IJAS Iranian Journal of Applied Animal Science

Effect of Different Levels of Turmeric and Rosemary Essential Oils on Performance and Oxidative Stability of Broiler Meat

Research Article

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Received on: 11 Jul 2016
Revised on: 16 Dec 2016
Accepted on: 31 Dec 2016
Online Published on: Dec 2017

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Online version is available on: www.ijas.ir

ABSTRACT

The present study was conducted to investigate the effect of dietary supplementation of turmeric (TEO) and rosemary (REO) essential oils on growth performance and oxidative stability of broiler meat. Five hundred forty day-old chickens (Cobb 500) were randomly allotted to a 3 × 3 factorial arrangement with three levels of turmeric essential oil (T1=0, T2=75 and T3=150 mg/kg) and three levels of rosemary essential oil (R1=0, R2=100, and R3=200 mg/kg), with 4 replicates of 15 chickens. The combination of the essential oils, R2T3 and R3T3 improved (P<0.05) body weight gain compared to control group, during the first 3 wk of the trial. Control group had the lowest feed conversion ratio (P<0.05) compared to the other treatments with the exception of R1T2, R2T3 and R3T1 groups during of grower period (22-42d) and total period (1-42d). The highest values of the relative weights of carcass and thigh muscle achieved by birds fed 75 and 150 mg TEO supplementation respectively. Adding TEO supplementation to the diets significantly reduced (P<0.05) pancreas, proventriculus, gizzard and crop relative weights. The highest value of relative weight of liver was achieved by birds fed control diet compared to the birds fed other diets. With the exception of R3T2 and R3T3 groups, all of the treatments had a significant different (P<0.05) in malondialdehyde (MDA) value compared to control group after days 30 of storage at -20 ˚C. The birds fed supplementation of R1T2, R2T2, R3T3 and R3T1 showed lower levels of MDA values (P<0.05) in the breast meat compared to control group after days 60 of preservation at -20 ˚C. It was concluded that adding REO and TEO to the feed did not improve the broiler chicken's performance, whereas these feed additives had great potential to improve oxidative stability of breast meat and reduced the concentration of MDA after days 30 and 60 of preservation at -20 ˚C.

KEY WORDS broiler, essential oil, oxidative stability, rosemary, turmeric.

INTRODUCTION

Lipid oxidation is one of the primary mechanisms of quality deterioration in meat products through adverse changes in flavor, color, texture, and nutritive value (Hossain *et al.* 2012). Prevention of lipid oxidation needs special attention because a high proportion of fatty acids in broiler meat are unsaturated. Nutritional means are the best way to stabilize the lipids in whole muscle foods (Loetscher *et al.* 2013).

The supplementation of diet with antioxidant components inhibit a series of oxidative reactions in tissues, which increase the meat stability and quality in broilers (Alagawany *et al.* 2015). The synthetic antioxidants were generally used in the past. However, their use has decreased due to undesirable effects on animal products and on animal or human health (Perić *et al.* 2009). During the last decade, interest in entirely natural plant-derived antioxidants has increased greatly (Loetscher *et al.* 2013).

Medicinal plants have been proposed as antioxidant feed additives (Windisch *et al.* 2008). Some reports have been published about the protective effects of medicinal herbs such as thymol, rosemary and turmeric rhizome against oxidative reactions (Williams *et al.* 2004). These substances may intercept and neutralize free radicals, preventing propagation of oxidation process (Hossain *et al.* 2012). The antioxidant activity of plant extracts in mainly related to the presence of phenolic compounds (Hossain *et al.* 2012).

High *in vitro* antioxidant activity has been described for rosemary (Loetscher *et al.* 2013). In rosemary, phenolic diterpenes, such as rosmanol and carnosol and phenolic acids, namely rosmarinic and caffeic acids, are the predominant active components (Loetscher *et al.* 2013). Furthermore, the essential oil of rosemary inhibits the growth of 3 pathogenic bacteria (*E. coli*, *S. Indiana*, and *L. innocua*) (Celiktas *et al.* 2007). Turmeric also inhibits many oxidative reactions (Wuthi-Udomler *et al.* 2000). Curcumin, desmethoxycurcumin and bisdemethoxycurcumin are 3 main curcuminoieds of turmeric with strong antioxidant activity (Daneshyar *et al.* 2012). Curcumin is the most active ingredient of turmeric and has been demonstrated to have antioxidant, anti-inflammatory, antimicrobial, anticoagulant, antidiabetic and antiulcer properties (Baghban Kanani *et al.* 2016). Also, dietary supplementation of turmeric has been exhibited significantly positive effects on feed intake, body weight gain, feed conversion ratio and other carcass characteristics (Alagawany *et al.* 2015). Although many herbs have been successfully tested as feed additives. The differences in the effects of the supplements could have been that supplementation of whole plant material inevitably results in the application of large number of biologically active substances that also may interact. The simultaneous application of different antioxidants has repeatedly resulted in synergistic effects (Kamal-Eldin *et al.* 1996). These group of additives have great potential, but the right combination doses have yet to determined. Accordingly, the prediction of the antioxidant potential *in vivo* is very complex (Loetscher *et al.* 2013) and need to be confirmed and further investigated specially for rosemary and turmeric, with different concentrations. Therefore, the aims of the present experiment were to investigate the effect of feeding turmeric and rosemary essential oils on growth performance and oxidative status of breast meat of broiler chicks.

MATERIALS AND METHODS

A total of five hundred forty day-old mixed sexes Cobb 500 purchased from a local hatchery and were randomly allotted to a 3 × 3 factorial arrangement at three levels of turmeric essential oil (0, 75 and 150 mg/kg) and three levels of rosemary essential oil (0, 100 and 200 mg/kg), with 4 replicates of 15 chickens. All the chicks were fed starter diet from 1-21 days of age and grower diet from 22-42 days of age (Table 1). Turmeric (TEO) and rosemary (REO) essential oils were provided by commercial company (Barij Essence). Feed and water were supplied *ad libitum* throughout the entire experiment. Birds were maintained under recommended environmental temperature. As the temperature continuously reduced from 32 ˚C in week 1 to 20 ˚C in week 5. The lighting condition was 23 h light and 1 h darkness. The relative humidity was 50-60% throughout the experiment. Vaccination and medical program were done according to different stages of age under supervision of a veterinarian. Cumulative weight gain was recorded at the end of each growth period. Total feed intake was measured per pen, and feed conversion ratio (FCR) calculated. Mortality was recorded daily.

Two birds of each pen were sampled randomly for carcass evaluations at 42 days of age, slaughtered and weighed. Whole carcass, breast, thigh, heart, pancreas, abdominal fat, proventriculus, gizzard, and crop were excised and weighed individually, then calculated their relative weights. The carcass relative weight was calculated as percentage of the pre-slaughter live body weight of broiler chickens.

For determination of oxidative stability of meat, breast muscles were packed, and preserved at 4 ˚C for days 1, 7, 14 and 21 and also at -20 ˚C for days 30 and 60. The degree of meat lipid peroxidation (malondialdehyde, (MDA)) was determined by means of thiobarbituric acid reactive assay (TBARS) as described by Botsoglou *et al.* (1994). All data were analyzed using the GLM procedure of SAS (2002). Comparison among means was conducted using LSD procedure considering $P < 0.05$ as significant.

RESULTS AND DISCUSSION

The effect of dietary supplementation of turmeric (TEO) and rosemary (REO) essential oils on growth performance is presented in Table 2. The chickens fed TEO supplementation (75 or 150 mg/kg diet) consumed the higher feed ($P<0.05$) from 1-21 and 1-42 d of age. Adding REO supplementation to the diets also revealed a numerical tendency ($P>0.05$) for increased feed intake (FI) during all experimental periods. Florou-Paneri *et al.* (2006) also observed no adverse effect on FI when adding up to 10 g/kg of ground rosemary to layer diets.

The results show no difference in body weight gain (BWG) and FCR among broilers receiving control diet and TEO supplemented diets. In agreement with our results, Namagirilakshmi (2005) stated that broilers fed on turmeric did not significantly affect BWG.

Table 1 Ingredients and nutrient composition of diets

Ingredients	1-21 days	22-42 days
Corn grain	59.76	63.98
Soybean meal (42% CP)	34.28	29.92
Soybean oil	2.14	2.49
$CaCO_3$	1.11	1.03
Dicalcium phosphate (DCP)	1.43	1.31
Common salt	0.34	0.34
Vitamin permix[1]	0.25	0.25
Mineral permix[2]	0.25	0.25
DL-methionine	0.28	0.27
Lysine HCl	0.11	0.12
L-threonine	0.05	0.05
Nutrient composition (%)		
Metabolizable energy (ME) (kcal/kg)	2975	3050
Crude protein (CP)	20.64	19.1
Ca	0.84	0.77
Available P	0.42	0.39
Met	0.49	0.46
Lys	1.24	1.13
Met + Cys	0.95	0.90

[1] Vitamin premix provided per kilogram of diet: vitamin A: 7050 IU; vitamin D_3: 2000 IU; vitamin E: 8.8 IU; vitamin K_3: 1.71 mg; vitamin B_{12}: 0.015 mg; Biotin: 0.12 mg; Thiamine: 0.72 mg; Riboflavin: 3.3 mg; Pantothenic acid: 6.5 mg; Pyridoxine: 2.1 mg; Niacin: 28 mg; Choline: 220 mg and Folic acid: 0.5 mg.
[2] Mineral premix provided per kilogram of diet: Mn: 80 mg; Fe: 40 mg; Zn: 80 mg; Cu: 5 mg; I: 1 mg and Se: 0.15 mg.

Table 2 Effects of turmeric and rosemary essential oils on growth performance of broiler chickens

Item	Body weight gain (g)			Feed intake (g)			Feed conversion ratio		
	Starter	Grower	Total phase	Starter	Grower	Total phase	Starter	Grower	Total phase
Turmeric essential oil									
T1	749.91	1186.29	1936.20	1077.19^{b}	1885.59	2962.78^{b}	1.44	1.63	1.54
T2	761.25	1177.89	1939.14	1145.97^{ab}	2080.47	3226.44^{a}	1.51	1.77	1.64
T3	793.38	1193.01	1986.39	1193.64^{a}	2134.65	3328.29^{a}	1.51	1.81	1.66
SEM	22.68	7.56	43.32	58.59	131.04	89.04	0.04	0.10	0.56
P-value	0.08	0.96	0.61	0.01	0.06	0.01	0.43	0.26	0.16
Rosemary essential oil									
R1	749.70	1181.64	1931.34	1104.18	1927.80	3031.98	1.48	1.66	1.57
R2	759.99	1162.56	1922.55	1140.30	2055.69	3195.99	1.50	1.79	1.65
R3	795.06	1212.96	2008.02	1172.43	2117.22	3289.65	1.48	1.76	1.62
SEM	23.73	25.41	30.17	34.02	96.60	65.41	0.01	0.07	0.71
P-value	0.07	0.60	0.27	0.18	0.21	0.11	0.90	0.48	0.55
Interaction									
R1T1	736.12^{cde}	1306.21^{a}	2042.33^{ab}	1076.05^{cde}	1752.49^{d}	2831.54^{e}	1.47	1.35^{d}	1.41^{e}
R1T2	802.19^{abc}	1129.08^{bc}	1931.27^{abc}	1124.26^{bcd}	1801.83^{cd}	2926.09^{cde}	1.40	1.60^{bcd}	1.50^{cde}
R1T3	711.14^{e}	1110.01^{bc}	1821.15^{c}	1110.37^{cde}	2230.06^{ab}	3340.43^{abc}	1.6	2.04^{a}	1.82^{a}
R2T1	786.23^{bcd}	1044.18^{c}	1830.41^{c}	1156.50^{abcd}	2110.37^{abcd}	3266.87^{abc}	1.47	2.03^{a}	1.75^{abc}
R2T2	688.21^{e}	1167.27^{abc}	1855.48^{bc}	1066.61^{de}	2041.20^{abcd}	3107.81^{bcde}	1.54	1.77^{abc}	1.65^{abcd}
R2T3	805.00^{ab}	1276.05^{ab}	2081.05^{a}	1199.89^{abc}	2016.14^{bcd}	3216.03^{bcd}	1.49	1.59^{bcd}	1.54^{bcde}
R3T1	727.11^{cd}	1209.04^{abc}	1936.15^{abc}	997.44^{e}	1795.40^{cd}	2792.88^{e}	1.38	1.51^{dc}	1.45^{de}
R3T2	794.09^{bcd}	1238.13^{ab}	2032.22^{ab}	1248.43^{ab}	2399.22^{a}	3647.65^{a}	1.58	1.95^{ab}	1.77^{ab}
R3T3	864.19^{a}	1192.06^{abc}	2056.25^{a}	1272.50^{a}	2158.66^{abc}	3431.16^{ab}	1.48	1.81^{abc}	1.65^{abcd}
SEM	63.25	105.39	121.26	86.54	223.28	251.42	0.08	0.31	0.43
P-value	0.001	0.022	0.021	0.005	0.025	0.011	0.33	0.004	0.007

T1: without turmeric essential oil; T2: turmeric essential oil at the rate of 75 mg/kg; T3: turmeric essential oil at the rate of 150 mg/kg; R1: without rosemary essential oil; R2: rosemary essential oil at the rate of 100 mg/kg and R3: rosemary essential oil at the rate of 200 mg/kg.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

In the current study, supplementing of REO to the diets also had no effect on BWG and FCR compared to control group. However, the combination of these essential oils, R2T3 (100 mg REO+150 mg TEO) and R3T3 (200 mg REO+150 mg TEO) improved (P<0.05) BWG compared to control group, during the first 3 weeks of the trial.

On the contrary, the highest BWG (P<0.05) was recorded for control group compared to R1T2 (0 mg REO+75 mg TEO), R1T3 (0 mg REO + 150 mg TEO) and R2T1 (100 mg REO+0 mg TEO) during the last 3 wk of trial. Therefore, control group had the lowest FCR (P<0.05) compared to the other treatments with the exception of R1T2 (0 mg REO+75mg TEO), R2T3 (100 mg REO+150 mg TEO) and R3T1 (200 mg REO+0 mg TEO) during the end of grower period (22-42 d) and total period (1-42 d). The addition of these essential oils indicated a tendency for increased FCR especially during the end of experimental period.

The increase in FI in some treatments (R1T3, R3T2 and R3T3), during grower period, could be due to increased palatability of the experimental diet following the addition of TEO and REO. A number of plant essential oils appear the effects of appetizing promoter and increasing secretion of pancreatic enzymes in animals and thus cause beneficial changes in intestinal microflora (Klein-Hessling *et al.* 2004). Some studies indicate that these feed additives are not efficient in broiler chickens (Lee *et al.* 2003; Botsoglou *et al.* 2004). Baghban Kanani *et al.* (2016) did not find any beneficial effects of adding turmeric to the feed of poultry diets. Botsoglou *et al.* (2005) also showed that the use of rosemary and oregano essential oils alone or in combination did not improve laying hen performance or broilers FCR. The large variation in the effects of essential oils on broiler chicken performance is due to intrinsic and extrinsic factors such as physiological status of animals, rearing environment, infections, diet composition, the content of active substances in essential oil sample, and the different experimental approaches used by the authors to test the suitability of these substances as growth-promoting feed additives for broiler chickens (Windisch *et al.* 2008). However, Mathlouthi *et al.* (2012) suggested that essential oils contained in rosemary, oregano and BEO (a commercial blend of these essential oils) can substitute for growth promoter antibiotics. Because these additives had similar and beneficial effects on the ecosystem of broiler chicken gastrointestinal microbiota. In contrast, Yesilbag *et al.* (2011) reported no difference in FI between broilers receiving control or rosemary supplemented diets. Whereas, Baghban Kanani *et al.* (2016) stated that curcuminoids and curcumin of turmeric increased utilization of feed, resulting in enhanced growth; and also showed dietary supplementation of cinnamon and turmeric either alone or together improved the performance of broiler chickens under heat stress by reducing lipid peroxidation. It is possible, if in current trial, the chickens had exposed to a stress, and we would have observed a beneficial effect of adding turmeric or rosemary essential oils to the feed. Since Alagawany *et al.* (2015) reported that turmeric supplementation improved the growth performance and oxidative status in broiler chicks exposed to endosulfan.

Adding TEO supplementation to the diets improved (P<0.05) carcass relative weight and proportions of valuable muscles from breast and thigh in total carcass, at 42 d of age (Table 3). The highest values of carcass and thigh relative weights achieved by birds fed 75 and 150 mg TEO supplementation respectively. However, Hossain *et al.* (2012) observed that meat yield was not affected by the plant extract. The increase in relative weight of breast and thigh muscle in the TEO groups indicates a possible effect of the TEO constituents on production of musculature in broilers. In the present study, carcass, breast and thigh relative weights of broilers were not statistically influenced (P>0.05) by the REO supplementation. Adding TEO supplementation to the diet significantly reduced (P<0.05) relative weights of pancreas, proventriculus, gizzard and crop, although had no effect on liver and abdominal fat relative weights. Al-Sultan *et al.* (2003) reported that feeding of turmeric did not alter the size of liver and gizzard. In contrast to our findings, Nouzarian *et al.* (2011) observed that fat content of broilers was decreased significantly by supplementation (0.5%) of turmeric powder in the diet (P<0.01). Supplementation of TEO at 100 mg level to the diets significantly decreased the relative weight of gizzard and at 200 mg level significantly reduced the crop relative weight compared to control group (P<0.05). The highest value of the relative weight of liver was achieved by birds fed control diet compared to the birds fed other diets. But, Loetscher *et al.* (2013) observed that rosemary-fed birds (25 g/kg of diet) had enlarged pancreas and liver in relation to carcass weight. In rat, feeding of the water-soluble extract from rosemary revealed a clear link between increased relative weight of liver and liver detoxification enzymes (Debersac *et al.* 2001), which suggests that this herb contained factors requiring additional efforts of the body to digest and metabolize the nutrients.

Some plant extracts influence digestion and secretion of digestive enzymes and besides, they exhibit antibacterial, antiviral and antioxidant activity (Ertas *et al.* 2005; Cross *et al.* 2007). However, some authors established no influence on growth performance (Cross *et al.* 2007; Ocak *et al.* 2008). The differences in results are consequences of numerous factors, of which Yang *et al.* (2009) point out four: 1) type and part of plant used and their physical properties, 2) time of harvest, 3) preparation method of phytogenic additive and 4) compatibility with other food components. If we add influence of the quality of chickens, their health condition and environment conditions in the production facility, then it can be concluded that positive effect of phytobiotics can not always be demonstrated.

Table 3 Carcass traits and mortality of broilers fed turmeric and rosemary essential oils in the diet

Item	As % live body weight									Mortality
	Carcass	Breast	Thigh	Liver	Pancreas	Abdominal fat	Proventriculus	Gizzard	Crop	
Turmeric essential oil										
T1	72.48^{c}	15.22^{b}	22.99^{b}	3.12	0.36^{a}	1.77	0.86^{a}	6.12^{a}	0.83^{a}	1.66
T2	76.77^{a}	17.05^{a}	22.81^{b}	3.22	0.39^{a}	1.59	0.89^{a}	5.38^{b}	0.58^{b}	0.56
T3	74.33^{b}	17.75^{a}	24.96^{a}	3.06	0.31^{b}	1.96	0.68^{b}	3.86^{c}	0.58^{b}	0.56
SEM	2.16	1.31	1.19	0.08	0.05	0.18	0.12	1.15	0.14	0.64
P-value	< 0.0001	0.01	0.02	0.37	< 0.0001	0.29	0.01	< 0.0001	0.01	0.57
Rosemary essential oil										
R1	74.36	16.93	24.28	3.47^{a}	0.36	1.70	0.85	5.60^{a}	0.74^{a}	1.11
R2	74.42	16.35	22.64	3.06^{b}	0.32	2.02	0.79	4.73^{b}	0.68^{ab}	0.00
R3	74.80	16.74	23.84	2.87^{b}	0.31	1.60	0.79	5.03^{ab}	0.56^{b}	1.66
SEM	0.24	0.29	0.85	0.31	0.02	0.22	0.03	0.44	0.08	0.85
P-value	0.84	0.74	0.11	< 0.0001	0.12	0.18	0.38	0.03	0.04	0.38
Interaction										
R1T1	70.02^{e}	15.00	24.12	3.94^{a}	0.35	1.53	0.87^{abc}	6.20^{ab}	0.55^{b}	1.67
R1T2	78.94^{a}	18.30	23.23	3.45^{b}	0.37	1.48	1.02^{a}	6.80^{a}	1.06^{a}	0.00
R1T3	74.11^{bc}	17.49	25.49	3.03^{cd}	0.30	2.09	0.66^{d}	3.81^{d}	0.59^{b}	1.67
R2T1	71.13^{de}	15.27	22.43	2.89^{cd}	0.27	2.17	0.77^{bcd}	5.25^{bc}	0.52^{b}	0.00
R2T2	76.81^{ab}	15.47	20.99	3.03^{cd}	0.40	1.74	0.90^{abc}	5.16^{bc}	0.88^{a}	0.00
R2T3	75.33^{bc}	18.33	24.50	3.25^{bc}	0.29	2.14	0.69^{d}	3.77^{d}	0.63^{b}	0.00
R3T1	76.28^{abc}	15.39	22.44	3.01^{cd}	0.33	1.60	0.94^{ab}	6.90^{a}	0.66^{b}	3.31
R3T2	74.56^{bc}	17.38	24.19	2.68^{d}	0.41	1.56	0.76^{cd}	4.17^{cd}	0.54^{b}	1.67
R3T3	73.55^{cd}	17.43	24.88	2.91^{cd}	0.33	1.64	0.68^{d}	4.02^{d}	0.52^{b}	0.00
SEM	2.88	1.03	0.93	0.35	0.30	0.19	0.10	0.97	0.17	1.10
P-value	< 0.0001	0.31	0.43	0.01	0.09	0.74	0.04	0.01	0.01	0.69

T1: without turmeric essential oil; T2: turmeric essential oil at the rate of 75 mg/kg; T3: turmeric essential oil at the rate of 150 mg/kg; R1: without rosemary essential oil; R2: rosemary essential oil at the rate of 100 mg/kg and R3: rosemary essential oil at the rate of 200 mg/kg.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Furthermore, this group of additives has great potential, but the right combination and doses of them have to be selected (Perić *et al.* 2009). However, mechanisms of the action of these additives are not completely clear.

Results of the analysis of MDA in breast muscles stored at 4 ˚C and -20 ˚C are shown in Table 4. During storage, MDA values of breast meat increased in all treatments. Feeding of poultry with a higher level of natural dietary antioxidants provides the poultry industry with a simple method for improvement of oxidative stability, sensory quality, shelf life and acceptability of poultry meats. The method of meat processing and temperature of storage have a significant effect on oxidative stability of lipid (Marcincak *et al.* 2005). Reduction of the ambient temperature results in slower process of all chemical reactions including lipid oxidation (Marcincak *et al.* 2005). The combination of freezing and adding of antioxidants such as rosemary and turmeric essential oils maybe to suppress the process of lipid oxidation.

In the current experiment, during the first 7 days of storage at 4 ˚C a significant decrease (P<0.05) in MDA concentration was recorded in 100 mg/kg REO group compared to 200 mg/kg REO and control groups. The highest amounts of MDA were in the control group on days 1, 7, 17 and 21 of storage at 4 ˚C. There was a numerical tendency for reduced MDA concentration and the better anti-oxidative effect in meat samples with combination of REO and TEO (P>0.05).

Some reports have been published about the protective effects of medicinal herbs, such as thymol, rosemary and turmeric rhizome against oxidative reactions (Williams *et al.* 2004).

Yesilbag *et al.* (2011) and Loetscher *et al.* (2013) also reported that supplementing rosemary to the feed has been successful in this respect in broilers. The anti-oxidative effect of rosemary is based on its ability to inactivate free radicals produced during the auto-oxidation process (Perić *et al.* 2009).

Table 4 Malondialdehyde (MDA) concentration in breast muscle of broiler (µg kg-1 of meat)

Item	Stored at 4 ˚C				Stored at -20 ˚C	
	Day 1	Day 7	Day 14	Day 21	Day 30	Day 60
Turmeric essential oil						
T1	51.55	61.03	129.84	148.32	57.84	108.47
T2	51.44	54.39	120.88	134.44	52.87	105.73
T3	51.30	53.33	122.91	131.85	58.97	104.34
SEM	0.13	4.17	4.69	8.86	3.24	2.10
P-value	0.98	0.15	0.05	0.38	0.24	0.89
Rosemary essential oil						
R1	51.45	59.11^{a}	125.25	150.78	58.26	117.08
R2	51.38	49.99^{b}	124.96	129.42	57.49	98.71
R3	51.46	59.64^{a}	123.42	134.40	53.93	102.75
SEM	0.05	5.42	0.98	11.17	2.31	9.65
P-value	0.99	0.04	0.97	0.22	0.48	0.12
Interaction						
R1T1	55.10	70.01	135.75	179.71	71.63^{a}	130.10^{a}
R1T2	52.05	52.77	128.34	124.55	50.79^{c}	96.69^{b}
R1T3	51.49	60.30	125.43	140.69	51.11^{c}	98.77^{ab}
R2T1	51.50	51.23	117.15	140.02	51.50^{c}	129.96^{a}
R2T2	50.97	51.49	124.61	127.16	55.63^{bc}	94.35^{b}
R2T3	51.86	60.44	120.89	136.13	51.49^{c}	92.74^{b}
R3T1	51.76	56.08	122.84	132.60	51.64^{c}	91.16^{b}
R3T2	51.11	45.73	121.94	136.55	66.06^{ab}	105.12^{ab}
R3T3	51.04	58.19	123.95	126.40	59.20^{abc}	116.75^{ab}
SEM	0.54	5.41	4.94	15.80	9.59	18.42
P-value	0.97	0.36	0.93	0.39	0.01	0.04

T1: without turmeric essential oil; T2: turmeric essential oil at the rate of 75 mg/kg; T3: turmeric essential oil at the rate of 150 mg/kg; R1: without rosemary essential oil; R2: rosemary essential oil at the rate of 100 mg/kg and R3: rosemary essential oil at the rate of 200 mg/kg.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The antioxidant activity of plant extracts in mainly related to the presence of phenolic compounds (Hossain *et al.* 2012). In rosemary, phenolic diterpenes such as rosmanol and carnosol, and phenolic acids, namely rosmarinic and caffeic acids, are the predominant active components (Loetscher *et al.* 2013). For most polyphenols, little is known about their bioavailability and even less about the form, rate, and place of deposition in the broiler tissue (Loetscher *et al.* 2013). It is possible, these phenols transfer to the muscles. In the current study, adding TEO supplementation to the diets had only numerical decline on the MDA concentration after days 1, 7, 14 and 21 of preservation at 4 ˚C. In agreement with our results, Baghban Kanani *et al.* (2016) showed that turmeric supplementation decreased oxidative stress in broilers by reducing levels of plasma and serum MDA and TBARS. Curcumin is the major component of turmeric, which has beneficial effects on many biological processes such as enhancing the antioxidant defense system (Chattopadhyay *et al.* 2004).

Curcumin is a strong scavenger of the superoxide radical, a free radical that potentially harmful oxidative processes such as lipid peroxidation (Rao and Rao, 1996) and increases the activity of anti-oxidative enzyme such as glutathione peroxidase, glutathione reductase, glucose 6-phosphate dehydrogenase and catalase in mouse liver (Iqbal *et al.* 2003).

In the present study, control group also showed higher MDA concentration after days 30 and 60 of preservation at -20 ˚C compared to other groups. The main effects of REO and TEO additives were not significant. However, with the exception of R3T2 (200 mg/kg REO+75 mg/kg TEO) and R3T3 (200 mg/kg REO+150 mg/kg TEO) groups, all of treatments had a significant different (P<0.01) in this respect compared to control group after days 30 of storage at -20 ˚C. It seems the suitable doses of TEO and REO have great potential on the oxidative stability of breast meat either days 30 or 60 of preservation at -20 ˚C. Since the birds fed R1T2 (0 mg REO+75 mg TEO), R2T2 (100 mg

REO+75 mg TEO), R3T3 (200 mg REO+150 mg TEO) and R3T1 (200 mg REO+0 mg TEO) diets showed lower levels of MDA values ($P<0.05$) in the breast meat compared to control group after days 60 of preservation at -20 ˚C.

CONCLUSION

In summary, adding turmeric and rosemary essential oils to the feed did not improve broiler chicken's performance, whereas these feed additives had great potential on oxidative stability of breast meat and reduced the concentration of malondialdehyde after days 30 and 60 of preservation at -20 ˚C.

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