Cinnamon and Rosemary Essential Oils Incorporated into Alginate Coating Improve Chemical and Sensorial Quality of Chicken Meat

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ABSTRACT: *The present study was conducted to evaluate the effectiveness of edible coating of Cinnamon Essential Oil (CEO) and Rosemary Essential Oil (REO) incorporated into alginate coating to maintain chemical and sensorial characteristics of chicken meat under refrigeration conditions. Firstly in vitro antioxidant activity of essential oils was evaluated. Then fresh chicken meats were coated with alginate solution containing CEO, REO alone and in combination, and treatments were evaluated for Peroxide value (PV), total carbonyls, ThioBarbituric Acid Reactive Substances (TBARS), TriMethylAmine Nitrogen (TMAN), Total Volatile Basic Nitrogen (TVBN) and sensory quality tests. Results indicated that there was a significant difference in chemical parameters and sensorial attributes in all treatments when compared to control during storage. Therefore the functional alginate-sodium coating containing CEO and REO extended the shelf life of fresh chicken meat during refrigerated storage and could have a valuable food preserving potential in the food industry.*

KEYWORDS: *Cinnamon; Rosemary; Essential oil; Alginate coating; Antioxidant activity.*

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INTRODUCTION

Chicken meat consumption, as one of the most popular food around the world, has increased greatly in many countries in recent years. Oxidative rancidity and microbial growth are the main factors that affect the shelf life of this product [1]. Many factors can affect the rate of lipid oxidation in meat, but the oxygen concentration, fat and polyunsaturated fatty acids content and antioxidants present in the meat (e.g. α-tocopherol content), play the most important roles. Chicken meat tissues are rich in polyunsaturated fatty acids and are therefore susceptible to oxidation by free radicals leading to the production of hydroperoxides [2, 3]. Further decomposition of hydroperoxides to secondary volatile compounds such as acids, alcohols aldehydes, and ketones, results in the development of rancid flavor, color changes, and reducing shelf life [4].

Oxygen concentration is another important factor, affecting the lipid oxidation rate. There are different methods such as vacuum packaging and nitrogen packing, used in the food industry for reducing the oxygen content around foods with a high content of polyunsaturated fatty acids. Edible coatings are used to prevent physical damage and moisture loss and are suitable carriers for flavoring and coloring agents, antioxidants, antimicrobials, spices, and nutrients [5, 6]. Sodium alginate is an alginic acid salt isolated from brown algae called *Phaeophyceae* [7]. The major species used for commercial sources of alginate production are *Ascophyllum nodosum*, *Laminaria hyperborea*, *Laminaria digitata* and *Macrocystus pyrifera* [8]. Unique colloidal properties of this edible coating result in its application for thickening, gel-forming, and emulsion stabilizing [7]. Besides being an oxygen barrier, alginate coating is a good carrier for additives such as antioxidants minimizing lipid oxidation. Alternative preservation techniques using naturally derived ingredients have attracted attention and their application in food products are being investigated [9-13]. Natural antioxidants such Essential Oils (EOs) are plant phenolic compounds playing the role as a reducing agent, metal chelator, and singlet oxygen quencher in the retardation of lipid oxidation [14, 15].

Cinnamon (*Cinnamomum zeylanicum*), is evergreen and tropical tree, belonging to the Lauraceae family and usually grows in South and South-East Asia. The barks and leaves of cinnamon are usually used as a flavoring agent in different foods. It has been reported that the oils and extracts from cinnamon have a specific antioxidant activity, which especially depends on their phenolic and polyphenolic compounds [16]. The genus *Rosmarinus* is a popular herb of the Lamiaceae family with potent antioxidant activity. This genus has some aromatic and medicinal species as follows: *Rosmarinus officinalis* L., *Rosmarinus eriocalyx* Jordan & Fourr, and *Rosmarinus tomentosus* Hub.-Mor & Maire. *Rosmarinus officinalis* L.. by which antimicrobial and antioxidant activities are well known [17, 18].

The use of different technology combinations (hurdle technology) to postpone the lipid oxidation in poultry meat is of great interest to many researchers [19, 20]. But more effective approaches have always been of interest to researchers. Considering the potential effects of rosemary and cinnamon EOs and alginate coating on retarding the lipid oxidation, as well as due to the lack of study about the combination use of these compounds in the food model system, it was decided to apply the alginate coating containing with mentioned essential oils in chicken meat. To the extent of our knowledge, there are a few studies using alginate as a coating in chicken meat [21, 22] and there is no report on the application of cinnamon and rosemary EOs as natural preservative evaluating chemical quality, lipid damage and sensory characteristics of chicken meats which may occur during storage. Therefore, this study aimed to determine 1) the *in vitro* antioxidant potency of Cinnamon Essential Oil (CEO) and Rosemary Essential Oil (REO), 2) the sodium alginate potency as a coating solution impregnated with CEO and REO in inhibiting chemical and sensorial changes of fresh chicken meat during refrigeration storage.

EXPERIMENTAL SECTION

Antioxidant activity of CEO and REO

2,2-diphenyl-1-picrylhydrazyl (DPPH)

Two mL of methanolic DPPH (Sigma-Aldrich Chemical Co. St. Louis, USA) solution (24 μg/mL) was added to 50 μL of the EOs. After an incubation step for one hour at room temperature, the absorbance was recorded by a spectrophotometer (Pharmacia LKB Novaspec, Sweden), at 517 nm. The capacity of the EOs for scavenging DPPH radicals was measured based on the following equation [23]:

$\%inhibition=100(A_{blank}-A_{sample})/Ablank$

The EOs capacity to scavenge DPPH radicals was determined based on the concentration of EOs providing 50% inhibition (IC_{50}).

β-carotene bleaching (BCB) test

The β-carotene (10 mg) (Sigma-Aldrich Chemical Co. St. Louis, USA) was added to a flask (100ºC) together with linoleic acid (20 mg) (Sigma-Aldrich Chemical Co. St. Louis, USA) and Tween 40 (200 mg) (Merck, Darmstadt, Germany), all dissolved in chloroform (Merck, Darmstadt, Germany). After evaporation in a rotary evaporator (Heidolph laborta 4003, SchwaBach, Germany) at 40ºC for 5 min, 50 mL of distilled water was added to form the emulsion. The same procedure was repeated with butylated hydroxyanisole (BHA) as reference antioxidants. The absorbance of each sample was read at 470 nm immediately at the zero time and subsequently over two hours at 50ºC [24]. 10 mL of water was added to the control samples instead of EO. The EOs capacity in protecting against oxidation of β-carotene was calculated according to the equation below:

$AA= (DR_{Control}- DR_{Sample})\ 100/\ DR_{sample}$

AA: Antioxidant activity; DR: Degradation rate of the control = [ln (a/b)/60];

a: Absorbance at the beginning (time 0); b: Absorbance after 60 min

Chelating capacity assay

A solution was prepared using different concentrations of REO and CEO (200 μL), 740 μL of methanol, and 20 μL of 2mM $FeCl_2$. 40 μL of 5mM ferrozine was added to the mixture and the absorbance was read after 10 min at 562 nm [25]. Inhibition rate of ferrozine-Fe^{2+} complex formation was determined based on the following formula:

$\%inhibition= [(A_{control} - A_{sample})/A_{control})] \times 100.$

Chelating power was determined according to the capacity of EO to chelate Fe^{2+} at 0.5 mg/mL concentration. Quercetin was used as control.

Total phenols Assay

Total phenols Assay was performed according to the Folin-Ciocalteu method based on the procedures described by *Aminzare et al.* (2017). Briefly, the essential oils were mixed with 0.5 mL of Folin-Ciocalteu's phenol reagent (Merck, Darmstadt, Germany). 1 mL of saturated 20% (V/V) sodium carbonate solution was added to the solution and was kept for 5 min. The absorbance of the sample was read at 730 nm after 10 min keeping in the dark. The concentration of phenolic compounds was calculated according to the following equation. The result was expressed as g/kg of gallic acid equivalents (GAEs) [5].

$Absorbance = 0.0271\ gallic\ acid\ (\mu g) - 0.253(R^2 = 0.99).$

Ferric reducing antioxidant power

Essential oils (1 mL), 2.5 mL of phosphate buffer (0.2 M) and $K_3Fe(CN)_6$ (1%) were mixed together. Trichloroacetic acid (2.5 mL of 10% solution) was added after incubation at 50 °C for 20 min and the mixture was centrifuged at 1036 g for 10 min. A solution containing 2.5 mL of the upper layer, 2.5 mL of distilled water and 0.5 mL of 0.1% aqueous $FeCl_3$ was made and the absorbance was measured at 700 nm [24]. The reducing power of the EOs was determined based on the concentration of EOs providing 50% inhibition (IC_{50}).

Chemical quality assessment of chicken meat

Sample preparation

Three hundred gram pieces of fresh and boneless chicken breast meats were purchased from local meat markets, placed on ice (4 °C) and then transported immediately to the laboratory of Amol University of Special Modern Technologies, Mazandaran, Iran for further analysis.

Coating preparation

The coating was prepared by dissolving alginate solution (2% w/v) (Sigma-Aldrich Chemical Co. St. Louis, USA) in sterilized distilled water, stirring vigorously at 80 °C [26]. Tween 80 (0.25 g/g of essential oil) was added to the alginate solution and stirred for 30 min at 40 °C [27]. Chicken breast fillets were randomly allocated into five groups (Table 1). All samples were first soaked in alginate solutions for 5 min, drained for 2 min, and then were immersed in $CaCl_2$ solution (Sigma-Aldrich Chemical Co. St. Louis, USA) for 1 min following a final draining at room temperature. Samples were stored at 4 °C while packaging in polyethylene pouches and were analyzed periodically on days: 0, 3, 6, 9, 12, and 15.

Table 1: List of treatments.

No.	Treatment	Description
1	C	Control
2	CA	Coated alone with alginate solution
3	CEO	Alginate coating containing 5 mg/ml cinnamon essential oil
4	REO	Alginate coating containing 5 mg/ml rosemary essential oil
5	CEO+REO	Alginate coating containing 5 mg/ml cinnamon essential oil in combination with 5 mg/ml rosemary essential oil

Peroxide value

A solution of 0.30 g of the sample in 9.8 mL chloroform-methanol was added to ammonium thiocyanate solution (10 mM) (0.05 mL) and was vortexed for 2–4 seconds. Then, 0.05 mL of Fe^{2+} solution was added and the sample was vortexed for another 2–4 seconds. The absorbance was measured at 500 nm using an *ultraviolet-visible* spectrophotometer (LKB Novaspec II; Pharmacia, Sweden) after incubation for 5min at room temperature [28]. The peroxide value, expressed as milliequivalents of peroxide oxygen per kg of lipid ($meqO_2$/kg) was calculated by using the following formula:

$$\text{Peroxide value} = \frac{(As - Ab) \times m}{55.84 \times m0 \times 2}$$

where *As* = absorbance of the sample; *Ab* = absorbance of the blank; *m* = slope, obtained from the calibration curve; *m0* = mass in grams of the sample; 55.84 = atomic weight of iron.

Total carbonyls

Samples (1 g) were homogenized in 20 mM phosphate buffer containing 6 M NaCl (pH 6.5) for 30 seconds. 1 mL of cold trichloroacetic acid (TCA 10%) was added to precipitate proteins after centrifugation for 5 min at 4200 g. To measure the protein and carbonyl concentrations, 1 mL of 2 M HCl and 0.2% (w/v) DNPH in 2 M HCl were added to pellets, respectively. After incubation for 1 h at room temperature, 1 mL of 10% TCA was used for precipitation following three times washing with ethanol-ethyl acetate. Pellets were dissolved by a solution of 1.5 mL of sodium phosphate buffer (20 mM) containing 6 M guanidine HCl (pH 6.5). Bovine Serum Albumin (BSA) (Sigma-Aldrich Chemical Co. St. Louis, USA) was used as standard. The absorption coefficient of 21.0 nM^{-1} cm^{-1} at 370 nm was used for protein hydrazones and the number of carbonyls was equal with nmol of carbonyl per mg of protein [29].

Thiobarbituric acid reactive substances (TBARS) value

A mixture containing 1 mL of the chicken meat homogenate (5 g / 15 mL of deionized distilled water), 50 µL of butylated hydroxytoluene (7.2%) and 2 mL of thiobarbituric acid (TBA)– trichloroacetic acid (TCA) (15 mMTBA–15% TCA) was prepared. After an incubation step in boiling water bath for 15 min, cooled samples were centrifuged (15 min at 2500 ×g) and the absorbance of the solution was then recorded at 531 nm. The blank contained 1 mL deionized water and 2 mL TBA–TCA solution [28].

Trimethylamine nitrogen (TMAN) determination

Trimethylamine nitrogen analysis was performed according to the method of the Association of Official Analytical Chemists [30]. The alkalization agent (potassium hydroxide) was used to reduce/avoid the interference of dimethylamine. Chicken samples (15 g) were extracted with a trichloroacetic acid solution (7.5 %, w/v) using a Virtis homogenizer (SIGMA, 3-30K) at 13,800 rpm for 1 min. The mixture was filtered with Whatman no. 1 paper. 10 mL of toluene, 1 mL of formaldehyde (20 %, v/v) and 3 mL potassium hydroxide solution (45 %, w/v) were added to 4 mL of filtrate. After vigorous shaking, toluene layer was transferred to another tube and 5 mL of picric acid solution (0.2 g/L) was added before absorbance (410 nm) reading (HACH, DR 5000, Germany). A calibration curve with a trimethylamine hydrochloride solution (0.01 mg/mL) was prepared to quantify TMAN, according to the AOAC method used. The results were expressed as TMAN/100 g of chicken meat.

Total volatile basic nitrogen (TVBN) determination

Total volatile basic nitrogen was determined according to the method of Shahinfar et al. (2017). Briefly, 200 mL of a 7.5% aqueous trichloroacetic acid solution was added to 100 g of chicken samples;

after homogenization, the mixture was centrifuged at 400 g for 5 min and then filtered using a Whatman No. 1 filter paper. 25 mL of filtrate was loaded into the distillation tube followed by 6 mL of 10% NaOH. A beaker containing 10 mL of 4% boric acid and 0.04 mL of methyl red and bromocresol green indicator was placed under the condenser for the titration of ammonia (Merck 6130). Distillation was started and steam entrainment continued until a final volume of 50 mL was obtained in the beaker. The results were expressed as mg TVBN/100 g of chicken meat [31].

Sensory evaluation

Chicken breast samples (100 g) were cooked using a microwave oven (Daewoo KOR-9G1A / KOR-9G1B, 900 W) for 4 min. Panel members were firstly instructed about the product and its characteristics (taste, odor, and overall acceptability) and finally, seven judges were selected based on their performance in initial evaluation trials. A preparatory session was held before the testing so that each panel member could thoroughly discuss and clarify each attribute in cooked chicken. Testing was initiated after the panelists agreed on the specifications, in the Nutrition laboratory, Golestan University of Medical Sciences, Gorgan, Iran. The 9-point hedonic scale was carried out. During the evaluation, the panelists were situated in a private booth under incandescent light. The sample presentation order was randomized for each panelist. Room temperature water was provided between samples to cleanse the palate. The attributes measured and their descriptors were as follows: For taste; acid taste, saltiness, and fatness (from imperceptible to extremely intense); For odor: from imperceptible to extremely intense; At the end of the test, panelist gave a score for overall acceptability from 0 to 9. All chicken meat samples *were* graded as followed excellent, 9; very good, 8; good, 7; acceptable, 6; poor < 6. The fresh chicken breast meat was defined as the control sample [32, 33].

Statistical analysis

All the analyses were performed in triplicate and data were analyzed using a one-way analysis of variance (ANOVA) (SPSS Statistics Software, version 19). Significant difference among samples was determined by Multiple comparisons Tukey's test. A confidence level of $P \leq 0.05$ was considered as significant.

RESULTS AND DISCUSSION

In vitro antioxidant activity of EOs

Antioxidant properties of phenolic compounds can be determined by reactivity with electron-donor agents, stabilization of radical, and finally, their metal chelating properties [34]. In this study, the antioxidant activity of EOs was determined by five assays, including DPPH radical scavenging, total phenolic contents, β-carotene/linoleic acid bleaching assay, reducing power, and chelating power. The results are shown in Table 2.

The *R. officinalis* EO showed relatively higher antioxidant activity in comparison with *C. zeylanicum* EO in total phenolic contents, β-carotene/linoleic acid bleaching assay, and chelating power. *Özcan et al.* (2011) studied *R. officinalis, C.zeylanicum,* and *S. aromaticum* essential oils and found stronger antioxidative effects when compared to control groups; although they were weaker when comparing to samples containing BHA, completely similar to the results of the current study [35]. There are other studies on the antioxidant activity of these EOs that were in line with the results of the present study [36-38]. Unlike this study, the results obtained in *Özcan et al.* (2011) study, showed that cinnamon EO had significantly persistent higher antioxidant activity than rosemary EO [35]. Different results of EOs antioxidant activity obtained from different studies depends on factors like extraction process, genetic and growth conditions of plants, geographical and climate location, harvest time, processing, and storage condition [39].

Chemical quality assessment of chicken meat

Peroxide value

The initial Peroxide Value (PV) in the chicken meat was in the range between 0.08 to 0.04 (Fig. 1). In control samples, PV increased during 6 remaining days of storage. The PV of CA, CEO, REO, CEO+REO treatments increased after 9 days of storage and decreased thereafter during 6 remaining days of storage, respectively. PV values were much higher than control samples at all sampling stages. Significant lower values were observed in all treatments at day 12, but lower values of REO and CEO+REO treatments were considerable (Fig. 1). Peroxide degradation was observed in chicken meat after 9 days of storage which implies the faster rate of peroxide formation compared to its destruction into secondary oxidation metabolites [29].

Table 2: Antioxidant potential of EOs using different antioxidant assays.

	DPPH Ic_{50}* (mg/ml)	Total phenolic contents	B carotene/ linoleic acid bleaching assay (%)	Reducing power Ic_{50} (mg/ml)	Chelating power at 0.5 (mg/ml)
R.officinalis	7.13±0.24 [a]	289±7.31 [a]	81.27 [a]	18.4±0.48 [a]	81.23±1.06 [a]
C. zeylanicum	9.36±0.14 [b]	193±4.29 [b]	62.44 [b]	15.2±0.31 [b]	64.29±1.4 [b]
BHA	0.48±0.003 [c]	**	88.29 [c]	1.17±0.002 [c]	**
Quercetin	**	**	**	**	69.21±1.12 [c]

** IC_{50}, defined as the concentration of the test material required to cause a 50% decrease in initial DPPH concentration.*
*** Not examined.*
Different letters in each column indicate a statistically significant difference (P< 0.05).

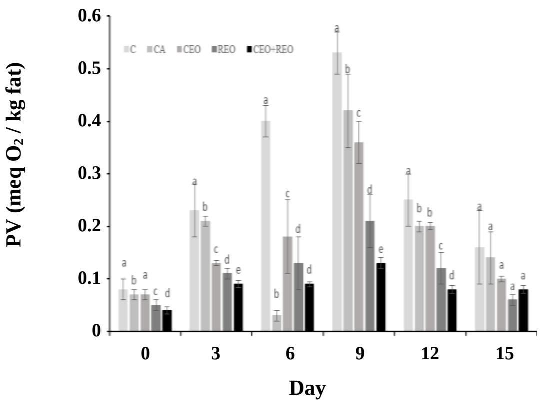

Fig. 1: Changes in peroxide value of chicken meat during refrigerated storage. Values followed by different small letter within the same days are significantly different according to Tukey's Multiple Range Test (P≤ 0.05).

Heydari et al. (2015) investigated the effect of *Mentha longifolia* essential oil incorporated into sodium alginate coating on the quality of bighead carp fillets storing at 4°C. Significant differences were observed between samples with horsemint EO and the control or sodium alginate [27]. *Georgantelis et al.* (2007) showed that coatings with combinations of REO + chitosan and α-tocopherol + chitosan antioxidants had lower PV concentrations in comparison with coatings containing each one of chitosan, rosemary or α-tocopherol antioxidants [40]. These mentioned results were completely in line with the results of the present study.

Results indicated that REO alone and in combination with CEO could improve the antioxidant activity of samples coated with alginate ($P \leq 0.05$), indicating the potency of phenolic antioxidants to inhibit the formation of free radicals.

Carbonyl content of chicken meat

The carbonyl content linearly increased for all groups during 15 days of storage (Table 3). There was not any significant effect of CA on carbonyl content of samples but CEO, REO, and CEO+REO samples showed limited carbonyl formation, indicating an inhibitory effect of CEO and especially REO and CEO+REO against protein oxidation.

The most prominent products of secondary oxidation of hydroperoxides are carbonyl compounds. They not only reduce the nutritional value but are also responsible for the rancid flavor of fried foods [41]. Direct oxidation of side chains in amino acids and reaction with reducing sugars are responsible for their formation. Phenolic compounds of REO and CEO treated samples exhibited antioxidant activity by sparing SH group of meat proteins from further oxidation. *Vuorela et al.* (2005), investigated the antioxidant effect of phenolics compounds of rapeseed and pine bark in meat. In control samples, protein carbonyls had higher concentration when compared to the standards during 9 days of storage [42]. *Lund et al.* (2007) studied the effect of rosemary extract, ascorbate/citrate, and modified atmosphere packaging on protein and lipid oxidation in minced beef patties, and the carbonyl content was ≤ 2 nmol/mg after 6 days of storage [43]. These mentioned studies reported similar results with the present study.

In fresh (non-oxidized) meat the carbonyl content is estimated to be 1 nmol/mg protein, which increases after meat oxidation up to 14 nmol/mg protein. Factors like oxidation triggers, muscle type, oxidation level, and protein solubility are effective in carbonyl generation [44]. Results of the present study showed that REO and CEO+REO treatments did not reach 2 nmol/mg protein during 15 days of storage.

Table 3: Changes in carbonyl content of chicken meat during refrigerated storage.

Day	C	CA	CEO	REO	CEO+REO
0	0.77± 0.23 [a]	0.73± 0.10 [a]	0.53± 0.26 [a]	0.50± 0.13 [a]	0.47± 0.17 [a]
3	1.47± 0.35 [a]	1.47± 0.25 [a]	1.23± 0.15 [a]	0.50± 0.17 [a]	0.77± 0.27 [b]
6	1.97± 0.27 [a]	1.77± 0.33 [b]	1.37± 0.17 [c]	1.13± 0.23 [d]	0.97± 0.17 [d]
9	2.53± 0.47 [a]	2.40± 0.37 [a]	1.67± 0.23 [b]	1.47± 0.21 [c]	1.03± 0.10 [d]
12	2.90± 0.53 [a]	2.87± 0.11 [a]	2.23± 0.27 [b]	1.77± 0.17 [c]	1.17± 0.21 [d]
15	3.20± 0.55 [a]	3.10± 0.37 [a]	2.23± 0.33 [b]	1.93± 0.27 [c]	1.27± 0.13 [d]

Control (C), Coated Alone (CA), Alginate coating containing Cinnamon Essential Oil (CEO), Alginate coating containing Rosemary Essential Oil (REO), Alginate coating containing cinnamon and rosemary essential oil (CEO+REO). Different letters in each row indicate a statistically significant difference (P< 0.05).

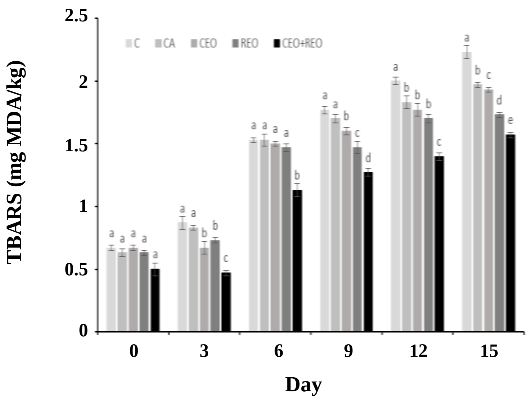

Fig. 2: Changes in TBARS value of chicken meat during refrigerated storage. Values followed by different small letter within the same days are significantly different according to Tukey's Multiple Range Test ($P \leq 0.05$).

Changes in TBARS value

TBARS value changes under the influence of different EOs are shown in Fig. 2. Over the storage period, TBARS values increased in C, CA, CEO, REO, and CEO+ REO samples. The differences were significant between all groups at the end of the storage period ($P \leq 0.05$). The results of the present study showed that adding phenolic compounds such as REO, CEO, and especially the combination of these EOs protects chicken meat against lipid oxidation. EOs can neutralize free radicals formation through donating an electron [45].

Moarefian et al. (2013) reported that after 2 and 30 days of storage, samples containing 20 and 40 ppm of the *C. zeylanicum* EO showed lower TBARS value comparing with control, respectively. All samples had significantly lower TBARS values comparing with control after 2 days ($P \leq 0.05$) [46]. Similarly, in the present study, all samples treated with EOs had significantly lower TBARS values compared to the control and CA samples after 3 days during storage.

Other studies have reported similar results as well. *McCarthy et al.* (2001) showed inhibited lipid oxidation of rosemary (0.10%) in fresh pork patties after 9 days of refrigerated storage which was assessed by TBARS values [47]. *Georgantelis et al.* (2007) investigated the lipid oxidation changes of fresh pork sausages under the effect of rosemary extract, chitosan, and a-tocopherol (Malondialdehyde (MDA) concentration determination) during 20 days at 4 °C. A combination of chitosan with either α-tocopherol or rosemary, showed valuable antioxidative effect while the combination of chitosan and rosemary had the best results [40]. In agreement with the results of this study, *Kahraman et al.* (2015) reported that the addition of rosemary EO to poultry fillets significantly reduced the uptrend of TBARS value in comparison with untreated fillets during the storage period ($P \leq 0.001$) [48]. On the other hand and contrary to the results of this study, Rojas and Brewer (2007) showed that REO did not have any effect on the lipid oxidation rate of cooked pork patties after 8 days of storage [49]. They explained that a higher level of oxidation was not inhibited by the concentration used in that study. The accepted level of TBARS value in meat products is estimated to be around 1 mg MDA/kg sample. In this study, REO, CEO, and CEO+REO samples had nearly acceptable TBARS values.

TMAN and TVBN values in chicken meat

TMAN and TVBN, are produced from the microbial enzymatic decarboxylation of amino acids and their

Table 4: Changes in TMA-N and TVB-N values per 100 g of chicken meat during refrigerated storage.

	Day	C	CA	CEO	REO	CEO+REO
TMAO	0	2.16± 0.2 [a]	2.20± 0.3 [a]	2.16± 0.5 [a]	2.40± 0.2 [a]	2.03± 0.3 [a]
	3	3.70± 0.7 [a]	3.63± 0.5 [a]	3.13± 0.5 [b]	2.73± 0.3 [c]	2.16± 0.7 [d]
	6	4.33± 0.3 [a]	4.16± 0.5 [a]	3.90± 0.5 [b]	3.53± 0.7 [c]	2.73± 0.7 [d]
	9	5.46± 0.7 [a]	5.16± 0.5 [b]	4.80± 0.5 [c]	4.33± 0.7 [d]	3.30± 0.3 [e]
	12	6.70± 0.7 [a]	6.66± 0.5 [b]	6.10± 0.5 [c]	5.70± 0.3 [d]	4.63± 0.7 [e]
	15	9.33± 0.5 [a]	9.06± 0.9 [b]	8.56± 0.7 [c]	7.23± 0.3 [d]	5.03± 0.5 [e]
TVBN	0	23.66± 1.05 [a]	22.00± 1.15 [a]	20.66± 1.10 [a]	21.33± 1.07 [a]	20.00± 0.90 [a]
	3	27.33± 1.50 [a]	24.00± 1.15 [b]	21.33± 1.07 [c]	22.66± 1.10 [c]	22.00± 1.12 [c]
	6	32.33± 1.27 [a]	28.33± 1.58 [b]	22.66± 1.73 [c]	21.66± 1.68 [d]	24.00± 1.17 [c]
	9	38.00± 2.05 [a]	32.33± 1.85 [b]	26.66± 1.78 [c]	26.00± 1.45 [c]	23.66± 1.85 [d]
	12	45.66± 2.27 [a]	45.66± 2.15 [a]	37.66± 1.87 [b]	34.00± 1.75 [c]	29.33± 1.65 [d]
	15	51.33± 2.50 [a]	50.33± 2.43 [a]	44.00± 1.95 [b]	39.33± 2.05 [c]	32.00± 1.48 [d]

Control (C), Coated Alone (CA), Alginate coating containing Cinnamon Essential Oil (CEO), Alginate coating containing Rosemary Essential Oil (REO), Alginate coating containing cinnamon and rosemary essential oil (CEO+REO). Different letters in each row indicate a statistically significant difference (P< 0.05).

determination is an applicable indicator in chicken meat spoilage [50].

In control and CA samples, TMAN values were significantly higher ($P \leq 0.05$) than CEO, REO, and CEO+REO chicken throughout 15 days of storage period. The TMAN values increased (9.33 and 9.06 mg N/100 g) respectively, in the control and CA samples after 15 days of storage (Table 4). TVBN values of chicken samples increased from an initial value and there were no significant results between control and CA samples but they showed significant differences with CEO, REO and CEO+REO samples (Table 4).

Nisin and Ethylene Diamine Tetra Acetic acid (EDTA) application, as antimicrobials, in alginate–calcium coating was used to improve the keeping quality of northern snakehead (*Channa argus*). The values for T1 (nisin and EDTA), T2 (alginate–calcium coating), and T3 (nisin and EDTA incorporated into alginate–calcium coating) were significantly lower than CK (untreated) during the storage period ($P \leq 0.05$). The TVBN values increased (95 to 320 mg/ kg) in CK treatment at the end of the storage period [51].

Values of 10 mg and 40 mg N/100 g are the acceptance limit for TMAN and TVBN of fresh chicken meat [48]. In the present study, the limit value of chicken samples treated with Control (C) and Coated Alone (CA), reached 40 mg TVBN/100g of sample approximately, on day 12. Interestingly, REO and CEO+REO treatment values did not increase to this level during the storage. In a study by *Economou et al.* (2009) on chicken samples, the limits exceeded these values, on days 16, 17, 20, and 22 for TMAN and on days 10, 12, 15, and 17 for TVBN. The limits reached 500 IU/g, 1500 IU/g, and 500 IU/g-10 mM in no nisin and EDTA added, no EDTA added, and EDTA treatments, respectively [52].

Sensory evaluation

The sensory scores (odor and taste acceptance) of control and CA samples declined after 9 and 12 days of storage, while the scores of REO, CEO+REO and especially CEO treatments were higher than the control and CA samples (Table 5). The addition of rosemary and cinnamon not only improved the aroma of samples but also retarded the off-odor resulted from fat oxidation. The lower score of CEO+REO treatments indicated a high concentration of EOs.

Ntzimani et al. (2010) found that rosemary (0.2%) had a desirable effect on odor and taste of cooked chicken meat [53]. They showed that the shelf-life of treatments including EDTA–lysozyme solution with rosemary oil

Table 5: Changes in sensory scores of chicken breast samples during refrigerated storage.

Coating additive	Sensorial values	Storage time (day)					
		0	3	6	9	12	15
C	taste	9.0±0.4	7.7±0.3	6.3±0.3	5.6±0.2	------------	------------
	odor	9.0±0.4	7.9±0.4	6.7±0.3	5.3±0.4	3.3±0.3	2.4±0.2
	overall	9.0±0.4	7.8±0.3	6.4±0.3	5.4±0.3	4.4±0.4	------------
CA	taste	9.0±0.4	7.7±0.4	6.4±0.2	5.6±0.4	6.1±0.4	------------
	odor	9.0±0.4	7.7±0.2	6.6±0.2	6.3±0.3	------------	4.1±0.3
	overall	9.0±0.4	7.9±0.2	6.6±0.3	6.2±0.4	5.4±0.2	4.6±0.4
CEO	taste	9.0±0.4	8.3±0.4	7.6±0.2	6.8±0.3	6.2±0.3	5.7±0.4
	odor	9.0±0.3	8.4±0.2	7.6±0.4	7.2±0.3	6.7±0.2	6.1±0.3
	overall	9.0±0.4	8.4±0.3	8.1±0.2	7.5 ±0.3	7.1±0.2	6.4±0.3
REO	taste	8.8±0.2	8.1±0.2	7.3±0.4	6.3±0.3	5.9±0.2	5.1±0.3
	odor	8.7±0.4	8.0±0.3	7.4±0.3	7.0±0.2	6.2±0.4	5.4±0.2
	overall	8.8±0.3	7.9±0.4	7.3±0.2	6.9±0.4	6.3±0.2	5.8±0.4
CEO+REO	taste	8.6±0.3	7.8±0.3	6.7±0.2	6.1±0.3	5.4±0.4	4.8±0.2
	odor	8.6±0.3	7.6±0.3	6.4±0.3	6.1±0.3	5.4±0.2	5.1±0.3
	overall	8.5±0.3	7.4±0.4	6.9±0.3	6.3±0.3	5.9±0.3	5.3±0.2

Control (C), Coated alone (CA), Alginate coating containing cinnamon essential oil (CEO), Alginate coating containing rosemary essential oil (REO), Alginate coating containing cinnamon and rosemary essential oil (CEO+REO).

and with oregano oil was longer for the 18 days, based on taste evaluation. Similar results were obtained in the present study as well.

CONCLUSIONS

Use of cinnamon and rosemary essential oils incorporated in alginate–sodium coating in this study resulted in shelf-life prolongation of fresh chicken meat during refrigerated storage through having antioxidant properties, reducing lipid oxidation and maintaining sensory attributes. Therefore, it can be practically applied to preserve the quality of fresh chicken meats, and producers and consumers would avail of the benefits of natural bioactive compounds as well as shelf-life extended products.

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