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The Effect of Lavender (*Lavandula angustifolia*) Extract in Comparison to Antibiotic on Growth Performance, Intestinal Morphology, Ileal Microflora, Antioxidant Status and Meat Quality of Broilers

Research Article

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ABSTRACT

This study was conducted to evaluate the effects of lavender (*Lavandula angustifolia*) extract as an alternative to flavophospholipol on performance, carcass characteristics, antioxidant status, meat quality, intestinal morphology and ileal microflora of broilers. A total of 220 day-old male broiler chicks (Ross 308) were used in a completely randomized design with five treatments each replicated four times (11 birds per replicate) for 42 days. Experimental diets consisted of a basal diet without any additives as a control group and supplemented with flavophospholipol (100 ppm) or three levels of lavender extract (200, 300 or 400 ppm). Body weight, feed intake and feed conversion ratio were measured during the starter (1- 10 d), grower (11-24 d) and finisher (25-42 d) periods. Meat quality indices and jejunum histomorphology were analyzed at 42 days of age. In addition to the mentioned measurements, ileal contents were assayed for *Coliforms* and *Lactobacillus* strains. The results revealed that lavender extract at 400 ppm level significantly increased feed intake during the whole rearing period, especially in finisher period and also improved body weight gain and feed conversion ratio during the grower, finisher and entire rearing periods. There were no significant differences in the carcass traits and the relative weight of internal organs of the broilers (including breast, thighs, liver, heart, gizzard and abdominal fat). All lavender supplementation levels significantly decreased crypt depth and increased villus height: crypt depth ratio compared to the control group. The *Coliform* counts in the ileal digesta significantly decreased in birds fed with 400 ppm lavender extract. The thiobarbituric acid-reactive substance and cooking loss were significantly decreased by supplementing the basal diet with 300 or 400 ppm lavender extract. In overall, the results of this experiment showed that lavender extract, esp. at 400 ppm level, could be used as a good alternative to antibiotic growth promoters in the diet of broiler chickens.

KEY WORDS broilers, intestinal morphology, lavender, meat quality.

INTRODUCTION

For decades, feed additives such as antibiotic growth promoters (AGPs) have been applied in poultry diets to improve health and performance (Engberg *et al*. 2000; Dibner and Richards, 2005). The increasing pressure on the livestock industry to reduce or eliminate antibiotics as growth enhancers has initiated new research to find safe and efficient alternatives (Salajegheh *et al.* 2018). Among the possible alternatives to AGPs, phytogenic and herbal products are considered interesting because they have acquired more reliability and acceptability among consumers as safe and natural additives (Brenes and Roura, 2010; Hashemi and Davoodi, 2011). Moreover, these additives can be supple-

mented in feed to alleviate the adverse effects of high ambient temperature (Hussein, 1995) that is reported to negatively influence productive performance in birds along with physiological changes (Ryder *et al*. 2004; Deng *et al*. 2012).

Lavender (*Lavandula angustifolia*), which is well-known to people as a powerful aromatic and medicinal herb, is one of such alternatives that could be used as a feed additive. This plant belongs to the '*Lamiaceae*' family and is a widely distributed aromatic herb. The composition of lavender essential oil (LEO) has been extensively probed (Kim and Lee, 2002; Fakhari *et al*. 2005; Jalali-Heravi *et al*. 2015; Giovannini *et al*. 2016; Kucukyilmaz *et al*. 2017).

This herb has antiviral, antibacterial, antifungal, and antioxidation properties (Hammer *et al*. 1999; Kim and Lee, 2002; Hui *et al*. 2010). Due to these widespread properties, it is expected that lavender will also have a significant impact on meat quality indicators. It has been demonstrated that the main chemical composition of LEO depends on genotype, environment, processing and extraction methods (Jalali-Heravi *et al*. 2015). Fakhari *et al*. (2005) declared that lavender oil contained linalool (32.8%), linalyl acetate (17.6%), lavandulyl acetate (15.9%), α-terpineol (6.7%), geranyl acetate (5%), and also lavandulol (4.3%). In another survey, linalool acetate (46.25%) and linalool (35.17%) is considered to be the major compounds of LEO (Adaszyńska-Skwirzyńska and Szczerbińska, 2018a).

Moreover, it contains high levels of flavonoids, which possess a broad spectrum of chemical and biological activities, including radical scavenging properties (Rabiei *et al*. 2014). Studies on animal and human models similarly have shown that lavender has potential immune-stimulatory, anxiolytic, sedative, hypnotic, analgesic, and anticonvulsant effects, and may also improve one's mood (Prusinowska and ´Smigielski, 2014; Adaszyńska-Skwirzyńska and Szczerbińska, 2018b).

Very little information is accessible on the effects of lavender on broiler performance. Nasiri-Moghaddam *et al*. (2012) demonstrated that supplementation of LEO to the broiler diet enhanced body weight gain (BWG) and decreased feed conversion ratio (FCR) at the period of 22 to 42 d. Ranjbar *et al*. (2014) reported that lavender, borage extract, and vitamin C, somewhat can decrease heterophil percentage and heterophil:lymphocyte ratio. Furthermore, Kucukyilmaz *et al*. (2017) concluded that carcass yield and relative weights of carcass parts of broilers were unaffected by supplementation of LEO. These authors also declared that lavender have an antioxidative effect in poultry meat.

Mokhtari *et al*. (2018) stated that broilers fed 600 mg/kg lavender essence had lower counts of caecal *Lactobacillus*, *E. coli*, and *Coliforms* than other groups.

Thus, the aim of the current study was to investigate the effects of adding different levels of lavender hydro-alcoholic extract as an alternative to AGPs on growth performance, the weight of visceral organs, antioxidant status, meat quality, intestinal histomorphology, and microflora population in broiler chickens.

MATERIALS AND METHODS

This study was performed at the Poultry Research Station of Shahid Bahonar University of Kerman (Kerman, Iran), and all the procedures used were approved by Shahid Bahonar University Animal Care Committee.

Sampling and plant preparation

Fresh lavender flowers were obtained from Isfahan Agricultural Research Center, Iran. The plants were identified by the Herbarium of Bahonar University of Kerman (Kerman, Iran). Flowers were dried under shade at room temperature for 72 h and then powdered. Alcoholic extract was obtained by maceration. The lavender powder was soaked in a mixture of ethanol/water (4:1) at the room temperature, in a tightly closed container for three days. The container was shaken two times a day.

The mixture was then filtered to separate the solute using rotary evaporator. The extract was dried in an oven at 40 ˚C and stored in air tight container in the refrigerator. The active components of lavender flower were measured previously by Kamali *et al*. (2014). Hereupon, lavender contained nearly 7.2% cineole, 37% linalool, 24% linalyl acetate, and 8.3% camphor. According to the ISO 3515 (2002) LEO should contain (%): linalool acetate (25–47), linalool (20–45), 4-terpineol (0.1–8.0); eucalyptol (<2.5); camphor (<1.2); α-terpineole (<2.0); lavandulol acetate (>0.2); lavandulol (>0.1).

Animals and dietary treatments

A total of 220 day-old male broiler chicks (Ross 308) were purchased from a local hatchery. On arrival, chicks were weighed and randomly housed in wood shavings- covered floor pens (11 chicks per pen, each 1×1.2 m). The experiment was conducted in a completely randomized design with 5 treatments, 4 replicates and 11 birds in each replicate. Experimental treatments consisted of the basal diet without any additives as control (C) and the basal diet supplemented with antibiotic flavophospholipol (100 ppm, AB) or three levels of lavender extract i.e., 200 (200LE), 300 (300LE) or 400 (400L) ppm. The ingredients and composition of the basal diets (starter from 1 to 10, grower from 11 to 24 and finisher from 25 to 42 days of age) are shown in Table 1.

Table 1 Ingredient and nutrient composition of the basal diets

Ingredients (%)	Starter (1-10 d)	Grower (11-24 d)	Finisher (25-42 d)
Corn	53.42	60.40	66.51
Soybean meal	37.80	33.00	27.50
Soybean oil	4.00	2.70	2.20
Calcium carbonate	1.30	1.05	1.02
Dicalcium phosphate	1.89	1.56	1.50
DL-methionine	0.39	0.27	0.24
L-lysine HCl	0.33	0.18	0.18
Vitamin premix[1]	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25
Salt	0.37	0.34	0.35
Chemical composition			
Metabolizable energy (MJ/kg)	12.49	12.55	12.70
Crude protein (%)	21.70	20.00	18.01
Lysine (%)	1.40	1.18	1.03
Methionine (%)	0.71	0.58	0.52
Methionine + cysteine (%)	1.06	0.90	0.82
Calcium (%)	1.04	0.85	0.80
Available phosphorus (%)	0.50	0.43	0.40
Sodium (%)	0.16	0.15	0.15

[1] Vitamin premix provided the following per kilogram of diet: vitamin A: 9000 IU; vitamin E: 36 IU; Cholecalciferol: 2000 IU; vitamin K_3: 2 mg; vitamin B_{12}: 0.015 mg; Thiamine: 1.8 mg; Riboflavin: 6.6 mg; Pantothenic acid: 10 mg; Niacin: 30 mg; Choline chloride: 250 mg; Biotin: 0.1 mg; Folic acid: 1 mg; Pyridoxine 3.0 mg and Butylated hydroxytoluene: 1 mg.
[2] Trace mineral premix provided the following in milligrams per kilogram of diet: Iron: 50 mg; Zinc: 85 mg; Manganese: 100 mg; Iodine: 1 mg; Copper: 10 mg and Selenium: 0.2 mg.

Diets were fed in mash form and formulated to meet the nutrient requirements of Ross-308 broiler chickens (Aviagen, 2007). The diets were prepared freshly every day except for the additive-free control diet. The ambient temperature was gradually decreased from 32 ˚C on day 1 to 25 ˚C on day 21 and was then kept constant. The lighting program was provided as 23h L:1 h D.

Sample and data collection

Growth performance

The BWG and feed intake (FI) of birds in each pen were recorded during the starter, grower and finisher periods. The average BWG and FI were adjusted for mortality and were used to calculate FCR. On d 42, two birds, representing the average live weight, per replicate were weighed and slaughtered. The weight of breast, thighs, liver, spleen, proventriculus, heart, gizzard, and abdominal fat was measured and expressed as percentages of BW.

Intestinal morphology

Two chicks per pen were randomly selected and sacrificed at 42 d of age. In order to examine the structure of the small intestine villi, segments of the jejunum (2 cm tissue sample from the middle of the jejunum) were cut off, washed with physiological saline solution, and fixed in 10% buffered formalin (100 mL of 40% formaldehyde, 4 g phosphate, 6.5 g dibasic sodium phosphate and 900 ml of distilled water) for 24 h, and then the 10% buffered formalin was renewed.

Tissues were dehydrated by transferring through a series of alcohols with increasing concentrations, placed into xylol and embedded in paraffin. A microtome was used to make five cuts that were 5 µm. The cuts were stained with hematoxylin-eosin. Measurements of villus height, width and crypt depth were performed with an Olympus light microscope using the digital lens (Dino-eye, AM-7023, 5Mp, Taiwan). A minimum of eight measurements per slide was made for each parameter and averaged into one value (Thompson and Applegate, 2006).

Microbial enumeration

Ten-fold serial dilution method using sterilized water was adopted to determine the number of colony-forming units (CFU) in digesta (1 g) harvested from the ileum of eight chicks per treatment at 42 d of age. The lactobacillus count was determined using MRS agar after incubation in an aerobic chamber at 37 ˚C for 72 h. The coliforms were enumerated on Mac Conkey agar, after aerobic incubation at 37 ˚C for 24 h.

Antioxidant status and meat quality

At the end of the experiment (d 42), two birds from each pen were slaughtered, thigh muscles were taken/obtained to assess meat quality parameters. Thigh muscle lipid peroxidation was estimated as thiobarbituric acid-reactive substance (TBARS) concentrations in samples by the method of Tarladgis *et al*. (1960).

Values were reported as the concentration of malondialdehyde (MDA). Meat pH was determined by blending a 10 g sample in 100 mL distilled water for one minute, and pH was measured using a pH meter (Ensoy *et al*. 2004). Furthermore, water-holding capacity was measured in approximately 2 g of each deboned thigh according to Hamm (1960).

The evaluation is based on measuring water loss when a pressure is applied to the muscle. Meat cubes were placed between two filter papers and two glass plates, and a 10-kg-weight was placed on the top glass plate for 5 minutes. The difference in thigh muscle weight before and after the procedure represents the water loss.

The results were expressed as a percentage of exudate water in relation to the initial sample weight. Cooking loss (%) was determined as thigh muscle samples were weighed and put in trays which were placed inside the oven until sample core temperature reached 75 ˚C. Samples were cooled at room temperature; re-weighed and cooking loss was calculated as the difference between the initial and the final sample weights according to Pelicano *et al*. (2003). Dripping loss (%) was also measured according to Christensen (2003).

Statistical analysis

Data were subjected to analysis of variance procedures for a completely randomized design using the general linear model procedures of SAS (2005). Pen served as the experimental unit for performance parameters and bird as the experimental unit for meat quality, intestine histomorphology, and microbiology parameters. Differences between means were separated by Tukey's multiple range tests and statistical significance was determined at a probability of $P < 0.05$.

RESULTS AND DISCUSSION

Growth performance

The broilers were healthy and normal throughout the experiment with a mortality of < 2% that was unrelated to the dietary treatments. The effects of the experimental treatments on FI, BWG and FCR are shown in Table 2. The results showed that the use of LE had no effect ($P>0.05$) on the performance of broilers during the starter period. However, LE at 400 ppm level significantly improved ($P<0.01$) FI during the finisher and whole rearing periods. During the grower, finisher and entire rearing periods, birds fed with 400 ppm LE showed significantly higher BWG and lower FCR compared to the birds fed the control diet.

Unfortunately, very little information is available in the literature on the effects of lavender on broiler performance. Salajegheh *et al*. (2018) concluded that lavender powder (at 1% level) significantly increased FI during the finisher and entire rearing periods.

These authors also stated that BWG and FCR improved during the grower, finisher and entire rearing periods. Nasiri-Moghaddam *et al*. (2012) reported that supplementation of LEO (350 ppm) to the broiler diet increased BWG and decreased FCR at the period of 22 to 42 d. Moreover, it has been reported that dietary supplementation of the herbs belonging to the *Labiatae* family such as oregano (Giannenas *et al*. 2005; Bampidis *et al*. 2005) and rosemary extract (Spernakova *et al*. 2007) can stimulate growth performance of broilers. Furthermore, improvement in FCR was observed when phytogenic substances were fed as supplements (Brenes and Roura, 2010), which thoroughly agrees with the findings of the current study. These authors concluded that in most studies about feeding essential oils (EOs), the improvement in FCR comes from a reduction in FI without a change in BWG. In another study, Adaszyńska-Skwirzyńska and Szczerbińska, (2018a) demonstrated the antimicrobial activity of LEO and its positive effect on the production traits of broilers. These authors remarked that the application of higher concentration of EO (0.4 mL/L) significantly affected production results (BW, FCR). In our experiment, an increase in feed intake with the lavender diet was accompanied by an increase in growth that leading to improvements in the efficiency of feed utilization (Table 2).

Linalool, linalyl acetate, and some other mono and sesquiterpenes, flavonoids like luteolin, triterpenoids like ursolic acid and coumarins like umbelliferone and coumarin were the main components of the aerial parts and flowers of lavender (Renaud *et al*. 2001; Adaszyńska-Skwirzyńska and Szczerbińska, 2018a). It seems likely that the active principles of herb EOs act as a digestibility enhancer, balancing the gut microbial ecosystem and stimulating the secretion of endogenous digestive enzymes and thus improving growth performance in poultry (Cross *et al*. 2007; Brenes and Roura, 2010). For example, it is already accepted linalool has appetizing properties and stimulates the digestion process in animals (Cabuk *et al*. 2003). However, other studies have not demonstrated significant beneficial effects of herb-byproducts from the *Labiatae* family on overall broiler performance (Botsoglou *et al*. 2002; Hernandez *et al*. 2004; Reisinger *et al*. 2011; Akbarian *et al*. 2013). Some active metabolites of medicinal plants may have intensive smell or taste (Windisch *et al*. 2008), so can lead to a decrease in feed intake and thus, limit their application in animal nutrition. However, in the present study feeding up to 400 ppm LE had no adverse effect on FI in broilers.

Table 2 Effect of flavophospholipol and different levels of lavender extract (LE) on growth performance of broiler chicks

Period	C	AB	Dietary LE levels (ppm)			SEM	P-value
			200	300	400		
FI (g/bird/d)							
Starter 1-10 d	16.15	16.42	16.42	16.57	16.52	0.224	0.7256
Grower 11-24 d	77.54	79.30	77.52	75.82	79.38	1.402	0.3869
Finisher 25-42 d	145.05^{c}	157.98^{ab}	149.03^{bc}	154.07^{abc}	159.13^{a}	8.084	0.0001
Entire period 1-42 d	91.86^{c}	98.05^{ab}	93.62^{bc}	95.25^{abc}	98.60^{a}	3.591	0.002
BWG (g/bird/d)							
Starter 1-10 d	12.94	14.20	13.24	13.79	13.87	0.772	0.766
Grower 11-24 d	51.66^{b}	56.48^{ab}	51.97^{b}	53.15^{b}	59.02^{a}	1.236	0.002
Finisher 25-42 d	70.17^{c}	86.59^{a}	75.19^{bc}	81.49^{ab}	88.10^{a}	5.052	0.0006
Entire period 1-42 d	50.55^{c}	59.32^{ab}	52.70^{bc}	55.93^{abc}	60.73^{a}	1.531	0.0001
FCR							
Starter 1-10 d	1.27	1.16	1.25	1.21	1.19	0.074	0.836
Grower 11-24 d	1.50^{a}	1.40^{bc}	1.49^{ab}	1.42^{abc}	1.34^{c}	0.028	0.008
Finisher 25-42 d	2.07^{a}	1.83^{b}	1.98^{ab}	1.89^{ab}	1.80^{b}	0.059	0.037
Entire period 1-42 d	1.81^{a}	1.65^{c}	1.77^{ab}	1.70^{bc}	1.62^{c}	0.035	0.007

C: basal diet without any additives as control; AB: basal diet supplemented with antibiotic flavophospholipol (100 ppm); FI: feed intake; BWG: body weight gain and FCR: feed conversion ratio.

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

SEM: standard error of the means.

The variability in the efficacy of phytogenic feed additives on poultry performance could be attributed either to the bird and management conditions (e.g., composition of the basal diet, sanitary and environmental conditions) or to the herb (e.g., genotype, environment, processing and extraction methods, harvesting time, and method and duration of storage).

Carcass traits

The results of the experiment showed that the relative weights of breast, thighs, proventriculus, gizzard, liver, pancreas, spleen, heart, and bursa of broilers at 42 days of age were not affected (P>0.05) by dietary treatments (Table 3).

Our results are in agreement with Nasiri-Moghaddam *et al*. (2012) and Salajegheh *et al.* (2018), who did not report any significant differences in the relative weight of proventriculus, gizzard, liver, pancreas, large and small intestine in chicks fed lavender. Other studies carried out with herbs from the *Labiatae* family (oregano EO) have not demonstrated any significant effect on carcass traits (Hernandez *et al*. 2004; Kirkpinar *et al*. 2010).

In contrast to our finding, Kucukyilmaz *et al*. (2017) reported that although the relative weights of the gizzard and pancreas were not affected by the dietary LEO supplementation, the relative weights of the liver and spleen were altered by LEO treatments.

Bampidis *et al*. (2005) also showed that dried oregano leaves decreased the relative weight of gizzard and intestine, but no effect was observed on the relative weight of carcass, liver, and heart in turkeys.

These partial discrepancies in findings might be explained by the effect of factors such as bird and management conditions (e.g., composition of the basal diet, sanitary and environmental conditions) or herb (e.g., genotype, environment, processing and extraction methods, harvesting time, method and duration of storage, diversity of product active compounds, supplemental administration dose and procedures (specific dosages in feed and/or in water), which may influenced and thus make it complicated to compare and expound the efficacy of various products.

Intestinal morphology

Effect of different dietary treatments on jejunal morphology characteristics (villus height, villus width, crypt depth, and villus height:crypt depth ratio) at 42 d of age are given in Table 4. Different levels of lavender significantly decreased crypt depth and increased villus height: crypt depth ratio compared to the control group (P<0.01). Also, broilers fed with 300 or 400 ppm LE, showed numerically higher villus height.

Available reports have shown no consistent changes in villi length and crypt depth in the jejunum and colon for broilers treated with phytogenic feed additives (Jamroz *et al*. 2006; Hong *et al*. 2012). Garcia *et al*. (2007) indicated that the addition of 200 mg/kg plant extract comprising a blend of oregano, cinnamon, and pepper EO increased villus height.

Hashemipour *et al*. (2013) reported that broilers fed 100 or 200 ppm carvacrol and thymol (major compounds of oregano) in the diet had higher villus height while no significant effect observed on villus width.

Table 3 Effect of flavophospholipol and different levels of lavender extract (LE) on carcass traits and the relative weight of internal organs of the broiler chickens (% of the live body weight)

Treatments	Gizzard	Spleen	Proventriculus	Heart	Bursa	Abdominal fat	Liver	Pancreas	Thighs	Breast
C	1.37	0.10	0.33	0.45	0.22	1.35	1.97	0.19	17.4	24.6
100 ppm AB	1.56	0.09	0.32	0.45	0.18	1.36	1.82	0.20	17.6	22.0
200 ppm LE	1.58	0.09	0.33	0.44	0.20	1.35	2.02	0.19	17.4	23.5
300 ppm LE	1.29	0.10	0.33	0.44	0.16	1.34	2.08	0.21	17.8	25.5
400 ppm LE	1.45	0.10	0.32	0.45	0.14	1.35	1.96	0.20	17.7	23.9
SEM	0.094	0.004	0.006	0.004	0.019	0.029	0.172	0.033	0.138	1.713
P-value	0.214	0.195	0.552	0.520	0.1001	0.977	0.861	0.995	0.215	0.675

C: basal diet without any additives as control and AB: basal diet supplemented with antibiotic flavophospholipol (100 ppm).
SEM: standard error of the means.

Table 4 Effects of flavophospholipol and different levels of lavender extract (LE) on intestinal morphology (µm) and microflora population (log CFU/g)

Treatments	Villus length (VL)	Villus width	Crypt depth (CD)	VL/CD	*Coliform*	*Lactobacilli*
C	1340.75	182.25	151.18^{a}	8.87^{c}	6.67^{a}	6.25
100 ppm AB	1342.50	182.25	137.04^{b}	9.80^{ab}	5.97^{ab}	6.30
200 ppm LE	1341.50	183.75	142.94^{b}	9.38^{b}	6.35^{ab}	7.03
300 ppm LE	1349.00	182.75	143.13^{b}	9.42^{ab}	5.85^{ab}	6.92
400 ppm LE	1348.75	182.25	136.84^{b}	9.86^{a}	5.47^{b}	7.39
SEM	2.031	7.763	1.541	0.107	0.212	0.325
P-value	0.217	0.867	0.0001	0.0001	0.011	0.108

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
C: basal diet without any additives as control and AB: basal diet supplemented with antibiotic flavophospholipol (100 ppm).
SEM: standard error of the means.

In general, PFAs could increase villus height and villus height: crypt depth ratio across the small intestine that could increase the absorptive surface area and efficiency of digestion and absorption of nutrients (Reisinger *et al*. 2011; Hong *et al*. 2012; Khattak *et al*. 2014) which led to better BWG and FCR, as seen in the current study. This improvement in digestion and absorption could be attributed to the decreased number of coliforms (Table 4).

Ileal microflora

Effects of treatments on the ileal microbial population are presented in Table 4. Lavender extract (400 ppm), significantly decreased (P=0.011) the concentration of coliforms in the ileal digesta in compare to the control diet. In the case of *Lactobacillus*, no significant differences were detected (P>0.05).

In this regard, Adaszyńska-Skwirzyńska and Szczerbińska, (2018b) showed that addition of LEO to broilers drinking water had a positive impact on the gut microflora of the ileum: the numbers of pathogenic microorganisms decreased (*Escherichia coli* and *Coliform*) while the number of probiotic bacteria increased.

Mokhtari *et al.* (2018) concluded that broilers fed 600 mg/kg lavender essence had lower counts of caecal *Lactobacillus*, *E. coli*, and *Coliforms* than other groups. Eventually, these results support the anecdotal use of lavender as an antibacterial agent and demonstrated that some herbs display good antibacterial activity against a wide range of bacteria. Lavender has been shown to exhibit a broad spectrum of activity against gram-positive and gram-negative bacteria and fungi (Lodhia *et al*. 2009; Benabdelkader *et al*. 2011; Djenane *et al*. 2012; Adaszyńska-Skwirzyńska and Szczerbińska, 2018b).

The antimicrobial mode of action is considered to arise mainly from the potential of the hydrophobic EOs to intrude into the bacterial cell membrane, disintegrate membrane structures, and cause ion leakage. These additives were also reported to stimulate intestinal secretion of mucus in broilers, an effect that was assumed to impair adhesion of pathogens (Jamroz *et al*. 2006). These observations support the hypothesis that phytogenic feed additives may favorably affect gut functions, but the number of *in-vivo* studies with swine and poultry is still quite limited.

Antioxidant status and meat quality

In the current study, no significant differences (P>0.05) were observed between different dietary treatments with regard to the water holding capacity (WHC), dripping loss and pH of thigh meat (Table 5). The TBARS was significantly improved by supplementing the basal diet with 300 or 400 ppm LE (P=0.0015).

The cooking loss in birds fed with 300 or 400 ppm LE was significantly lower (P=0.0001) than the other treatments (Table 5). It is now well accepted that chicken meat is susceptible to oxidative deterioration owing to its phospholipid content, which contributes a robust response to the lipid antioxidant status of poultry meat (Kucukyilmaz *et al*. 2017).

In our study, significant contributions to meat quality from treatments supplemented with 300 or 400 ppm LE were achieved by decreases of TBARS and cooking loss in thigh meat.

Table 5 Effects of flavophospholipol and different levels of lavender extract (LE) on thigh meat quality in broiler chickens

Treatments	PH	TBARS	WHC (%)	Cooking loss (%)	Dripping loss (%)
C	6.16	1.02[a]	0.55	39.66[a]	12.29
100 ppm AB	6.16	1.00[ab]	0.57	38.07[b]	11.90
200 ppm LE	6.21	0.99[abc]	0.56	39.45[a]	11.62
300 ppm LE	6.04	0.97[bc]	0.61	37.15[c]	12.01
400 ppm LE	6.11	0.94[c]	0.56	36.53[c]	11.92
SEM	0.324	0.010	0.015	0.158	0.346
P-value	0.996	0.0015	0.102	0.0001	0.747

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
C: basal diet without any additives as control and AB: basal diet supplemented with antibiotic flavophospholipol (100 ppm); TBARS: thiobarbituric acid-reactive substance (mg malondialdehyde/kg) and WHC: water holding capacity.
SEM: standard error of the means.

This was fully in agreement with earlier studies, which exhibited that active components of feed additives from the *Labiatae* family containing phenolic compounds improved the oxidative stability of poultry meat (Botsoglou *et al*. 2002; Giannenas *et al*. 2005; Djenane *et al*. 2012; Lauren and Soheil, 2015; Kucukyilmaz *et al*. 2017). For instance, in one of these studies, Kucukyilmaz *et al*. (2017) reported that EOs from the *Lavandula stoechas* ssp. in Turkey contain more than 40% camphor which is characterized by antibacterial and antioxidant properties. Thus, a possible reason for improved meat quality, as obtained in the present study, by the addition of LE, may be related to the antioxidative properties of this plant due to the components such as camphor, linalool, and linalyl acetate. Moreover, this plant contains high levels of polyphenols such as flavonoids, which possess a broad spectrum of chemical and biological activities, including radical scavenging properties (Rabiei *et al*. 2014; Adaszyńska-Skwirzyńska and Szczerbińska, 2018b).

CONCLUSION

The present study exhibited that lavender hydro-alcoholic extract at 400 ppm level, can improve growth performance, enhance meat quality, and modulate intestinal microbial counts in broilers fed on a corn-soybean meal-based diet. These results have both productive and health implications for the broiler industry and warrant further investigation.

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