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REGULAR ARTICLES

Effect of adding lavender oil to laying quail diets on performance, egg quality, oxidative status, and fatty acid profile

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Abstract

This study aims to investigate the effects of lavender essential oil on performance, egg quality parameters in quails, malondialdehyde (MDA) in fresh and stored (28 days at $_{+}4$°C) eggs, and individual and total fatty acids. To this end, 100 female quails (*Coturnix coturnix Japonica*) which were 5 weeks old with an average weight of 224 g were used. The study lasted 45 days, including 10 days of introduction and 35 days of study. Quails were fed ad libitum with four different treatments. Four groups were formed as control groups (0g lavender essential oil/kg feed), Lav125 (125mg lavender essential oil/kg feed), Lav250 (250mg lavender essential oil/kg feed), and Lav500 (500mg lavender essential oil/kg feed). There were five subgroups under each group and five quails in each subgroup. Feed consumption and egg weight parameters increased in Lav500 group compared to the control group ($p<0.05$). The highest egg yield compared to the control group was determined in Lav500 group ($p>0.05$), and the highest egg mass compared to the control group was determined in Lav125 group. The highest feed conversion ratio compared to the control group was in Lav250 group ($p>0.05$). In addition, egg white height and Haugh Unit (HU) compared to the control group were the highest in Lav500 group ($p<0.05$). The MDA concentration decreased in Lav125 and Lav250 group in fresh and in Lav500 group in stored eggs (at +4C for 28 days) compared to the control group ($p<0.05$). Omega 3 fatty acids in fresh and stored eggs were higher in lavender groups compared to the control group ($p<0.05$). However, the concentration of omega 9 (oleic acid) fatty acid decreased in the lavender groups compared to the control group ($p<0.05$). As a result, it was found that adding lavender essential oil to the diet leads to an increase in body weight, egg yield, egg mass, egg weight, egg white height, HU, omega 3 fatty acids, and a decrease in MDA concentration.

Keywords Egg quality · Lavender · PUFA · Quail · Stored

Introduction

Both the intensive use of antibiotics in agriculture and the increased antimicrobial resistance of humans led to the banning of the use of antibiotics in animal and poultry products in the European Union (EU) and other countries in 2006 due to the residues (Windisch et al. 2008; Karásková et al. 2015; Franz et al. 2010). Lavender (*L. angustifolia Mill. subsp. Angustifolia*) is the most a bloom plant of the Lamiaceae family native to Mediterranean countries (Cavanagh and Wilkinson, 2002). Essential oils (EO) from the Lavender plant attracted wide attention due to their bioactive compounds that have antibacterial, antioxidant, and anti-inflammatory properties, and they were reported to provide a significant increase in yield properties of poultry (Franz et al. 2010; Casewell et al. 2003). Bioactive compounds (alkaloids, glycosides, tannins, essential oils, and phenolic compounds, among many others) were reported to have positive effects on feed consumption and the functioning of the digestive system (Mirzaei-Aghsaghali, 2012).

In general, essential oils are important in removing the secretion of digestive enzymes, increasing metabolism and affecting the intestinal microbiota, and increasing feed consumption, nutrient digestibility and usability (Zhai et al. 2018). Frankic et al. (2009) alleged that essential oils

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(including essential oil of sage, peppermint, and garlic) stimulated the release of fatty acids, bile, and digestive enzymes and had a positive effect on excretion processes. There were many studies on the performance of health and performance in poultry with the addition of essential oil to the diet (Wang et al., 2019; Adaszyńska-Skwirzyńska et al., 2021; Ramirez, Peñuela-Sierra and Ospina, 2021). There was also a study on egg production and shell quality in laying hens by adding lavender essential oil to the diet (Taki et al., 2015). Torki et al. (2021) reduced egg production as well as egg mass values by adding peppermint oil alone or by combining it with lavender essential oil significantly. It was also reported that egg weights were not affected in peppermint oil and lavender essential oil groups compared to the control group . It was reported that the addition of thyme essential oil in the diet was not affected by feed consumption in poultry. (Zhao et al., 2021; Feng et al., 2021). Besides, the addition of oregano essential oil to laying hen diets had no significant effect on feed conversion ratio, feed consumption, or egg weight (Florou- Paneri et al. 2005). Marume et al. (2020) reported that the addition of watermelon (*Citrullus lanatus*) essential oil to the diet had no effect on egg internal and external quality parameters. Nadia et al. (2008) put forward that dietary essential oil supplementation in wings increased egg production and feed efficiency. It increased egg yield and broken-cracked egg ratio in birds consuming rations fortified with essential oil containing thyme, bay leaf oil, sage leaf oil, myrtle leaf oil, fennel seed oil, and citrus peel oil (24 mg fat/kg whole feed). Ding et al. (2017) reported that the addition of Enviva (Dupont Nutrition Biosciences ApS, Denmark) essential oils to the laying hen diet had no positive effect on performance and the yolk fatty acid. Deniz et al. (2022) reported that adding rosemary essential oil to the laying quail diets showed a significant decrease in the MDA parameter in the egg yolk on the 7th and 28th days of stored at +4°C.

Given the previous studies, it was clear that a plethora of studies focused on essential oils. However, there are only few studies examining the effect on egg stored and fatty acid profile of lavender essential oil. This study therefore aims to contribute to the existing literature by probing the effects of lavender essential oil on egg quality parameters, fatty acid profile, stored of eggs, and oxidation in egg yolks.

Material and method

Animal and treatment groups

This study continued for 45 days, ten days of exercise and 35 days of trial, with 100 female quails (*Coturnix coturnix Japonica*) that were 5 weeks old, with an average weight of 224 grams. Quails were housed in wire cages (length × width × height, 90×45×25 cm). Quails were pounded into four groups based on four different treatments. Four groups were formed as control group (0g lavender essential oil/kg feed) and lavender treatment groups ((Lav125 (125mg lavender essential oil/kg feed), Lav250 (250mg lavender essential oil/kg feed), and Lav500 (500mg lavender essential oil/kg feed)). Groups were five subgroups under each group, and five female quails (*Coturnix coturnix japonica*) were employed for each subgroup. Lavender (*L. angustifolia Mill. subsp. Angustifolia*) essential oil used in the study was provided from Afyonkarahisar Medicinal and Itri Plants Center. In the lavender stock solution, each 1 ml of oil was diluted in 100 ml of ethanol (99.5% purity) and mixed with the feed by atomizing it with the help of a spray bottle. Chemical analysis of lavender essential oil was carried out by Anadolu University Herbal Medicine and Scientific Research Center (Table 1). The feed components and nutrient content of the basal diet, which was formulated according to the recommendations of NRC (1994), basal diet used in the study are presented in Table 2.

Performance parameters

Animals were fed daily throughout the study. Quails were weighed at the beginning (at fifth weeks) and end (at eleventh weeks) of the study. Total body weight gain and feed consumption were calculated.

Table 1 Main compounds in Lavender essential oil (%)

Compounds	Content (%)
1,8-cineole	1.20
(Z)-β-ocimene	0.50
3-octanone	1.10
Hexyl acetate	0.50
Octenyl acetate	1.10
Trans-Linalool oxide (Furanoid)	1.50
Cis-Linalool oxide (Furanoid)	0.90
Camphor	0.60
Linalool	31.60
Linalyl acetate	32.50
α-santanel	0.60
β-caryophyllene	5.30
Terpinen-4-ol	3.90
(Z)-β-farnesene	5.10
Lavandulol	1.80
α-Terpineol	0.50
Borneol	1.00
Caryophyllene oxide	1.60
Total	91.30

Table 2 Ingredients and nutrient composition of quail diet used in the study

Ingredients, %	
Corn	23.63
Wheat grain	11.32
Wheat bran	10.00
Vegetable oil	9.49
Cotton seed meal, CP 36%	22.78
Soybean meal CP 48%	11.95
Marble dust	10.00
Salt	0.57
Vitamin-minerals premix	0.25
Calculated values	
Dry matter, %	91.39
Crude protein, %	18.76
Crude ash, %	14.00
Crude fiber, %	5.48
Ether extract, %	11.05
Methionine+cystine, %	0.55
Lysine,%	0.86
Metabolic energy, kcal/kg	2900
Calcium, %	3.85
Available phosphorous, %	0.21

*Vitamin-Mineral premix: 3 mg of retinol (vitamin A), 62,5 µg of cholecalciferol (vitamin D3), 30 mg of tocopherol (vitamin E), menadione (vitamin K3): 5 mg, thiamine (vitamin B1): 1 mg, riboflavin (vitamin B2) : 5 mg, pyridoxine (vitamin B6): 3 mg, cobalamin (vitamin B12): 20 µg, nicotinic acid: 30 mg, pantothenic acid: 10 mg, folic acid: 0,8 mg, biotin: 100 µg, ascorbic acid (Vitamin C): 10 mg, choline chloride: 450 mg, Co: 0,2 mg, I: 0,5 mg, Se: 0,3 mg, Fe: 25 mg, Mn: 120 mg, Cu: 10 mg, Zn: 100 mg, and CP: Crude protein

Egg quality

Eggs from all groups were collected at the same time each day throughout the study. At the end of the study, eggs were taken from each group (n=10 total 40 eggs) in order to determine the physical quality parameters. The egg-specific gravity (g/cm3) of all eggs was calculated using the Archimedes (Thompson and Hamilton, 1982; Hempe et al., 1988) method every week. The eggs were weighed (g) on a precision scale after being kept at room temperature for 24 h. The egg albumen height of eggs was measured and used to calculate the Haugh unit (HU). HU was calculated using the following formula: Haugh unit = 100 × log (H + 7.57 − 1.7 × W 0.37), where H = albumen height (mm) and W = egg weight (g) (Eisen et al., 1962). The eggshell thickness (mm × 10−2) was measured using a micrometer (Mitutoyo, Dial Caliper Gage, Japan) by averaging the samples of three different locations on the eggshell from which the eggshell membranes were removed (Wells, 1968). Egg mass was calculated with the formula (egg yield × egg weight) / 100. The feed conversion ratio (FCR, henceforth) was calculated with the formula feed consumption/egg mass.

The determination of lipid oxidation in egg yolk

At the end of the study, fresh eggs (n=10 and a total of 40 eggs) and eggs stored at +4°C for 28 days (n=10 and a total of 40 eggs) were taken. Thiobarbituric acid-reactive substances (TBARS) were determined using the spectrophotometric method reported by Zhang and Hung (2013). The malondialdehyde (MDA)/1, 1, 3, 3-tetraethoxypropane (TEP) standard (0.024–239 µg/mL MDA/TEP) curve (f (x) = 0.00972x + 0.1674, $R2 = 0.9929$) was generated. Results were given in mg MDA/kg fresh and stored egg yolk. Analysis was conducted in three replicates.

The determination of fatty acid compositions in egg yolk

Egg yolk samples were taken from fresh eggs collected at the end of the study (n=10 and a total of 40 eggs). The fatty acids (free and bound) in egg yolk samples were methylated with the modified three-step procedure by Wang et al. (2015). The supernatants (methylated fatty acids in n-hexane) were put in a 1.5-ml screw neck ND-9 amber vial with 9 mm screw caps (silicone white/PTFE caps) and analyzed in a gas chromatograph (TRACE 1300, Thermo Scientific, USA) with automatic sampling (Thermo AI 1310, Thermo Scientific, USA). FAME mix (37 C) standard solution in dichloromethane (Chem-Lab, CL.40.13093.0001, Zedelgem, Belgium) was used to identify the peaks. Heptadecanoic acid (C17:0) was used as an internal standard. A fatty acid methyl esters column (Length 60 m, I.D: 0.25 mm, film: 0.25 µm and maximum temperature 250–260 °C) with an injection split temperature of 255 °C, a column of 140 °C, and a flow rate of 30 ml/min was used as the processing method for 42 minutes. Fatty acid identification was performed by comparing the peaks in the chromatogram with the standard retention times by the standard.

Statistical analysis

The one-way analysis of variance was conducted for body weight gain, egg qualities. Experimental data were first subjected to the Levene test to determine the homogeneity of variance (Levene, 1960). Two-way analysis of variance was used to check for the significance of the effect of egg variants and the interaction of egg*groups on lavender groups. The study followed a factorial pattern consisting of 4 groups, 2 stored formes. Tukey's multiple range test was used for multi-group comparisons (Scheffe, 1953). The significance

level is determined as $P < 0.05$. Statistical analyzes of the data were performed using SPSS 22.0 software (IBM Corp., Armonk, NY, USA).

Results

The body weight gain (g/35days) increased in Lav500 group compared to the control group ($p>0.05$) throughout the study. Egg yield increased in Lav250 and Lav500 groups compared to the control group ($p>0.05$). Egg mass also increased in the lavender groups compared to the control group ($p>0.05$). Feed consumption decreased in Lav125 and Lav250 groups, while it increased in Lav500 group compared to the control group ($p<0.05$). The feed conversion rate increased in Lav125 and Lav500 groups, while it decreased in the Lav250 group compared to the control group ($p>0.05$) (Table 3). Egg weight parameter increased in the Lav125, Lav250 and Lav500 groups compared to the control group ($p<0.05$). On the other hand, the eggshell thickness decreased in Lav125 and Lav500 compared to the control group ($p>0.05$). The specific weight of the eggs decreased in Lav250 and Lav500 groups compared to the control and Lav125 groups ($p>0.05$). Egg white height and Haugh unit, among the egg internal quality parameters, increased in the lavender groups compared to the control group ($p<0.05$).

There was egg interaction in terms of MDA concentration in fresh and stored (+4°C for 28 days) eggs ($p<0.05$); The MDA concentration was highest in the stored egg Lav250. There was no egg*groups interaction in terms of MDA concentration ($p>0.05$) (Table 4).

In terms of individual fatty acids was found egg effect on the concentration of myristic, palmitic, palmitoleic, heptadecanoic, stearic, elaidic, oleic, arachidic, lignoceric, nervonic, docosahexaenic acids ($p<0.05$) (Table 4). In terms of group effect on individual fatty acids; myristic, palmitic, palmitoleic, alpha linolenic acid concentrations were higher in the stored egg Lav500 group compared to the control group ($p<0.05$). The highest group in terms of oleic acid concentration is the control group in fresh eggs; Lav125, Lav250 and Lav500 groups were also the lowest ($p<0.05$). There was an effect on the egg* group interaction on the concentration of the individual fatty acids (myristic, heptadecanoic, stearic, elaidic, eicosatrienoic, and nervonic acid) ($p<0.05$) (Table 5). In terms of total fatty acids, MUFA concentration was highest in the control group in fresh eggs; PUFA concentration was highest in Lav500 group in stored egg. In

Table 4 Malondialdehyde (mcg/g) concentration in fresh and stored (+4°C 28days) eggs

Egg	Groups	MDA
Fresh	Control	5.67±1.56
	Lav125	4.11±1.80
	Lav250	4.24±1.56
	Lav500	5.73±1.80
Stored	Control	15.19±1.56
	Lav125	16.71±2.21
	Lav250	20.52±2.21
	Lav500	14.33±2.21
Egg	Fresh	4.94±0.84[b]
	Stored	16.67±1.03[a]
p	Egg	<0.001
	Groups	0.62
	Egg * groups	0.21

Groups: C – basal diet, Lav125 – basal diet with 125 mg/kg lavender essential oil, Lav250– basal diet with 250 mg/kg lavender essential oil; Lav500- basal diet with 500 mg/kg lavender essential oil; shown as mean and standard error

Table 3 Effect of lavender essential oil on body weight and egg physical parameters

	Groups[1]				*p*
	Control	Lav125	Lav250	Lav500	
Body weight gain, g	24.88±1.84	23.70±1.16	23.90±1.44	28.20±1.43	0.13
Egg yield, %	78.91±1.90	78.69±2.46	83.84±3.07	84.09±0.76	0.43
Egg mass	13.87±0.91	14.68±0.47	14.45±0.85	14.41±0.79	0.85
Feed intake, g/day	30.12±1.27[b]	29.43±1.49[b]	29.94±2.09[b]	43.40±1.92[a]	<0.001
Egg weight, g	11.19±0.04[b]	11.50±0.01[a]	11.43±0.03[a]	11.46±0.02[a]	<0.001
Feed concervation rate	2.03±0.14	2.24±0.25	1.94±0.26	2.72±0.41	0.25
Egg white height, mm	4.28±0.38[b]	5.17±0.46[b]	5.36±0.46[b]	9.35±0.25[a]	<0.001
Egg shell thickness, mm	20.56±0.67	19.63±0.45	20.10±0.62	18.98±0.47	0.24
Specific gravity, g/g	1.06±0.001	1.06±0.001	1.05±0.001	1.05±0.001	0.70
Haugh unit	86.39±1.89[b]	87.36±1.37[b]	88.33±1.63[b]	99.28±1.03[a]	<0.001

[1]Groups: C – basal diet, Lav125 – basal diet with 125 mg/kg lavender essential oil, Lav250– basal diet with 250 mg/kg lavender essential oil; Lav500- basal diet with 500 mg/kg lavender essential oil. [a-b] –means with different superscripts in the same line are significantly different at $P < 0.05$

Table 5 The percentage (%) of individual fatty acid concentration in fresh and stored (+4°C 28days) eggs

Egg	Groups	C14:0	C15:0	C16:0	C16:1	C17:0	C18:0	C18:1n9t	C18:1n9c	C18:2n6c	C20:0	C18:3n3	C20:3n6	C24:0	C24:1	C22:6n3
Fresh	Control	0.05^{d}	0.05	25.50^{b}	0.67^{ab}	3.47^{ab}	9.60^{bd}	2.03^{a}	46.29^{a}	9.24^{b}	0.15^{ab}	0.18^{b}	0.16^{a}	0.14	0.31^{bc}	0.83^{ab}
	Lav125	0.42^{bc}	0.08	25.62^{b}	0.83^{ab}	4.25^{ab}	7.72^{d}	1.89^{ab}	44.14^{ab}	10.77^{ab}	0.14^{ab}	0.26^{ab}	0.13^{ab}	0.17	0.49^{b}	1.20^{ab}
	Lav250	0.45^{bc}	0.04	25.57^{b}	0.76^{ab}	4.16^{ab}	7.42^{d}	1.96^{a}	44.47^{ab}	12.41^{a}	0.17^{a}	0.22^{ab}	0.11^{b}	0.18	0.50^{b}	0.79^{b}
	Lav500	0.42^{b}	0.20	25.95^{ab}	0.69^{ab}	3.92^{ab}	8.26^{cd}	1.92^{a}	43.91^{ab}	12.17^{a}	0.12^{ab}	0.26^{ab}	0.11^{b}	0.16	0.46^{bc}	0.80^{b}
Stored	Control	0.32^{c}	0.02	26.33^{ab}	0.76^{ab}	3.85^{ab}	10.11^{bc}	1.76^{b}	44.78^{ab}	10.28^{ab}	0.12^{ab}	0.21^{ab}	0.12^{ab}	0.12	0.24^{c}	0.67^{b}
	Lav125	0.39^{bc}	0.03	26.58^{ab}	1.11^{a}	3.96^{ab}	16.58^{a}	2.33^{a}	43.10^{ab}	9.70^{b}	0.15^{ab}	0.20^{ab}	0.09^{b}	0.14	3.14^{a}	1.32^{ab}
	Lav250	0.35^{c}	0.04	26.78^{ab}	1.12^{a}	2.91^{b}	11.39^{b}	1.46^{b}	41.57^{b}	11.85^{a}	0.13^{ab}	0.27^{ab}	0.12^{ab}	0.14	0.48^{b}	1.33^{a}
	Lav500	0.55^{a}	0.04	27.68^{a}	1.00^{a}	4.61^{a}	9.11^{bd}	1.62^{b}	42.47^{b}	11.23^{ab}	0.11^{b}	0.29^{a}	0.12^{ab}	0.12	0.41^{bc}	0.92^{b}
Eggs	Fresh	0.34	0.09	25.66	0.74	3.95	8.25	1.95	44.70	11.15	0.15	0.23	0.13	0.16	0.44	0.91
	Stored	0.41	0.03	26.84	1.00	3.83	11.80	1.79	42.98	10.77	0.13	0.24	0.11	0.13	1.07	1.06
	SEM	0.02	0.02	0.18	0.04	0.12	0.40	0.05	0.33	0.23	0.00	0.01	0.00	0.01	0.15	0.10
p	Egg	<0.001	0.10	<0.001	<0.001	0.59	<0.001	0.03	<0.001	0.25	0.02	0.45	0.06	0.01	<0.001	0.47
	Groups	<0.001	0.31	0.16	0.03	0.06	<0.001	<0.001	0.01	<0.001	0.01	0.03	0.02	0.15	<0.001	0.36
	Egg * groups	<0.001	0.34	0.71	0.47	0.01	<0.001	<0.001	0.65	0.10	0.15	0.24	0.02	0.85	<0.001	0.71

Myristic Acid (C14:0), Pentadecanoic Acid (C15:0), Palmitic Acid Methyl Ester (C16:0), Palmitoleic Acid (C16:1), Heptadecanoic Acid (C17:0), Stearic Acid (C18:0), Elaidic Acid (C18:1n9t), Oleic Acid (C18:1n9c), Linoleic Acid (C18:2n6c), Arachidic Acid (C20:0), α-Linolenic Acid (C18:3n3) (ALA), Eicosatrienoic acid (C20:3n6), Lignoceric Acid (c24:0), Nervonic Acid (C24:1), Docosahexaenoic Acid (C22:6n3) (DHA)

Groups: C – basal diet, Lav125 – basal diet with 125 mg/kg lavender essential oil, Lav250– basal diet with 250 mg/kg lavender essential oil; Lav500- basal diet with 500 mg/kg lavender essential oil. $\bar{x}\pm$SE: Mean± Standart error; * $^{a\text{-}d}$ – averages with different superscripts in the same column are significantly different

addition, the omega 3 fatty acid concentration was highest in the Lav125 group in fresh eggs. Omega 6 and omega 9 fatty acid concentrations were highest in the Lav250 group in fresh eggs. The VLCFA concentration was highest in the Lav250 group in stored eggs ($p<0.05$) (Table 6).

Discussion

Performance parameters

Plant and spice essential oils can increase the flavor of feed due to their aromatic properties, thus increasing feed intake when added to layer and broiler rations (Hertrampf, 2001; Williams and Losa, 2001). The previous study indicated that adding lavender oil to the ration decreased body weight gain and feed consumption in Lav125 and Lav250 groups but increased feed consumption and feed conversion rate in Lav500 group. Abu Isha et al. (2018) showed that broiler chickens fed a diet supplemented with peppermint oil (2%) from the Laminaceae family, such as lavender, improved growth performance with an increase in FCR, and feed consumption. Barbarestani et al. (2020) acknowledged that while adding lavender essential oil to broiler rations at the level of 300 mg/kg did not affect the body weight and feed conversion rate, adding lavender essential oil at concentrations of 600 mg/kg increased them. Likewise, Al-Ankari et al. (2004) found in their study that *Mentha piperita* supplement at the level of 1.5% for 35 days positive impacts on body weight, feed consumption, and FCR in broilers. Similarly, Nobakht et al. (2011) alleged that feeding with 0.5% dried *Mentha pulegium* yielded positive effects on performance in 42-day-old broilers. Ocak et al. (2008) put forth that *Mentha piperita* (0.2%) supplement had no effect on weight gain and FCR of broilers during the 42-day fattening period. Torki et al. (2021) (250 mg lavender oil/kg), Mokhtari et al. (2018), and Küçükyılmaz et al. (2017) (24-48 mg lavender oil/kg) articulated that the addition of lavender essential oil to the rations of layer and broiler chickens did not affect performance parameters. However, Taki et al. (2015) posited that lavender essential oil supplement at the level of 600 mg/kg reduced feed consumption. Consistent with the present study, the positive effect of essential oils on growth performance in poultry might be attributed to the bioactive compounds of essential oil structuring the hatching morphology by stimulating the secretion of digestive enzymes and pancreatic enzymes (Giannenas et al., 2018, Chowdhury et al., 2018).

Eggquality parameters

The present study found that using lavender oil increased egg weight in the lavender groups compared to the control group but did not cause changes in egg yield and egg mass and reduced feed consumption (in the Lav250 group). Nasiri-Moghaddam et al. (2012) have demonstrated that no increase in egg weight, feed consumption, and egg yield was observed upon adding lavender oil in the rations of layers.

Table 6 The percentage (%) of total fatty acid concentration in fresh and stored (+4°C 28days) eggs

Egg	Groups	MUFA	PUFA	n-3	n-6	n-9	n-3/n-6	MCFA	LCFA	VLCFA
Fresh	Control	48.95^{a}	10.49^{b}	1.13^{b}	9.49^{b}	47.98^{a}	0.12^{ab}	0.05^{a}	97.77	1.11^{c}
	Lav125	47.45^{ab}	12.24^{ab}	1.64^{a}	11.16^{ab}	46.16^{ab}	0.15^{a}	0.03^{b}	96.80	2.19^{a}
	Lav250	47.78^{ab}	14.06^{a}	1.42^{a}	12.64^{a}	46.58^{a}	0.11^{ab}	0.03^{b}	98.38	1.43^{bc}
	Lav500	47.13^{ab}	14.39^{a}	1.27^{b}	12.11^{a}	46.04^{ab}	0.10^{b}	0.02^{b}	98.22	1.79^{ab}
Stored	Control	47.60^{ab}	11.46^{b}	0.89^{b}	10.57^{ab}	46.60^{a}	0.09^{b}	0.01^{b}	98.78	0.99^{c}
	Lav125	47.79^{ab}	12.43^{ab}	1.07^{b}	10.15^{ab}	45.54^{ab}	0.11^{ab}	0.04^{ab}	97.07	1.35^{bc}
	Lav250	44.51^{b}	13.67^{ab}	1.61^{a}	12.06^{a}	43.08^{b}	0.13^{a}	0.02^{b}	97.99	1.98^{a}
	Lav500	45.71^{ab}	12.63^{ab}	1.23^{b}	11.41^{ab}	44.19^{ab}	0.11^{ab}	0.01^{b}	98.50	1.47^{b}
Egg	Fresh	47.83	12.79	1.36	11.35	46.69	0.12	0.03	97.79	1.63
	Stored	46.40	12.55	1.20	11.05	44.86	0.11	0.02	98.08	1.45
	SEM	0.01	0.50	0.02	0.44	0.001	0.07	0.001	0.47	0.02
p	Egg	0.02	<0.001	<0.001	<0.001	0.01	0.05	0.18	0.06	<0.001
	Groups	0.14	0.07	<0.001	0.24	0.28	0.02	<0.001	0.68	<0.001
	Egg * groups	0.31	0.26	0.05	0.24	0.33	<0.001	<0.001	0.21	0.07

Monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 (omega 3 fatty acids), n-6 (omega 6 fatty acids), n-9 (omega 9 fatty acids), n-3/n-6 (omega 3 omega 6 ratio), medium-chain fatty acids (MCFA) (fatty acids among 6 C and 12 C chains), long-chain fatty acids (LCFA) (fatty acids among 14 C and 20 C chains), and very-long-chain fatty acids (VLCFA) (fatty acids with >20 C chains)

Groups: C – basal diet, Lav125 – basal diet with 125 mg/kg lavender essential oil, Lav250– basal diet with 250 mg/kg lavender essential oil; Lav500- basal diet with 500 mg/kg lavender essential oil. $\bar{x}\pm$SE: Mean$\pm$ Standart error; * $^{a-d}$ – averages with different superscripts in the same column are significantly different

Torki et al. (2021) addressed that when lavender oil (250 mg/kg feed) was supplemented in the diet, it was more effective in egg production and egg mass than peppermint oil (250mg/kg) in layers. Deniz et al. (2022) underscored that the addition of rosemary essential oil to the diet at 200 and 400 mg/kg levels increased the egg production of the experimental groups. Bozkurt et al. (2009) noted that rations with essential oil mixes (oregano oil, laurel leaf oil, sage leaf oil, myrtle leaf oil, fennel seed oil, citrus peel oil) did not affect egg production and egg weight. In another study, Botsoglou et al. (2005) asserted that dietary aromatic plant extracts (rosemary 5 g/kg feed, thyme 5 g/kg and saffron 20 mg/kg feed) yielded no significant difference in egg production and egg weight of chickens of 32 to 40 weeks. The improvement in egg weight in the current study might be explained based on the fact that essential oils positively affect the absorption rate of minerals (especially Mg^{+2} and Ca^{+2}) and their effect on the activity of beneficial colonies in the intestine. The increase in egg weight and egg production in laying hens can be attributed to essential oils improving ovarian function and intestinal nutrient digestibility (Olgun, 2016).

The present study found that lavender oil supplement to the rations did not change the eggshell thickness. Similarly, Torki et al. (2021) reported that the addition of lavender essential oil (250 mg/kg) did not affect the eggshell quality parameters in laying hens, including shell thickness. However, Xiao et al. (2022) supplementation of essential oil to the diets of poultry has been reported to increase eggshell strength. Taki et al. (2015) reported that shell quality parameters including eggshell thickness improved upon adding lavender essential oil (200, 400 and 600 mg/kg) to laying hen rations. The reason behind the inconsistency in eggshell thickness in the current study with previous studies is obscure.

The findings of the present study indicated that FCR decreased in Lav250 group, feed consumption decreased in the Lav125 and Lav250 groups, while egg mass increased in all lavender groups compared to the relevant control groups ($p>0.05$). Additionally, it was reported that the introduction of eucalyptus (lavender contains cisteol) into the rations at different rates in Japanese quails increased egg mass and improved FCR compared to the control rations (Hassan et al., 2011). Similarly, Salari, et al. (2014) emphasized that the laying hens addition of lavender (*Lavandula stoechas*) essential oil (200, 400 and 600 ppm) caused a slight improvement in FCR. Nasiri-Moghaddam et al. (2012) stated that lavender essential oil (350 mg/kg feed) significantly improved FCR in broilers. An increase in egg mass may coincidentally lead to an improvement of FCR (Nobakht et al., 2011; Sayedpiran, et al., 2011). The FCR refers to the overall efficiency of chickens in converting consumed feed into egg mass over a certain period of time (Langhout, 2000). Phytogenic feed additives and lavender oil are assumed to cause a decrease in feed consumption, an improvement in FCR, and thus, an increase in egg mass.

The findings of the present study pointed to egg white height, and therefore Haugh unit (HU) among the egg internal quality parameters increased in the lavender groups compared to the control group ($p<0.05$). However, Torki et al. (2021) found no significant effect of *Lavandula angustifolia* essential oil supplement in laying hens' rations on egg weight, egg white index, yolk index, or HU. Similarly, Salari et al. (2014) stated that the addition of lavender oil (200, 400, and 600 ppm) to the rations did not affect HU. Bozkurt et al. (2012b) stressed that HU, egg white height, and yolk indices were not significantly affected by the addition of essential oil to the laying hen rations. The main components of lavender oil in the current study are linalool, linalyl acetate, which can retain oil-soluble components. Therefore, the increase in egg weight, egg production, HU, and egg white height in the lavender groups may be associated with these compounds accumulated in eggs.

Lipid oxidation in egg yolk

Lipid oxidation is of pivotal importance during the food processing and stored. Oxidation of polyunsaturated fatty acids may result in the emergence of further oxidation or hydroperoxides such as secondary reaction products such as short-chain aldehydes, ketones, and other oxygenated compounds that can negatively affect food flavor, taste, nutritional value, and general quality (Vercellotti et al., 1992). Egg lipids are reported to be sensitive to oxidation since a vast amount is found in the yolk (Aghdam Shahryar et al., 2010). In addition, oxidation is also affected by dietary supplements such as fat composition and stored times (Rahimi et al., 2011). Therefore, upon the decrease in egg yolk MDA concentrations, adding essential oils in the broiler rations might be an effective tool to improve the oxidative stability of eggs, thereby extending their shelf life. In the present study, the MDA concentration decreased in Lav125 and Lav250 group in fresh and in Lav500 group in stored eggs (at +4C for 28 days) compared to the control group ($p>0.05$). Similar to this study, Bozkurt et al. (2012a) announced that the addition of sage oil to the ration decreased the yolk MDA concentration during refrigeration on the 3rd, 6th, 9th, 12th, and 15th days, while MDA values increased over time in the control group. Kaya et al. (2013) observed that the combination of sage and thyme essential oil and Vitamin E supplement to the rations caused a decrease in MDA values in eggs stored at + 4°C on the 0th, 21st and 42nd days. Kamely et al. (2016) highlighted that the addition of essential oil to quail rations (500 mg/kg) reduced the oxidation of lipids in egg yolks during stored at +4°C and at room temperature. Deniz et al. (2022) marked that the addition of rosemary oil to quail rations decreased the MDA concentration in egg yolk stored

at +4°C on days 7 and 28. Batista et al. (2017) addressed that adding rosemary essential oil (200mg/kg feed) to the diet improved the lipid oxidation stability of eggs stored at 25°C. Bayoumi and Helmy (2015) found that adding sage (1, 8-cineol) to the diet in the form of powder and oil significantly reduced the MDA level in the egg yolk. Juergens et al. (2018) noted that MDA concentration decreased due to inhibition of superoxide radical and hydrogen peroxide due to 1,8 cineole (monoterpene). In the present study, the high MDA concentration in the lavender groups can be attributed to the presence of high unsaturated fatty acid concentration in poultry. Additionally, it is thought that the MDA concentration in eggs increases due to the long stored period.

Fatty acid profile in egg yolk

Eggs enriched with PUFA can be beneficial for human health (Özbilgin et al. 2021). The present study found a decrease in oleic and α-linolenic (ALA) acid concentrations in fresh and stored eggs in terms of fatty acid profile in the lavender groups compared to the control group ($p<0.05$). In terms of DHA, it increased in lavender groups compared to the control group ($p<0.05$). Galobart et al. (2001) expressed that the addition of rosemary oil to the diet reported that egg yolk had no effect on fatty acid composition. Shimizu et al. (2001), Alvarez et al. (2004), Cachaldora et al. (2005), and Cachaldora et al. (2006) argued that feeding with essential oil increased the percentage of EPA and DHA in egg yolks. Furthermore, Huang et al. (1990) alleged that the n-3 polyunsaturated fatty acids (EPA and DHA) in egg yolks could be increased by supplementing essential oil (30g/kg) to the rations. Puvaca et al. (2020) Cheel (*Melaleuca alternifolia*) essential oil added to broiler diets were reported to increase PUFA concentration. Kamely et al. (2016) claimed that the addition of Savory (*Satureja khuzestanica*) essential oil to laying quail diets increased the concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in eggs. Bölükbaşı et al. (2010) put forth that the n-3 ratio of DHA and egg yolk increased significantly with the addition of bergamot essential oils to the diet. Ding et al. (2017) were emphasis that the increase in omega 3 concentration might vary depending on the amount of essential oil and source. In the current study, lavender essential oils have antioxidant potential with compounds such as 1,8-cineol and beta-caryophyllene. These compounds are thought to both reduce egg oxidation and increase omega 3 fatty acid concentration.

Overall, the findings of the present study showed that the addition of lavender oil to the ration led to an increase in body weight, egg yield, egg mass, egg weight, egg white height, HU, omega 3 fatty acids (ALA, DHA), and a decrease in MDA concentration. That is because, under market conditions, obtaining eggs that are larger and rich in omega 3 fatty acids is important for egg producers. It is necessary to carry out further studies on the lavender essential oil.

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Data availability The datasets generated during and/or analyzed during the current study are not publicly available due to [REASON(S) WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.

Declarations

Ethical approval This study has been carried out with approval from the Sivas Cumhuriyet University (39°42′34.8″N 37°01′13.0″E), Animal Experiments Local Ethics Board (approval number: 497/2022).

Conflict of interest The authors declare no competing interests.

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