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The effect of dietary supplementation of thyme and garlic essential oils on meat quality, storage stability and sensory properties in commercial broilers

Ravula Tulasi[1], Thota Srilatha[1], Gurram Srinivas[2], Nagireddy Nalini Kumari[3], Anumolu Vijaya Kumar[4] and Ratna Supriya[1*]

[1] Department of Poultry Science, College of Veterinary Science, Rajendra Nagar, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana, India

[2] Poultry Research Station, College of Veterinary Science, Rajendra Nagar, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana, India

[3] Department of Animal Nutrition, College of Veterinary Science, Rajendra Nagar, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana, India

[4] Department of Veterinary Public Health and Epidemiology, College of Veterinary Science, Rajendra Nagar, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana, India

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ABSTRACT

Some essential oils (EO), renowned for their all-natural and eco-friendly characteristics, improve the quality and storage stability of meat. An experiment was conducted to determine the effect of feeding thyme and garlic EOs to broilers, on meat quality and storage stability. The four treatments consisted of a control diet, a control diet supplemented with thyme essential oil (TEO) or garlic essential oil (GEO) at 25 g/100kg, and thyme and garlic essential oil (TGEO) at 50 g/100kg. The birds were fed with iso-nitrogenous and iso-caloric diets according to the recommendations for six weeks. Supplementation of the EOs individually and their combination in the broilers' diet improved the physiochemical properties, fatty acid profile, and storage stability of the meat, but did not show any effect on the proximate composition or texture profile of the meat, except hardness which decreased with supplementation of EOs. In meat color analysis, redness (a*) was higher in the GEO group than in other treatments, whereas lightness (L*) and yellowness (b*) were not affected. The sensory quality parameters for texture and juiciness of meat were improved with the supplementation of EO individually. Coliform count and psychrophilic bacterial count (PBC) were reduced in the TEO group, whereas the yeast and mold count (YMC) was low in the TEO and GEO groups. However, no effect on total plate count (TPC) with dietary treatments was found. On the basis of the study, it may be concluded that Thyme essential oil (TEO) or Garlic essential oil (GEO) supplementation at a dosage of 25 g/100kg in the broilers' diet improved the meat's quality and storage stability.

Key words: garlic; thyme; essential oil; meat quality; storage stability; sensory properties; broiler chicken

* Corresponding author:
Ratna Supriya, Ph.D. Scholar, Department of Poultry Science, College of Veterinary Science, Rajendra Nagar, P.V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana, India – 500030, e-mail: supriyaratna1996@gmail.com

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Introduction

The poultry industry plays a pivotal role in meeting the global meat demand, making it a cornerstone of the modern food industry. This sector has grown significantly in recent decades due to its efficiency in meat production and relatively low environmental footprint compared to other livestock. The increase in the average income and preference for consumption of a nutritious diet in the urban population has led to a tremendous increase in the demand for poultry meat. Chicken meat is a healthier choice due to its lower fat content and higher ratio of monounsaturated and polyunsaturated fatty acids when compared to other meat species (RIOVANTO et al., 2012). The application of genetic selection has led to the attainment of required growth by five weeks (FANATICO et al., 2007), which may cause additional stress on the birds. This extra stress may compromise organoleptic, functional qualities, and cause histological and biochemical muscle changes, which may degrade certain indicators of meat quality, which in turn influence the initial and final quality judgment by consumers, before and after purchasing meat (WEN et al., 2017).

Lipid oxidation is considered a major cause of the deterioration of meat quality during refrigeration (SONG et al., 2022). To improve chicken health, and ensure better meat quality and longer storage duration, antioxidants have been used in poultry feeds (KONKOL et al., 2021). The usage of synthetic antioxidants has been rejected by consumers due to their deleterious effects (ZHANG and TSAO, 2016). The use of naturally occurring antioxidants is important to improve the quality and quantity of meat, without leaving residues (ISMAIL et al., 2021; SULIMAN et al., 2021).

Herbs and herbal products are used in poultry diets to substitute synthetic additives to stimulate or improve the efficient utilization of feed nutrients, which can lead to faster body weight gain, higher production rates and better feed efficiency (RAJALEKSHMI et al., 2020). Furthermore, active components of herbs, such as essential oils, may help broilers digest their feed and improve meat quality (GHAZALAH and ALI, 2008).

Essential oils are extracted from herbs and spices through steam distillation. They are a complex mixture of various compounds, primarily consisting of aromatic and volatile substances that have been generally regarded as safe (TIIHONEN et al., 2010). Most of the essential oils consist of compounds such as polyphenols, terpenoids, saponins, quinine, flavone, flavonoids, tannins, alkaloids and non-volatile residues. These compounds have antimicrobial, anticoccidial and antioxidant activities (ZIARLARIMI et al., 2011). The strong smell of essential oils may penetrate muscles and organs, which could improve their qualitative indicators and decrease oxidative processes (KIRKPINAR et al., 2014). TEO and GEO are used widely as condiments, and medicament, hypolipidemic and antihypertensive agents, alongside their other pharmacological properties, including antioxidant, anti-inflammatory and antifungal activities (HAMMOUDI HALAT et al., 2022).

In recent years, the effect of TEO and GEO on growth performance in broilers has been extensively studied (GALLI et al., 2020), but studies on meat quality attributes and sensory properties are limited. Hence, the present work planned to study the effect of dietary supplementation of TEO and GEO, both individually and in combination, on meat quality, storage stability and sensory properties in broiler chicken meat.

Materials and methods

Birds and management. Two hundred day-old commercial male broiler chicks were procured, wing-banded and individually weighed. These birds were randomly distributed into four dietary treatment groups, with ten replicates in each treatment and five birds in each replicate. The birds were reared in battery brooders in an open-sided poultry house, with optimum brooding conditions from day-old to 42 days of age. The birds were immunized against New Castle disease (ND) with the Lasota vaccine on the 7th (primary) and 28th (booster) days, and the IBD (intermediate - Georgia strain) vaccine on the 14th (primary) and 21st (booster) days.

Table 1. Ingredients and nutrient composition of the basal diet (%) fed to commercial broilers from day 1 to day 42

Ingredient	Pre starter (1-14d)	Starter (15-28d)	Finisher (29-42d)
Maize	51.94	52.86	57.05
Vegetable oil	3.70	5.10	6.00
Soybean meal	40.10	37.80	32.70
Stone grit	1.31	1.31	1.31
DCP	1.66	1.70	1.78
Salt	0.40	0.40	0.40
DL-methionine	0.204	0.210	0.230
L-lysine HCl	0.252	0.190	0.100
Trace mineral mixture***	0.100	0.100	0.100
Vitamin AB2D3K*	0.017	0.02	0.02
Vitamin B-complex**	0.020	0.02	0.02
Choline chloride	0.100	0.100	0.100
Toxin binder	0.100	0.100	0.100
Total	100	100	100
Nutrient composition (calculated values)			
ME (kcal/kg)	3002	3101.57	3200.70
Crude protein (%)	23.05	22.05	20.07
Lysine (%)	1.30	1.20	1.01
Methionine (%)	0.52	0.51	0.51
Calcium (%)	1.02	1.01	1.01
Available phosphorous (%)	0.45	0.45	0.45

*AB2D3K provided per kg diet: Vitamin A 20000 IU, Vitamin B2 25 mg, Vitamin D3 3000IU and Vitamin K 2mg

** Vitamin B-complex provided per kg diet: Riboflavin 25mg, Vitamin B1 1mg, Vitamin B6 2mg, Vitamin B12 40mg and Niacin 15mg

*** Trace mineral provided per kg diet: Manganese 120mg, Zinc 80mg, Iron 25mg, Copper 10mg and Iodine 1mg

Diets. The composition of the experimental diets, along with their nutrient composition are given in Table 1. All the dietary treatment groups received iso-nitrogenous and iso-caloric diets (BIS, 2007). The treatments consisted of a corn-soybean meal-based control diet with no essential oil (CD), a control diet supplemented with TEO, or GEO at 25 g/100kg, and TGEO at 50 g/100kg. Broiler pre-starter, starter and finisher diets were formulated to contain 23%, 22% and 20% CP and ME of 3000, 3100 and 3200 kcal/kg, respectively. The pre-starter and starter diets were fed up to day 14 and day 28, respectively, while the finisher diets were fed from day 29 to day 42 of age. The commercial essential oil products were supplied by Ayur Vet Private Limited, Katha, Baddi – 173205, Himachal Pradesh, India.

Parameters

Meat quality parameters. From the birds slaughtered on day 42, deboned breast meat without skin was collected, packed in low-density polyethylene bags (LDPE) and stored at refrigerated temperature (4±1°C) to assess the physicochemical properties, proximate composition, texture profile analysis, instrumental color analysis and sensory evaluation.

$$\text{Drip loss (\%)} = \frac{\text{The initial weight of the sample (g)} - \text{final weight (g) x100}}{\text{Initial weight (g)}}$$

Cooking yield**:** The percentage of cooking yield was determined (MURPHY, 1975).

$$\text{Cooking yield (\%)} = \frac{\text{Weight of meat block after cooking (g) x100}}{\text{Weight of meat block before cooking (g)}}$$

Cholesterol content: Cholesterol was estimated from breast meat samples as per calorimetric procedure of RAJKUMAR et al. (2004).

$$\text{Cholesterol (mg/100g)} = \frac{\text{Unknown OD x 100}}{\text{Standard OD}}$$

Physicochemical properties. Drip Loss**:** Drip loss of the meat samples was determined (AOAC, 2012).

Fatty acid profile (FAP). Fatty acids were analyzed according to AOAC, (2012) and SHAIK et al. (2017). Fatty acids were estimated by Gas Chromatograph (7890B of Agilent Technologies) equipped with flame ionization detector and Agilent - DBFFAP column (nitroterephthalic-acid-modified polyethylene glycol (PEG) of high polarity for the analysis of volatile fatty acids).

Shear force value (SFV). The meat sample was first packed in LDPE bags and sealed properly to avoid water entry, then the packed sample was cooked in a water bath for 10 to 20 minutes at 80°C. After cooking, the meat samples were made into cores and the cores from each sample were sheared across the length of the meat sample. These sample cores were placed under the V- V-notched shear blade of the texture analyzer (Tinius Olsen, HIKF, United Kingdom). Cores were sheared perpendicular to the fiber orientation to measure the shear force. The peak shear force was recorded in Newtons (N) and the average value from the three cores was recorded.

Proximate analysis. Proximate analysis of the breast meat without skin was performed according to the procedures described previously (AOAC, 2012). Dry matter was estimated by subtracting the moisture percentage from 100. Moisture content is typically assessed by subjecting a sample to drying at 100°C overnight in a hot air oven. The ash content in products can be determined by incinerating samples at a temperature of 600 degrees Celsius for 2 hours. The crude protein content of the meat was analyzed using the Micro-Kjeldahl method. Quantitative determination of fat content was carried out by extracting the sample with the chloroform-ethanol method.

*Texture profile analysis (TPA).*Texture measurements, in the form of a texture profile analysis (TPA), were performed at room temperature with a texturometer (Tinius Olsen. Model HlKF, 6 Perrywood Business park, Redhill, RHl SDZ, England). Core samples of restructured chicken roll samples of 8 mm diameter were tested (BOURNE, 1978).

Instrumental color analysis. The color measurement (Hunter L*, a* and b*) was performed using a X-Rite RM200QC Imaging Spectrocolorimeter, Lovibond, China with a 8 mm aperture set for illumination D 65, 10° standard observer angle. Color measurement was conducted on the surface of meat at randomly chosen spots (HUNTER and HAROLD, 1987).

Sensory evaluation. The sensory attributes of the meat samples were evaluated using an 8-point descriptive scale. In the eight point scale, 8 corresponded to components characteristic of the highest quality, scores from 5 to 8 were considered acceptable and scores from 1 to 5 were considered unacceptable. The panel consisted of minimum of six trained and experienced members of the institute, who were familiar with the characteristics of the meat. The fresh meat samples were cooked in water

bath for 20 minutes at 80°C by adding salt (0.5% by weight of sample). These coded samples are then served at room temperature in separate sensory evaluation booths. Water was served for cleansing the mouth between sample analyses.

Storage studies. The storage stability of meat in terms of pH, TBARS and microbiological studies were evaluated at every 3-day interval until insipient spoilage.

pH. The pH of the meat samples was estimated according to the procedure of TROUT et al. (1990). Five grams of sample were blended with 45 ml of distilled water using an Ultra 45 Turrax Tissue Homogenizer (IKA digital ULTRA-TURRAX, Model T- 25, Germany) for one minute. The pH was recorded by immersing the glass electrode of a digital pH meter (Eutech Instrument, Cyberscan, Singapore Model) into the homogenate. The pH of the sample was measured with the pH meter, which was calibrated with buffer solutions of pH 4, 7 and 14 according to the user manual instructions to avoid errors.

Thiobarbituric acid reactive substances (TBARS): The TBARS value was determined (WITTE et al., 1970).

Microbiological studies: The microbial quality of the meat was evaluated by estimating the total plate count (TPC), coliform count, PBC, and YMC, following the spread plating technique.

Statistical analysis. The data were analyzed using the GLM procedure of SPSS (20th version), and comparison of means was done using Duncan's multiple range test (DUNCAN, 1955) and the significance level was considered at $P<0.05$.

Results

Meat quality parameters

Physicochemical properties. The effect of dietary treatments on physiochemical properties are depicted in Table 2.

Values for drip loss on breast meat of broilers ranged between 1.85 and 2.59%. Supplementation with TEO and GEO, both individually and in combination (TGEO), significantly ($P<0.05$) reduced drip loss compared to the control. The drip loss values from birds supplemented with TEO, GEO and TGEO were similar.

Table 2. The effect of dietary supplementation of thyme and garlic essential oils and their combination on physicochemical properties in broiler chicken meat

Treatments	Drip Loss (%)	Cooking yield (%)	Cholesterol (mg/100g)	Fatty acid profile				Shear force (N)
				SFA (g)	MUFA (g)	PUFA (g)	TUFA (g)	
CD	2.59^{a}	78.37^{c}	50.98^{a}	33.75^{a}	40.25	24.22^{b}	64.47^{b}	6.88^{a}
TEO	1.87^{b}	81.61^{a}	46.36^{b}	31.18^{b}	41.57	26.47^{a}	68.86^{a}	4.88^{bca}
GEO	1.85^{b}	80.68^{a}	42.05^{c}	30.52^{b}	41.45	27.39^{a}	68.13^{a}	5.52^{b}
TGEO	1.86^{b}	79.44^{b}	39.18^{c}	30.98^{b}	41.77	26.81^{a}	69.62^{a}	6.44^{b}
SEM	0.11	0.35	1.24	0.48	0.28	0.45	0.56	0.28
N	6	6	6	6	6	6	6	6
P-value	0.01	0.01	0.01	0.05	0.34	0.05	0.01	0.04

Values bearing different superscripts within a column differ significantly ($P<0.05$)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil. SFA = Saturated Fatty Acid; MUFA = Mono Unsaturated Fatty Acid; PUFA = Poly Unsaturated Fatty Acid; TUFA = Total Unsaturated Fatty Acid

Table 3. The effect of dietary supplementation of thyme and garlic essential oils and their combination on proximate analysis in broiler chicken meat

Treatments	Dry matter (%)	Crude protein (%)	Crude fat (%)	Total ash (%)
CD	27.44	19.53	2.53	3.25
TEO	26.74	19.84	1.94	2.98
GEO	27.71	20.01	2.03	2.81
TGEO	27.65	19.21	2.34	3.10
SEM	0.20	0.85	0.43	0.17
N	6	6	6	6
P-value	0.33	0.19	0.54	0.90

Values bearing different superscripts within a column differ significantly (P<0.05)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean.

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

Cooking yield was significantly (P<0.05) higher in the chicken breast meat of the treatment groups supplemented with TEO and GEO, both individually and in combination (TGEO), when compared to the control group. Supplementation of TEO and GEO individually and their combination (TGEO) significantly (P<0.05) decreased the cholesterol content of broiler breast meat as compared to the control.

The PUFA and TUFA values significantly (P<0.05) increased with treatment with TEO and GEO, both individually and in combination (TGEO) when compared to the control.

Supplementation of TEO and GEO individually or in combination in the diet, significantly (P<0.05) reduced SFV as compared to the control, while the SFV of the meat of birds supplemented with TEO, GEO and TGEO were similar.

Table 4. The effect of dietary supplementation of thyme and garlic essential oils and their combination on texture profile analysis in broiler chicken meat

Treatments	Chewiness (N)	Cohesiveness (ratio)	Gumminess (N)	Hardness (N)	Resilience (ratio)	Springiness (mm)
CD	11.16	1.25	11.75	13.81[a]	0.17	0.87
TEO	10.20	0.53	9.61	11.68[b]	0.17	0.78
GEO	10.94	1.14	9.93	11.98[b]	0.16	1.11
TGEO	10.53	1.06	10.14	11.78[b]	0.18	0.80
SEM	0.40	0.14	0.43	0.27	0.01	0.08
N	6	6	6	6	6	6
P-value	0.85	0.27	0.32	0.01	0.97	0.43

Values bearing different superscripts within a column differ significantly (P<0.05).

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

Table 5. The effect of dietary supplementation of thyme and garlic essential oils and their combination on instrumental color analysis in broiler chicken meat

Treatments	Color (L*)	Color (a*)	Color (b*)
CD	55.32	3.21^{b}	12.86
TEO	50.35	4.02^{ab}	13.89
GEO	52.45	4.68^{a}	15.81
TGEO	53.16	3.84^{b}	13.40
SEM	0.67	0.23	0.50
N	6	6	6
P-value	0.07	0.02	0.18

Values bearing different superscripts within a column differ significantly (P<0.05)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

Table 6: The effect of dietary supplementation of thyme and garlic essential oils and their combination on sensory evaluation in broiler chicken meat

Treatments	Color	Appearance	Flavor	Texture	Juiciness	Tenderness	Overall acceptability
CD	7.00	6.86	6.43	6.29^{b}	6.57^{b}	6.57	6.57
TEO	7.14	7.14	7.14	7.43^{a}	7.43^{a}	7.28	7.28
GEO	6.86	6.71	6.86	7.29^{a}	7.36^{a}	6.86	6.86
TGEO	7.43	7.57	7.14	6.86^{ab}	6.64^{b}	7.71	7.28
SEM	0.17	0.15	0.16	0.15	0.13	0.17	0.17
N	6	6	6	6	6	6	6
P-value	0.71	0.21	0.34	0.02	0.02	0.07	0.24

Values bearing different superscripts within a column differ significantly (P<0.05)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

*Proximate analysis***.** No significant effect on the proximate composition of breast meat was observed with dietary treatments (Table 3).

Texture profile analysis. In the chicken breast meat, the hardness was significantly (P<0.05) higher in birds fed the control diet compared to the diets supplemented with TEO and GEO, individually or in combination (TGEO). However, the chewiness, cohesiveness, gumminess, resilience and springiness of broiler chicken meat were not significantly affected by the dietary addition of TEO and GEO (Table 4).

Instrumental color analysis. A significant (P<0.05) improvement in the redness (a*) of breast meat was observed in the meat of broilers supplemented with GEO when compared to other treatments (Table 5).

Sensory evaluation. The values of sensory evaluation are presented in Table 6. Texture values were significantly (P<0.05) higher in groups

Table 7: The effect of dietary supplementation of thyme and garlic essential oils and their combination on pH and TBARS during the storage period (0, 3 and 6 days) in broiler chicken meat

Treatments	pH			TBARS (mg MDA/kg)		
	0d	3d	6d	0d	3d	6d
CD	6.23[a]	6.15[a]	5.98[a]	0.43[a]	0.73[a]	0.95[a]
TEO	6.09[b]	6.06[b]	5.86[b]	0.36[b]	0.59[b]	0.80[b]
GEO	6.14[b]	6.07[b]	5.81[b]	0.35[b]	0.58[b]	0.79[b]
TGEO	6.13[b]	6.07[b]	5.85[b]	0.34[b]	0.55[b]	0.78[b]
SEM	0.02	0.01	0.02	0.01	0.02	0.02
N	6	6	6	6	6	6
P-value	0.02	0.05	0.01	0.01	0.01	0.01

Values bearing different superscripts within a column differ significantly (P<0.05)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

supplemented with TEO and GEO individually when compared to the control, while the meat of birds fed with TEO, GEO and TGEO had a similar texture. However, the values of color, appearance, flavor, tenderness and overall acceptability were not affected by the addition of dietary essential oils. The mean scores of juiciness were significantly (P<0.05) higher in broilers fed with essential oils individually than in combination and the control group.

Storage studies. The pH values of the meat of the birds in all the treatment groups decreased and the mean TBARS values for all the groups of birds increased gradually over the storage period. The pH values and the mean TBARS values were significantly (P<0.05) different in birds fed with TEO and GEO individually and in combination compared to the control, while the pH and mean TBARS values of the TEO, GEO and TGEO groups were similar (Table 7).

*Microbiological studies***.** The mean values of TPC on days 0, 3 and 6 ranged from 3.89 to 4.27, 4.26 to 4.60 and 4.48 to 5.22 log10 CFU/g, respectively (Table 8). The TPC values of broiler breast meat were not affected by dietary treatments during the whole storage period, but numerically lower values were observed in TEO, GEO and TGEO compared to the meat of birds fed the control diet.

The mean coliform count values for all groups of birds increased gradually over the storage period. On day 3, broiler breast meat resulting from the diet supplemented with TEO and TGEO had significantly (P<0.05) lower coliform counts compared to the control. On day 6, significantly (P<0.05) lower coliform counts were observed in the group fed with TEO when compared to other treatments and control.

On day 3, significantly lower PBC values were observed in the TEO group when compared to the other treatments. On day 6, broiler breast meat from diets supplemented with TEO and GEO individually had significantly lower PBC values than the control.

The mean YMC values for all groups of birds increased gradually over the storage period. On day 3, the diet supplemented with TEO and GEO individually resulted in significantly lower YMC values in breast meat when compared to the control.

Discussion

Physicochemical properties. In the present study, the decrease in drip loss of breast meat of broilers fed with a diet containing essential oils is supported

Table 8: The effect of dietary supplementation of thyme and garlic essential oils and their combination on microbiological elements during the storage period (0, 3 and 6 days) in broiler chicken meat

Treatments	Total Plate Count (log_{10}cfu/g)			Coliform Count (log_{10}cfu/g)			Psychrophilic Bacterial Count (log_{10}cfu/g)			Yeast and Mold Count (log_{10}cfu/g)		
	0d	3d	6d	0d	3d	6d	0d	3d	6d	0d	3d	6d
CD	4.27	4.60	5.22	4.87	5.85^{a}	6.67^{a}	4.38	4.79^{a}	5.39^{a}	3.85	4.56^{a}	5.01
TEO	3.89	4.28	4.48	3.88	5.21^{c}	6.38^{b}	3.97	4.20^{b}	4.71^{c}	3.45	4.18^{b}	4.55
GEO	4.12	4.42	4.72	4.45	5.65^{ab}	6.58^{a}	4.27	4.61^{a}	4.95^{bc}	3.56	4.23^{b}	4.77
TGEO	3.98	4.26	4.93	4.33	5.39^{bc}	6.60^{a}	4.29	4.68^{a}	5.16^{ab}	3.80	4.45^{ab}	4.96
SEM	0.11	0.11	0.13	0.14	0.07	0.03	0.07	0.06	0.08	0.07	0.06	0.09
N	6	6	6	6	6	6	6	6	6	6	6	6
P-value	0.66	0.69	0.21	0.08	0.01	0.01	0.15	0.01	0.01	0.12	0.03	0.23

Values bearing different superscripts within column are significantly ($P<0.05$)

P-value = Probability value; N = Number of replicates (five birds in each replicate); SEM = Standard Error Mean

CD = Control Diet; TEO = Thyme Essential Oil; GEO = Garlic Essential Oil; TGEO = Thyme and Garlic Essential oil

by WANG et al. (2015), who also reported that drip loss was significantly reduced by supplementation of herbs in broiler diets. The decreased drip loss might be due to the antioxidant properties of thyme and garlic essential oils, which are responsible for maintaining the integrity of the cell membrane.

The higher cooking yield of breast meat of chicken in treatments supplemented with TEO and GEO individually or in combination in the present study is also supported by ARYA et al. (2019), who reported that dietary supplementation of TEO significantly increased the cooking yield.

The decrease in the cholesterol content of broiler breast meat with essential oil supplementation in the present study is in agreement with the combination of ginger and thymol (ZIDAN et al., 2016), and garlic supplementation (FAYED et al., 2011) in broiler diets. The hypocholesterolemic effect of thymol and garlic essential oils has been ascribed to the inhibition of 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase, the rate-controlling enzyme of the cholesterol synthetic pathway (ELSON, 1995).

In present study there was an increase in PUFA and TUFA and a decrease in SFA concentration in the meat of birds with dietary treatments containing essential oils. These results were similar to the findings of KIM et al. (2009) and CHOI et al. (2010) with garlic supplementation, and HASHEMIPOUR et al. (2013) with an equal mixture of thymol and carvacrol in the diet, who reported decreased SFA, and increased TUFA and PUFA levels in broiler breast muscle. Enhancement of USFA in meat lipids could result from the diminution of fatty acid oxidation in tissue, and the blockage of lipid peroxidation of tissue due to the antioxidant properties of garlic and thyme essential oils (HASHEMIPOUR et al., 2013).

Shear force strength determines the tenderness of meat, which is an important factor related to meat palatability and quality. Dietary supplementation of essential oils, individually or in combination, decreased the shear force value in the present study, which is in agreement with the findings of KIM et al. (2009) with supplementation of 2 and 4% of garlic bulb and husk, and REIS et al. (2018) with diets containing 0.5 and 1% thymol and carvacrol. This decrease in shear force values could be due to the tenderizing effects of essential oils when supplemented to broilers (KIM et al., 2009).

Proximate analysis. The non-significant effect of essential oils on the proximate composition (dry matter, crude protein, crude fat and total ash) of breast meat in the present study was in harmony

with the findings from use of garlic essential oil at 300 mg/kg (KIRKPINAR et al., 2014), and thyme at a dosage of 0.7% (FOTEA et al., 2018) in broiler diet, which did not affect chemical constituents such as moisture, protein, fat and total ash content in the meat samples. In contrast, dietary supplementation of 2 and 4% garlic bulb and husk powder significantly increased the protein and lowered the fat content in the muscles (KIM et al., 2009). These results might be due to differences in the supplementation levels of EO, the sources of the herbs, the intestinal microbial ecology of the host, and basal diet composition.

Texture profile analysis. Texture is the most important attribute in the consumer's final satisfaction with poultry meat. Texture is a sensory property that the consumer commonly uses to determine the meat's quality and acceptability (ISSANCHOU, 1996). Important textural characteristics of solid foods such as meat products are cohesiveness, chewiness, hardness, gumminess, resilience and springiness. The results of the texture profile analysis undertaken in the present study with supplementation of essential oils in broilers are in harmony with the findings of HERNANDEZ et al. (2010), who reported that hardness was reduced with supplementation of essential oils in feed, whereas chewiness, cohesiveness, gumminess, resilience and springiness remained unchanged. Generally, there was an improvement in meat hardness in response to inclusion of essential oils. Thus, meat quality could be improved by adding natural antioxidants, especially TEO and GEO, which have the highest antioxidant capacity related to their high phenolic content (VELASCO and WILLIAMS, 2011).

Instrumental color analysis. The color of raw poultry meat is essential for consumer selection, while the color of cooked meat is critical for final evaluation. In the present study, the meat of the commercial broilers fed with essential oils showed higher redness (a*) values. Although differences were noticed in lightness (L*) and yellowness (b*) values, they were not significant amongst the treatment groups. These results agree with the findings of CHOI et al. (2010) and REIS et al. (2018), who observed higher redness (a*) values in garlic and thyme supplemented treatments, indicating high levels of myoglobin in the muscle. Normally redness (a*) value decreases due to an increase in metmyoglobin formation, and also due to the oxidation process. However, the presence of antioxidant compounds in garlic and thyme could retard metmyoglobin formation and oxidation in the muscle, and thus the redness value increased (CHOI et al., 2010).

Sensory evaluation. The present findings agree closely with previous reports by KIRKPINAR et al. (2014), who observed that the juiciness of breast meat was significantly better in the garlic oil supplemented group than the control, whereas color, appearance and tenderness were not significantly different between the groups. Flavor and overall acceptability were also not significantly affected by the addition of essential oils in the broiler diet. Lower drip losses could be an advantage for improving the juiciness of breast meat, since higher juiciness is mainly derived from meat with lower drip loss.

Storage studies. Better meat quality and longer storage duration are possible with an optimum pH range of 5.5-6.5. The current study's pH findings fall between 5.81 and 6.23, which is in the optimum range, indicating better meat quality. The lower pH value of breast meat in groups supplemented with essential oils in the present study agrees with the findings of KIM et al. (2009) and CHOI et al. (2010), who used 4% garlic husk and 3% garlic powder supplementation in the diet, respectively. The reduction in pH may be attributed to the fact that essential oils could stimulate lactic acid production (VAREL and MILLER, 2004). The pH levels dropped with an increase in freezing storage time. This is in line with the results of LEYGONIE et al. (2012) who reported that, if the storage conditions were suitable for freezing, the pH of broiler chicken breast meat decreased with increasing storage time.

This is due to the loss of water and its associated soluble substances, and the progression of irreversible anaerobic glycolysis, which happens when oxygen is permanently removed from the muscle at death (LAWRIE and LEDWARD, 2014).

A major cause of chicken meat deterioration is oxidative rancidity. The oxidative deterioration of muscle lipids depends upon its degree of unsaturation and antioxidant content. Various methods have been

used to estimate the oxidative changes in meat, and of these the 2-thiobarbituric acid value (TBA) is often used for assessing the degree of lipid oxidation. This test measures the quantity of malonaldehyde (MDA), which is a breakdown product of oxidation, formed mainly from peroxidized PUFA (SINNHUBER and YU, 1977). TBARS values increased throughout the storage period in both the control and treatment groups under aerobic packaging conditions. Supplementation of essential oils resulted in significantly lower TBARS values throughout the storage period in the treatment groups than in the control. The present findings are similar to CHOI et al. (2010) and GALLI et al. (2020), who reported that dietary inclusion of garlic and thyme essential oils, respectively, significantly lowered TBARS values. The reduction of TBARS in the treatment groups might be attributed to the polyphenols present in essential oils, which can react with free radicals and hydroxyls, and transform them into more stable forms (JAYAWARDANA et al., 2015).

Microbiological Studies. The dietary treatments did not show any significant effect on TPC. Mean coliform count and PBC were significantly reduced with the supplementation of TEO. The diets supplemented with TEO and GEO individually significantly reduced YMC. The present results are in agreement with the findings of SHARMA et al. (2017), who reported that psychrophilic, yeast and mold, and coliform counts significantly decreased with the supplementation of a blend of essential oils. Similarly, coliforms and yeast counts were reduced with the supplementation of garlic in the broiler diet (FAYED et al., 2011). Thymol and carvacrol of TEO caused the expansion of the liposomal membrane of bacteria. Carvacrol destabilizes the cytoplasmic membrane and also acts as a proton exchanger, subsequently reducing the pH gradient across the cytoplasmic membrane, resulting in the collapse of the proton motive force, and depletion of the ATP pool, eventually leading to cell death (ULTEE et al., 2002). Both carvacrol and thymol decreased the intracellular ATP pool of *E. coli* by increasing extracellular ATP, indicating their destructive action on the cytoplasmic membrane (HELANDER et al.; 1998). The reduction in YMC might be due to thymol, which reacts with ergosterol and shows antifungal activity (EZZAT et al., 2016).

Conclusions

Based on the overall results, it was concluded that supplementation of TEO at the rate of 25 g/100kg, or GEO at the rate of 25 g/100kg in the broilers' diet improved meat quality. The combination of thyme and garlic essential oils at 50 g/100kg had no additional advantage regarding meat quality or storage stability.

Ethical approval

The research trials were approved by the Institutional Animal Ethics Committee of the College of Veterinary Science, PV Narsimha Rao Telangana Veterinary University, Telangana, India vide 11/25/C.V.Sc, Hyd.IAEC.

Declaration of competing interests

We certify that there is no conflict of interest in relation to any financial organization regarding the material discussed in the manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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TULASI, R., T. SRILATHA, G. SRINIVAS, N. N. KUMARI, A. V. KUMAR, R. SUPRIYA: Učinak esencijalnih ulja timijana i češnjaka kao dodataka prehrani na kvalitetu, stabilnost pri konzerviranju i senzorička svojstva mesa tovnih pilića. Vet. arhiv 95, 61-74, 2025.

SAŽETAK

Neka eterična ulja (EO), poznata po svojim prirodnim i ekološkim svojstvima, poboljšavaju kvalitetu i stabilnost svojstava konzerviranog mesa. Istraživanje je provedeno kako bi se ustanovio učinak prehrane tovnih pilića s dodatkom timijana i češnjaka na navedena svojstva. Četiri pokusne skupine uključile su kontrolnu skupinu, skupinu čija je prehrana bila obogaćena esencijalnim uljem timijana (TEO), skupinu čija je prehrana bila obogaćena esencijalnim uljem češnjaka (GEO) u dozi od 25 g/100 kg te skupinu u kojoj su pilići dobivali kombinaciju esencijalnog ulja timijana i češnjaka (TGEO) u dozi od 50 g/100 kg. Pilići su hranjeni izonitrogenom i izokalorijskom hranom u skladu s preporukama tijekom šest tjedana. Suplementacija EO-om pojedinačno kao i njihova kombinacija u tovnih su pilića poboljšale fiziokemijska svojstva, profil masnih kiselina i stabilnost svojstava konzerviranog mesa, ali nije uočen nikakav učinak na sastav ili teksturu mesa, osim tvrdoće koja je dodatkom EO-a smanjena. Analiza boje mesa pokazala je da je crvenilo mesa (a*) bilo izraženije u skupini GEO u odnosu na druge skupine, no nije bilo učinka na svjetloću (L*) i žutilo mesa (b*). Senzorička svojstva koja uključuju teksturu i sočnost mesa poboljšana su pojedinačno dodatkom EO-a. Broj koliformnih i psihrofilnih bakterija (PBC) smanjen je u skupini TEO, dok je broj kvasaca i plijesni (YMC) bio manji u skupinama TEO i GEO. Nije, međutim, zapažen učinak na ukupni broj mikroorganizama (TPC) u pokusnim skupinama. Rezultati istraživanja pokazali su da dodatak esencijalnog ulja timijana (TEO) i esencijalnog ulja češnjaka (GEO) u prehrani tovnih pilića u dozi od 25 g/100 kg poboljšava svojstva mesa i stabilnost konzerviranog mesa.

Ključne riječi: češnjak; timijan; esencijalno ulje; kvaliteta mesa; stabilnost svojstava konzerviranog mesa; senzorička svojstva