*. (1994).

Sensory evaluation

Trained sensory panels were used to evaluate the sensory characteristics of the ground cooked chicken thigh meat. Sensory panels evaluated the cooked meat for: chicken aroma, oregano spice odor, oxidation odor, and overall acceptability. The meat samples submitted to the six different treatments were prepared using the same method described in the oxidation analysis section.

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

All sensorial attributes were measured using a 1-9 score scale. For example, for overall acceptability, 9 represented extremely desirable and 0 represent extremely undesirable (extremely desirable – 9; very desirable – 8; moderately desirable – 7; slightly desirable – 6; indifferent – 5; slightly undesirable – 4; moderately undesirable – 3; very undesirable – 2; and extremely undesirable – 1). Similar terminology (detectable or undetectable) was applied for the other attributes. Sensorial evaluation sessions were carried out on separate days to decrease any variability.

The cooked meat samples (10g) were evaluated by the panelists after cooling to the room temperature (25°C). The panelist was given 1 glass vial (20 mL) of each treatment to evaluate odor of cooked thigh meat samples. All samples vials were labeled by a randomly selected three-digit number. Panelists were asked to smell the samples in random order and record the intensity of odor or over all acceptability on the scale line.

Cooking loss percentage

Ground chicken fresh meat samples (100g) were prepared as the method described in lipid and protein oxidation part for all treatments. Ground meat patties were stored for 4 days in oxygen-permeable bags at 4°C, weighed and vacuum-packed before cooking. The meat was cooked at a constant temperature using pre-heated water bath (Memmert, WNB 14, Germany) to 80 °C internal temperature of for 90 min for the maximum expected water loss (Murphy & Marks, 2000). After cooking, meat samples were cooled in cold water bath using to 20°C internal temperature, then water blotted or purged until the sample became dry. Cooking loss percentage was calculated as percent weight reduction of the cooked sample compared to the raw fresh meat sample using the following equation:

$$\text{Cooking loss \%} = \frac{(\text{raw meat weight} - \text{cooked meat weight}) \times 100}{(\text{raw meat weight})}$$

Raw meat pH values

The pH value of the ground raw meat samples were determined using a pH meter (PL-600, pH/mV/Temp Meter, Taiwan) after homogenizing 1.0-g samples with 9 mL de-ionized distilled water (DDW) (Sebranek *et al*., 2001).

Statistical analysis

Data were analyzed using the generalized linear model procedures (Proc. GLM, SAS program, version 9.3, 2012). Mean values and standard error of the means (SEM) were reported. The significance was defined at $p<0.05$ and Tukey's test or Tukey's Multiple Range test were used to determine whether there are significant differences between mean values.

RESULTS AND DISCUSSION

Lipid Oxidation

In general, TBARS values results are higher in cooked than in raw chicken meat samples (Al-Hijazeen *et al*., 2016a and b; Ahn *et al*., 2009). This due to the higher oxidation rate of cooked meat, in which antioxidant enzymes are denatured, ion is released from the intracellular compartment and the phospholipid bi-layer of the cell membrane is damaged, allowing oxygen and catalysts to enter the cell during cooking and storage (Ahn & Lee, 2002). No difference ($p>0.05$) in TBARS values among treatments were detected on day 0 of storage for both breast and thigh meat samples (Table 1). On days 4 and 7 of storage, both breast and thigh samples containing additives showed significantly lower TBARS values ($p<0.05$) compared with the control samples. However, no TBARS differences among additive-treated breast samples were found ($p>0.05$) on days 4 and 7 of storage. On the other hand, evaluating additive-treated thigh samples, the TBARS level of samples treated with OE at 100 ppm were significantly higher than those treated with OE at 150 ppm, BHA, E-300, and E-250 on day 4 and a wide variation was observed on day 7 of storage. This may be due to the higher fat content of thigh meat compared to the breast meat samples. At the end of storage time (day 7), OE at 150 ppm and E-250 had the highest antioxidant effect on thigh meat compared

to the other treatments, whereas L-ascorbic acid was the least effective additive to delay lipid oxidation in thigh samples on day 7. No statistical differences in TBARS levels (p>0.05) between E-250 and OE at 150 ppm on day 7 of storage were found. This indicates that OE at 150 ppm may have comparable effect to E-250 and other synthetic antioxidants onmalonaldehy deformation in cooked thigh meat samples (Table 1). This result agrees with other research studies where OE directly added to the meat and meat products (Chouliara *et al*., 2007; Fasseas *et al*., 2008; Kumar *et al*., 2015). However, further research studies are needed to investigate the partial replacement of E-250with oregano essential oil.

Table 1 – TBARS values of cooked ground chicken meat at different time of storage at 4ºC.

Time	Control No additives	100 ppm OE	150 ppm OE	300 ppm E-300	5/14 ppm BHA*	E-250 150 ppm	SEM
	---------- TBARS (mg/kgmeat) ----------						
Breast							
day 0	0.22^{az}	0.19^{az}	0.21^{ay}	0.19^{ay}	0.20^{az}	0.21^{ay}	0.013
day 4	1.59^{ay}	0.91^{by}	0.83^{bx}	0.88^{bx}	1.02^{by}	0.96^{bx}	0.069
day 7	2.50^{ax}	1.49^{bx}	0.93^{bx}	1.28^{bx}	1.47^{bx}	0.94^{bx}	0.133
SEM	0.042	0.043	0.074	0.173	0.061	0.052	
Thigh							
day 0	1.15^{az}	0.97^{az}	1.09^{az}	0.99^{az}	1.05^{az}	1.102^{ay}	0.078
day 4	3.54^{ay}	2.19^{by}	1.42^{cy}	1.63^{cy}	1.58^{cy}	1.38^{cy}	0.073
day 7	7.54^{ax}	3.05^{bx}	2.32^{cdx}	2.96^{bx}	2.73^{bcx}	2.11^{dx}	0.095
SEM	0.106	0.064	0.067	0.062	0.107	0.075	

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

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

TBARS value in mg malonaldehyde/kg meat.

Treatments: Control; 100 ppm OE; 150 ppm OE; 300 ppm E-300; 5 ppm and 14 ppm BHA in the breast and thigh meat, respectively; 150 ppm E-250.

Protein oxidation

Protein oxidation significantly affects meat quality and its storage stability, and it is highly correlated with lipid oxidation (Lund *et al*., 2011;Eztevies, 2011; Howell *et al*., 2001; Ahn *et al*., 2009). Changes in protein functionality, such as gelation, viscosity, solubility, and emulsion stability, as a result of oxidation process affects the final quality of meat products (Xiong, 2000). In the present study, protein oxidation (total carbonyl levels) were measured and determined according to the general method described by Lund *et al*. (2008). No significant differences (p>0.05) were detected in total carbonyl values (nmol/mg protein) among treatments in breast and thigh samples on day 0 of storage. However, total carbonyl values were significantly reduced (p<0.05) on days4 and 7 of storage in breast and thigh additive-treated samples compared with the control samples (Table2), except for breast meat treated with OE at 100 ppm, which presented an intermediate value.

Table 2 – Effect of adding different level of oregano oil on protein oxidation in cooked ground chicken meat during storage time.

Time	Control without	100 ppm Oregano	150 ppm Oregano	300 ppm E-300	5/14 ppm *BHA	150 ppm E-250	SEM
	---------- Carbonyl (nmol/ mg of protein) ----------						
Breast							
day 0	0.87^{az}	0.91^{ay}	0.92^{ay}	0.99^{ay}	0.93^{az}	0.88^{ay}	0.049
day 4	1.71^{ay}	1.23^{bxy}	1.09^{by}	1.26^{bxy}	1.15^{by}	1.04^{by}	0.064
day 7	2.09^{ax}	1.64^{abx}	1.36^{bx}	1.47^{bx}	1.39^{bx}	1.29^{bx}	0.134
SEM	0.045	0.181	0.066	0.074	0.043	0.05	
Thigh							
day 0	1.49^{az}	1.45^{ay}	1.42^{ay}	1.42^{ay}	1.37^{ay}	1.44^{ay}	0.048
day 4	3.36^{ay}	2.71^{bx}	2.31^{bx}	2.63^{bx}	2.82^{bx}	2.58^{bx}	0.12
day 7	4.22^{ax}	2.99^{bx}	2.47^{bx}	3.04^{bx}	2.82^{bx}	2.58^{bx}	0.14
SEM	0.115	0.106	0.086	0.19	0.068	0.048	

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

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

Treatments: Control; 100 ppm OE; 150 ppm OE; 300 ppm E-300; 5 & 14 ppm *BHA; 150 ppm E-250.

In general, these results are in agreement with those of Al-Hijazeen *et al*. (2016a and b), and other researchers (Estevez *et al*., 2005; Sun *et al*., 2010), who reported that the total carbonyl values reached up to 5 nmol/mg protein in cooked chicken meat. The addition of BHA or E-300significantly reduced carbonyl values both in breast and thigh meats ($p< 0.05$) relative to the control treatment measured on day 7; however, among the tested additives, E-300 resulted in numerically higher total carbonyl values in thigh meat on day 7. Both breast and thigh samples treated with oregano essential oil at 150 ppm and E-250 presented numerically lower total carbonyl values, suggesting higher antioxidant effect compared with the other treatments. Although OE at 150 ppm had anti-carbonyl formation activity both in breast and thigh samples, higher total carbonyl values (nmol/ mg of protein) were detected in thigh samples. Al-Hijazeen *et al*. (2016a), studying the effect of different levels of *Origanum vulgare* addition to ground cooked breast chicken meat. In addition, both OE levels (100 & 150 ppm) had significantly reduced thigh protein oxidation during storage time. Similar effects were found by Fasseas *et al*. (2008) when adding OE (3%*w/w*) to ground cooked pork and beef.

Cooking loss and ultimate pH values

The pH value was measured in all treatment samples before cooking, and was not significantly different ($p>$ 0.05) among treatments. Therefore, all samples had the same pH value before the cooking loss evaluation. In addition, no significant differences ($p>0.05$) in cooking loss % among treatments were detected (Table 3). There is a strong relationship of cooking loss with protein and lipid oxidation of raw meat, which affects meat quality (Kumar *et al*., 2015; Soladye *et al*., 2015; Aalsyng *et al*., 2003). The oxidation of meat protein (tissues) usually reduces meat water-holding capacity, causing dehydration (Liu *et al*., 2010) and further water loss (free water) during cooking (Soladye *et al*., 2015; Wang *et al*., 2009).

Table 3 – Cooking loss % and ultimate pH value of ground chicken thigh meat samples

*Treatment	*Raw meat pH*	*Cooking loss (%)*
T1	5.78[a]	0.179[a]
T2	5.67[a]	0.166[a]
T3	5.74[a]	0.163[a]
T4	5.76[a]	0.173[a]
T5	5.77[a]	0.163[a]
T6	5.80[a]	0.165[a]
SEM	0.064	0.0199

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

*Treatments: (T1) Control (no additives); (T2) 100 ppm OE; (T3) 150 ppm OE; (T4) 300 ppm E-300; (T5) 14 ppm BHA; (T6) 150 ppm E-250.

These results indicate that the evaluated antioxidant additives did not influence meat water-holding capacity. However, very few research studies on the effect of direct the addition OE on the storage stability and quality characteristics of cooked ground meat were published: one by Al-Hijazeen *et al*. (2016a) with chicken meat, and another by Fasseas *et al*. (2008) with pork and beef. Oxidized raw meat may increase cooking loss (Liu *et al*., 2010), as oxidation affects meat water-holding capacity, fatty acid profile, protein functionality, cooking procedure, and volatile compound production (Lorenzo & Dominguez, 2014). Water-holding capacity of raw meat is also affected by total protein content and their amino acid composition. This agrees with the total carbonyl value differences obtained between the control and additive treatments; however, only numerically higher cooking loss values were observed ($p>0.05$). It should be mentioned that meat cooking loss may also affected by many other factors (internal and external), such as grinding, surface area, fat content, cooking procedure, muscle fiber type, and freshness (Murphy & Marks, 2000; Guerrero *et al*., 2013; Barbanti & Pasquini, 2005; Lorenzo *et al*., 2014).

Sensorial evaluation

The sensorial evaluation results of thigh meat samples are shown in Table 4.

The highest chicken aroma score (7.77) was obtained with the addition of E-250addition, followed by the addition of OE at 150 ppm (6.94), which, however, was not statistically different ($p>0.05$) from the scores obtained with BHA (6.82), E-300 (6.50), and OE at 100 ppm (5.73). The meat sample with no additives received the lowest ($p<0.05$) chicken aroma score, which was statistically similar to that obtained with E-300 and OE at 100 ppm.

The oregano odor was strong enough to be clearly recognized by the panelists, as shown by the significantly higher scores ($p<0.05$) compared with the other treatments. This is consistent with the findings of other researchers, who studied the effect of OE addition by dipping (Pavelkova *et al*., 2013), coating (Vital *et al*., 2016), and/or mixing (Al-Hijazeen *et al*., 2016a) on meat sensory attributes and consumer acceptability.

The high estoxidation odor score was obtained in the control samples (6.05), while the lowest in the samples added with OE at 150 ppm (3.02). The oxidation odor score obtained with OE at 100 ppm (4.34) was not statistically different from those obtained with the

Table 4 – Sensory attributes of cooked ground thigh chicken meat patties.

Sensory attributes[1]				
TRT*	Cooked chicken aroma	Oregano Odor	Oxidation Odor	Over All Acceptability
T1	4.58^{c}	0.67^{b}	6.05^{a}	4.63^{b}
T2	5.73^{bc}	4.72^{a}	4.34^{abc}	6.83^{a}
T3	6.94^{ab}	5.60^{a}	3.02^{c}	7.56^{a}
T4	6.50^{abc}	0.58^{b}	5.14^{ab}	6.11^{ab}
T5	6.82^{ab}	0.61^{b}	3.76^{bc}	6.47^{a}
T6	7.77^{a}	0.52^{b}	3.49^{bc}	7.06^{a}
SEM[2]	0.49	0.21	0.42	0.37

[1]Sensory attributes: Samples were evaluated on day 4 of storage.

[2]SEM: Standard error of the mean.

$^{a\text{-}f}$Means within same column with different superscripts are different (p<0.05) n= 10.

*Treatments: (T1) Control (no additives); (T2) 100 ppm OE; (T3) 150 ppm OE; (T4) 300ppm E-300; (T5) 14 ppm BHA; (T6) 150 ppm E-250.

other treatments, whereas E-250 and BHA scores were statistically similar to the obtained with OE at 150 ppm. The low oxidation odor score obtained with OE at 150 ppm suggests it delayed oxidation and rancidity development.

The overall acceptability score of the control sample was significantly lower (p<0.05), compared with the other treatments, except for E-300, which score value was intermediate. Both E-250 and OE at 150 showed numerically higher (p>0.05) overall acceptability scores, which is consistent with the lipid and protein oxidation results obtained with these additives.

CONCLUSIONS

The addition of *Origanum syriacum* L. essential oil at 100 and 150 ppm to ground chicken breast and thigh meat reduced meat lipid and protein oxidation, demonstrating it was very effective to enhance the storage stability, comparable to that obtained with the evaluated synthetic meat preservativesE-250, BHA, and E-300. In addition, the thigh chicken meat with OE at 150 ppm promoted excellent sensory attribute scores. Therefore, it is concluded that OE at 150 ppm may be used in replacement of synthetic antioxidants to improve the storage stability of chicken meat.

ACKNOWLEDGEMENTS

This study was financially supported by the Deanship of Scientific Research at Mutah University, Al-karak, Jordan. Grant number: 120/14/118 (2015). This funding is highly appreciated. My deep thanks to all Animal Production Department staff for their help and advice.

REFERENCES

Aaslyng MD, Bejerholm C, Ertbjerg P, Bertram HC, Anderson HJ. Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. Food Quality and Preference 2003;14:277-288.

Abdel-Hamied AA, Nassar AG, El-Badry N. Investigations on antioxidant and antimicrobial activities of some natural extracts. World Journal of Dairy & Food Sciences 2009;4(1):1-7.

Adam K, Siropoulou A, Kokkini S, Lanaras T, Arsenakis M. Antifungal activities of *origanum vulgare subsp. hirtum, mentha spicata, lavandula angustifolia*, and *Salvia fruticosa* essential oils against human pathogenic fungi. Journal of Agricultural and Food Chemistry 1998;46:1739-1745.

Ahn DU, Lee EJ. Production of off-odor volatiles from liposome-containing amino acid homopolymers by irradiation. Journal of Food Science 2002;67:2659-2665.

Ahn DU, Nam KC, Lee EJ. Lipid oxidation and flavor. In: Du M, McCormick RJ, editors. Applied muscle biology and meat science. 3rd ed. Boca Raton: CRC Press; 2009. p.227-246.

Ahn DU, Olson DG, Jo C, Chen X, Wu C, Lee JI. Effect of muscle type, packaging, and irradiation on lipid oxidation, volatile production and color in raw pork patties. Meat Science 1998;49:27-39.

Akeel RW, Rawashdeh M, Haddad N, Haddadin M. Genetic variation between and among *Origanum syriacum L*. and *Origanum majorana L*. populations collected from different location in Jordan using RAPD markers. Crop Research 2009;38:245-257.

AL-Bandak G. Antioxidant properties and composition of *Majorana syriaca* extracts. European Journal of Lipid Science and Technology 2007;109:247-255.

Al-Hijazeen M, Lee EJ, Mendonca A, Ahn, DU. Effect of oregano essential oil (*Origanum vulgare subsp. hirtum*) on the storage stability and quality parameters of ground chicken breast meat. Antioxidant (MDPI) 2016a;5:18.

Al-Hijazeen M, Lee EJ, Mendonca A, Ahn, DU. Effects of tannic acid on lipid and protein oxidation, color, and volatiles of raw and cooked chicken breast meat during storage. Antioxidant (MDPI) 2016b;5:19.

Al-Shuibi AM, AL-Abdullah BM. Substitution of nitrite by sorbate and the effect on properties of mortadella. Meat Science 2002;62 (4):473-478.

Altmann HJ, Grunow W, Mohr U, Richter-Reichhelm HB, Wester PW. Effects of BHA and related phenols on the forestomach of rats. Food and Chemical Toxicology 1986;24:1183-1188.

Barbanti D, Pasquini M. Influence of cooking conditions on cooking loss and tenderness of raw and marinated chicken breast meat. LTW-Food Science and Technology 2005;38(8):895-901.

Baser H. Aromatic biodiversity among the flowering plant taxa of Turkey. International Union of Pure and Applied Chemistry 2002;74(4):527-545.

Berna'th J. Some scientific and practical aspect of production and utilization of Oregano in centeral Europe. Proceedings of the IPGRI International Workshop on Oregano; 8-12 May 1996; Valenzano, Bari. Rome: IPGRI; 1997. p.75-92.

Ceylan A, Bayram E, Sahbaz N, Otan H, Karaman S. Yield Performance and Essential Oil Composition of Individual Plants and Improved Clones of *Origanumonites L*. Grown in The Aegean Region of Turkey. Israel Journal of Plant Sciences 2003;51(4):285-290.

Chouliara E, Karatapanis A, Savvaidis IN, Kontominas MG. 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 2007;24:607-617.

Daouk R, Dagher SM, Sattout E. Antifungal activity of the essential of *Origanum syriacum L*. Journal of Food Protection 1995;58:1147-1149.

Estevez M, Ventanas S, Cava R. Protein oxidation in frankfurters with increasing levels of added rosemary essential oil: effect on color and texture deterioration. Journal of Food Science 2005;70:427-432.

Estevez M. Protein carbonyls in meat system: a review. Meat Science 2011;89:259-279.

Farooqi AHA, Sangwan N S, Sangwan RS. Effect of different photoperiodic regimes on growth, flowering and essential oil in Mentha species. Plant Growth Regulation 1999;29:181-187.

Fasseas MK, Mountzouris KC, Tarantilis PA, Polissiou M, Zervas G. Antioxidant activity in meat treated with oregano and sage essential oils. Food Chemistry 2008;106 (3):1188-1194.

Gonuz A, Ozorgucu B. An investigation on the morphology, anatomy and ecology *of Origanumonites L.* Turkish Journal of Botany 1999;23:19-32.

Guerrero A, Valero MV, Campo MM, Sanudo C. Some factors that affect ruminant meat quality:from the farm to the fork: review. Acta Scientiarum. Animal Science 2013;35(4):335-347.

Honikel KO. The use and control of nitrate and nitrite for the processing of meat products. Meat Science 2008;78:68-76.

Howell NK, Herman H, Li-Chan ECY. Elucidation of protein-lipid interactions in lysozyme – Corn oil system by Fourier transform Raman spectroscopy. Journal of Agricultural and Food Chemistry 2001;49:1529-1533.

Ibrahim RW, Haddad N, Haddadin M, Abu-Salah K, Amri A. Diversity among and within wild populations of *Origanum syriacum* collected from Jordan. Crop Research 2012a;43(1/3):249-259.

Ibrahim RW, Haddad N, Haddadin M, Abu-Salah K. Evaluation of agro-morphological characters and oil percentage of *Origanum syriacum L*. and *Origanum majorana L*. at three dates of initial cutting. Jordan Journal of Agricultural Sciences 2012b;8(1):33-44.

JSMO - Jordan Standards and Metrology Organization. List of allowed additives in food products [Codex Standard 192]. European Directives; 2016.

Kumar Y, Yadav DN, Aham T, Narsaiah K. Recent trend in the use of natural antioxidants for meat and meat products. Comprehensive Reviews in Food Science and Food Safety 2015;14:796-812.

Levine RL, Williams JA, Stadtman ER, Shacter E. Carbonyl assays for determination of oxidatively modified proteins. Methods Enzymology 1994;233:346-357.

Liu Z, Xiong YL, Chen J. Protein oxidation enhances hydration but suppresses water-holding capacity in porcine *longissimus* muscle. Journal of Agricultural and Food Chemistry 2010;58(19):10697-10704.

Lorenzo JM, Dominguez R. Cooking losses, lipid oxidation and formation of volatile compounds in foal meat as affected by cooking procedure. Flavourand Fragrance Journal 2014;29:240-248.

Lund MN, Heinononen M, Baron CP, Estevez M. Protein oxidation in muscle food: a review. Molecular Nutrition & Food Research 2011;55:83-95.

Lund MN, Hviid MS, Claudi-Magnussen C, Skibsted LH. Effects of dietary soybean oil on lipid and protein oxidation in pork patties during chill storage. Meat Science 2008;79:727-733.

Murphy RY, Marks BP. Effect of meat temperature on proteins, texture and cook loss for ground chicken breast patties. Poultry Science 2000;79:99-104.

Nunez Gonzalez MT, Osburn WN, Hardin MD, Longencker M, Garg HK, et al. Survey of residual nitrite and nitrate in conventional and organic/natural/uncured/indirectly cured meats available at retail in the United State. Journal of Agricultural and Food Chemistry 2012;60:3981-3990.

Oostindjer M, Alexander J, Amdam GV, Anderson G, Bryan NS, Chen D, et al. The role of red and processed meat in colorectal cancer development: a perspective. Meat Science 2014;97:583-596.

Oran S, Al-Eisawi D. Check-List of medical plants in Jordan. Dirasat Medical and Biological Sciences 1998;25(2):84-112.

Pavelkova A, Kacaniova M, Hleba L, Petrova J, Pochop J, Cubon J. Sensory evaluation of chicken breast treated with oregano essential oil. Journal of Animal Science and Biotechnology 2013;46(2):379-383.

Sahin F, Gcullcuce M, Daferera D, Scokmen A, Scokmen M, Polissiou M, et al. Biological activities of the essential oils and methanol extract of *Origanum vulgare ssp.* vulgare in the Eastern Anatolia region of Turkey. Food Control 2004;15:549-557.

SAS Institute. Base SAS® 9.3. Procedures guide copyright c 2011. Cary; 2011.

Sebranek GJ, Bacus JN. Cured meat products without direct addition of nitrate or nitrite. Meat Science 2007;77(1):136-147.

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

Sindelar JJ, Milkowski AL. Sodium nitrite in processed meat and poultry meats: a review of curing and examining the risk/benefit of its use [white paper series 3]. Champaign: American Meat Science Association; 2011. p.1-14.

Soladye OP, Juarez ML, Aalhus JL, Shand P, Esteves M. Protein oxidation in processed meat:mechanisms and potential implications on human health. Comprehensive Reviews in Food Science and Food Safety 2015;14:106-122.

Sun WQ, Zhang YJ, Zhou GH, Xu XL, Peng ZQ. Effect of apple polyphenol on oxidative stability of sliced cooked cured beef and pork hams during chilled storage. Journal of Muscle Foods 2010;21:722-737.

Taghvaei M, Jafari SM. Application and stability of natural antioxidants in edible oils in order to substitute synthetic additives. Journal of Food Science and Technology 2015;52(3):1272-1282.

Tannenbaum SR, Wishnok JS, Leaf CD. Inhibition of nitrosamine formation by ascorbic acid. The American Journal of Clinical Nutrition 1991;53:2475-2505.

Tepe B, Daferera D, SÖkmen M, Polissiou M, SÖkmen A. The in vitro antioxidant and antimicrobial activities of the essential oil and various extracts *of Origanumsyricacum L var bevanii*. Journal of the Science of Food and Agriculture 2004;84:1389-1396.

U.S. Food and Drug Administration. CFR - Code of Federal Regulations Title 21 [section: 72.110;172.115;172.185]. Silver: US Food; 2016a.

U.S. Food and Drug Administration. CFR-title 21—Food and Drug. Silver: US Food; 2016a . p.172.

Velasco V, Williams P. Improving meat quality through natural antioxidants: review. Chilean Journal of Agricultural Research 2011;71 (2):313-322.

Vital ACP, Guerrero A, Monteschio JO, Valero MV, Carvalho CB, Filho BAA, et al. Effect of edible and active coating (with rosemary and oregano essential oils) on beef characteristics and consumer acceptability. PloS ONE 2016;11(8):e0160535.

Viuda-Martos M, Navajas YR, Zapata ES, Fernandez-Lopez J,Perez-Alvarez JA. Antioxidant activity of essential oils of five Spice plants widely used in a Mediterranean diet. Flavour and Fragrance Journal 2010;25:13-19.

Wang RR, Pan XJ, Peng ZQ. Effects of heat exposure on muscle oxidation and protein functionalities of *pectoralis majors* in broilers. Poultry Science2009;88:1078-1084.

Xiong YL. Protein oxidation and implications for muscle foods quality. In: Decker EA, Faustman C, Lopez-Bote CJ, editors. Antioxidant in muscle foods. New York: Wiley; 2000. p.85-111.

Yanishlieva NV, Marinova EM, Gordon MH, Raneva VG. Antioxidant activity and mechanism of action of thymol and carvacrol in two lipid systems. Food Chemistry 1999;64:59-66.

Zekovic Z, Lepojevid Z, Vujid D. Supercritical Extraction of thyme (*Tymus vulgaris L*.). Chromatographia 2000;51(3):175-179.

Zheng W, Wang SY. Antioxidant activity and phenolic compounds in selected herbs. Journal of Agricultural and Food Chemistry 2001;49:5165-5170.