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Effect of feeding of peppermint and eucalyptus essential oils on the performance of Japanese quails (Coturnix japonica)

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Abstract

Researchers are challenged to identify effective feed additives that enhance feed utilization efficiency in poultry production. The present study evaluated the effects of dietary peppermint and eucalyptus essential oils on growth performance, carcass traits, and production economics in quails over a five-week period. A completely randomized design was employed with five treatments, three replications, and twelve birds per experimental unit. The treatments included: T0 (basal diet, control), T1 (basal diet + 0.2% peppermint essential oil), T2 (basal diet + 0.2% eucalyptus essential oil), T3 (basal diet + 0.1% peppermint + 0.1% eucalyptus essential oil), and T4 (basal diet + 0.05% peppermint + 0.05% eucalyptus essential oil). Growth performance was assessed weekly and during starter (1–2 weeks), finisher (3–5 weeks), and overall (1–5 weeks) periods. Results revealed that supplementation with peppermint and eucalyptus essential oils significantly ($P < 0.05$) reduced feed intake, enhanced body weight gain, and improved feed conversion ratio, with the best overall performance observed in the T3 group. Carcass evaluation showed significantly higher dressed yield (with and without giblets) and improved cut-up parts, including breast, thigh, drumstick, and neck weights. The highest thigh, breast, and neck weights were recorded in T3, while maximum drumstick weight was observed in T2. It is concluded that peppermint and eucalyptus essential oils can be effectively utilized as feed additives in quail diets to improve growth performance, carcass quality, and profitability.

Introduction

India has vast livestock resources including poultry, which play a vital role in improving the socio-economic conditions of rural masses. Poultry production in India has taken a quantum leap in the last five decades, emerging from conventional farming practices to a commercial production system with state-of-the-art technological interventions (Singh et al. 2017). Currently, the total Poultry population in our country is 851.81 million (as per 20th Livestock Census) and egg production is around 122.05 billion numbers during 2020-21 (Provisional). The per capita availability during 2020-21(Provisional) is around 90 eggs per annum (DAHD GoI 2022-23). The Honorable Prime Minister (India) is encouraging better income for the farmers via diversification into the livestock and poultry sectors. The poultry sector is one of the most promising sectors because this sector ensures reasonable income around the year to small and landless farmers with the least capital investment. The herbal plant feed additives will help in addressing much health's related challenges in the livestock sector and at the same time will reduce the cost of production for the farmers by affordable good quality medicine and feed additives. If made affordable, it will also reduce the use of antibiotic applications, which is becoming a big human health challenge in the form of AMR around the world. Quail is probably the smallest avian species used for table eggs and meat. Because of prolific egg production and meat yield, it attains the status of a viable commercial poultry enterprise. Quail has unique qualities of hardiness and adaptability to diverse agro-climatic conditions. Several attributes of the species making it ideal for rural poultry production for the creation of rural employment for solving gender issues in employment and to provide supplemental income and protein requirements to rural farmers. Nutrition and diseases have been identified as the

major limiting factors in poultry rearing. Feed is an important and critical input for the poultry industry as it accounts for 60 to 70% of the production costs (Singh et al., 2015).

The use of feed additives is gaining popularity as they can be a trusted source of replacement for the Antimicrobials which are mostly included in the diet of meat animals as an agent of growth promotion. Irrational use of antibiotics as growth promoters in the animal industry has led to more adverse effects causing antibiotic resistance in humans. It encourages researchers to look for a few safer supplements so that a healthy alternative can be included whose use can benefit both the producers and consumers. One such category of feed additives is essential oils which are natural oils extracted from herbs, seeds, or plants that are mostly obtained by distillation. They are volatile compounds having a characteristic odour. Due to its anti-inflammatory, antioxidant, antifungal, and antibacterial effects, it was also used as a medicinal substance (Bento et al., 2013). Many studies in poultry have shown that essential oils like cinnamon, clove, peppermint, eucalyptus, lemon, sage, oregano, *etc.* not only have medicinal properties but also produce better growth performance, FCR, carcass yield, carcass characters and improve egg production and quality (Krishan and Narang, 2014). In India, these are mostly used either as spices or as flavouring agents and are easily available at the producer's level. However, the proper utilization of their extracts or essential oil as a commercial feed additive remains unexplored.

Therefore, the present study was conducted to investigate the effects of peppermint and eucalyptus essential oils on performance, carcass yield, organ weights, and their economic impact on Japanese quails.

MATERIALS AND METHODS

Experimental birds and dietary treatments

Day-old Japanese quails (*Coturnix japonica*) used in the present study were procured from University Poultry Farm. Upon arrival, the birds were randomly allocated to experimental groups and reared under standard management and feeding conditions throughout the experimental period. One hundred and eighty, six days old, straight-run Japanese quails (unsexed) were weighed and randomly assigned to five treatment groups with three replicates of 12 quail chicks each. The study was conducted for five weeks under standard management conditions. The first treatment was considered as the control group (T0) which received the basal diet without the addition of the essential oil, whereas T1, T2, T3, and T4 groups received peppermint and eucalyptus essential oil either alone or in combination with the basal diet at varied concentration. The experimental treatment groups and Nutrient composition (on a dry matter basis) of the basal diets are given in Tables 1 and 2.

Table 1
Different dietary treatments for experimental broiler chicks

Group	Treatment	Feeding program
1	T0	Basal feed (control)
2	T1	Basal feed + Peppermint essential oil (0.2%)
3	T2	Basal feed + Eucalyptus essential oil (0.2%)
4	T3	Basal feed + Peppermint essential oil (0.1%) + Eucalyptus essential oil (0.1%)
5	T4	Basal feed + Peppermint essential oil (0.05%) + Eucalyptus essential oil (0.05%)
T0: Control group, and T1-T4: Treatment groups		

Table 2
Nutrient composition (on dry matter basis) of the basal diets

Feed ingredients (%)	Starter ration (0–2 weeks)	Finisher ration (3–5 weeks)
Moisture	9.28	9.11
Crude protein	24.60	22.40
Crude fibre	3.96	4.16
Ether extract	4.11	4.25
Total ash	6.51	7.03
Acid insoluble ash	1.40	1.43
Calcium (g)	1.08	1.03
Total phosphorus (g)	0.79	0.73
Nitrogen-free extract	60.82	62.16

Table 3
Effect of diet supplemented with peppermint and eucalyptus essential oils on Japanese quails' BW gain (Mean ± SE)

Period	Age (wk)					
		T0	**T1**	**T2**	**T3**	**T4**
Starter (1–2 weeks)	1	25.05 ± 0.59^{b}	28.94 ± 0.59^{a}	27.66 ± 0.85^{a}	29.25 ± 0.34^{a}	28.16 ± 1.01^{a}
	2	46.19 ± 0.24^{c}	52.16 ± 1.75^{ab}	50.89 ± 0.82^{ab}	53.49 ± 0.74^{a}	49.94 ± 0.64^{b}
Finisher (3–5 weeks)	CWBG^{A}	71.25 ± 0.64^{c}	81.10 ± 1.17^{a}	78.56 ± 0.95^{b}	82.74 ± 0.40^{a}	78.90 ± 0.43^{b}
	3	59.14 ± 1.31	60.81 ± 2.38	63.05 ± 1.33	62.51 ± 1.33	59.39 ± 1.53
	4	29.81 ± 1.13^{c}	35.69 ± 0.56^{ab}	33.92 ± 1.90^{b}	37.78 ± 0.51^{a}	33.45 ± 1.06^{b}
Overall	5	32.88 ± 1.121^{c}	48.49 ± 3.27^{a}	42.21 ± 3.57^{ab}	47.90 ± 0.92^{a}	39.46 ± 0.60^{bc}
	CWBG^{B}	121.83 ± 1.29^{c}	144.99 ± 5.15^{a}	139.17 ± 3.78^{ab}	148.19 ± 1.18^{a}	132.29 ± 2.42^{b}
	CWBG^{C}	193.07 ± 1.67^{d}	226.09 ± 5.13^{ab}	217.73 ± 4.49^{bc}	230.93 ± 1.14^{a}	210.39 ± 2.14^{c}

$^{a–d}$ Means within rows with different superscript differ significantly ($P < 0.05$). ^{A} Cumulative BW gain for the previous 2-week study period, ^{B} Cumulative BW gain for the previous 3-week study period, and ^{C} Cumulative BW gain for the 5-week study period. BW: Body weight, CWBG: Cumulative body weight gain, wk: Week, T0: Control group, and T1-T4: Treatment groups.

Table 4
Effect of diet supplemented with peppermint and eucalyptus essential oils on Japanese quails' feed intake (Mean ± SE)

Period	Age (wk)					
		T0	**T1**	**T2**	**T3**	**T4**
Starter (1–3 weeks)	1	54.39 ± 1.07^{b}	52.72 ± 0.21^{ab}	53.43 ± 0.44^{b}	53.17 ± 0.44^{ab}	50.95 ± 0.87^{a}
	2	98.12 ± 0.52^{b}	95.43 ± 0.83^{a}	94.16 ± 0.73^{a}	94.04 ± 0.55^{a}	95.16 ± 1.12^{a}
	TFC^{A}	152.52 ± 1.51^{b}	148.15 ± 0.63^{a}	147.59 ± 0.35^{a}	147.20 ± 0.11^{a}	146.11 ± 1.96^{a}
Finisher (3–5 weeks)	3	141.33 ± 0.93^{b}	135.75 ± 0.58^{ab}	136.33 ± 0.72^{ab}	131.83 ± 3.54^{a}	135.69 ± 1.19^{ab}
	4	129.22 ± 0.84	129.28 ± 1.45	125.75 ± 0.51	123.08 ± 2.81	123.31 ± 2.70
	5	182.42 ± 0.64^{c}	168.11 ± 3.01^{ab}	170.10 ± 1.98^{b}	161.79 ± 2.61^{a}	166.03 ± 1.85^{ab}
	TFC^{B}	452.97 ± 2.11^{b}	433.14 ± 4.53^{a}	432.18 ± 0.76^{a}	416.71 ± 8.95^{a}	425.03 ± 3.77^{a}
Overall	TFC^{B}	605.49 ± 3.04^{c}	581.29 ± 4.83^{b}	579.77 ± 0.61^{ab}	563.91 ± 8.99^{a}	571.13 ± 2.53^{ab}

$^{a–c}$ Means within rows with no common superscript differ significantly ($P < 0.05$). ^{A} Total feed consumption for the previous 2-week study period, ^{B} Total feed consumption for the previous 3-week study period and ^{C} Total feed consumption for the 5-week study period. TFC: Total Feed consumption, wk: Week, T0: Control group, and T1-T4: Treatment groups.

Table 5
Effect of diet supplemented with peppermint and eucalyptus essential oils on Japanese quails' feed conversion ratio (FCR) (Mean ± SE)

Period	Age (wk)	T0	T1	T2	T3	T4
Starter (1–2 weeks)	1	2.17 ± 0.02^{b}	1.82 ± 0.03^{a}	1.94 ± 0.06^{a}	1.82 ± 0.03^{a}	1.82 ± 0.06^{a}
	2	2.12 ± 0.01^{c}	1.83 ± 0.05^{ab}	1.85 ± 0.02^{ab}	1.76 ± 0.03^{a}	1.91 ± 0.04^{b}
	AFCR^{A}	2.14 ± 0.00^{c}	1.83 ± 0.02^{ab}	1.88 ± 0.02^{b}	1.76 ± 0.03^{a}	1.76 ± 0.03^{a}
Finisher (4–6 weeks)	3	2.39 ± 0.05^{b}	2.24 ± 0.10^{ab}	2.17 ± 0.05^{a}	2.11 ± 0.03^{a}	2.29 ± 0.07^{ab}
	4	4.35 ± 0.15^{c}	3.62 ± 0.09^{ab}	3.73 ± 0.20^{b}	3.26 ± 0.09^{a}	3.70 ± 0.05^{b}
	5	5.56 ± 0.21^{d}	3.49 ± 0.20^{ab}	4.08 ± 0.28b^{c}	3.38 ± 0.11^{a}	4.21 ± 0.11^{c}
	AFCR^{B}	3.72 ± 0.02^{d}	2.99 ± 0.08^{ab}	3.11 ± 0.08b^{c}	2.81 ± 0.05^{a}	3.21 ± 0.04^{c}
Overall	AFCR^{C}	3.14 ± 0.01^{d}	2.57 ± 0.04^{b}	2.67 ± 0.05b^{c}	2.44 ± 0.03^{a}	2.17 ± 0.01^{c}

$^{a–d}$ Means within rows with no common superscript differ significantly ($P < 0.05$). ^{A} Average feed conversion ratio for the previous 2-week study period, ^{B} Average feed conversion ratio for the previous 3-week study period,and ^{C} Average feed conversion ratio for the 5-week study period. AFCR: Average feed conversion ratio, wk: Week, T0: Control group, and T1-T4: Treatment groups.

Table 6

Effect of diet supplemented with peppermint and eucalyptus essential oils on carcass yield (% of live weight) (mean ± SE) in Japanese quails

Treatments	Carcass yield	
	Dressed yield with giblet (%)	Dressed yield without giblet (%)
T0	72.47 ± 1.25^{b}	63.18b ± 0.20
T1	75.06 ± 1.04^{ab}	68.84a ± 1.75
T2	74.90 ± 1.11^{ab}	67.08a ± 0.89
T3	76.21 ± 1.12^{a}	69.96a ± 0.33
T4	76.62 ± 0.16^{a}	68.04a ± 1.10

$^{a–b}$ Values with different superscripts column-wise differ significantly (P < 0.05). T0: Control group, and T1-T4: Treatment groups .

Table 7

Effect of diet supplemented with peppermint and eucalyptus essential oils on cut up parts (% of live weight) (mean ± SE) in Japanese quails

Treatments	Cut up parts					
	Back	Breast	Thigh	Drumstick	Wing	Neck
T0	12.35 ± 0.45	23.24 ± 0.53^{b}	7.49 ± 0.16^{b}	5.02 ± 0.38^{b}	4.59 ± 0.43^{b}	2.24 ± 0.41
T1	11.82 ± 0.69	25.26 ± 0.99^{ab}	9.00 ± 0.46^{ab}	6.32 ± 0.30^{a}	6.17 ± 0.41^{a}	3.15 ± 0.48
T2	12.88 ± 0.53	27.30 ± 0.22^{a}	9.29 ± 0.21^{a}	5.70 ± 0.36^{ab}	5.65 ± 0.11^{ab}	2.85 ± 0.39
T3	14.07 ± 1.22	26.53 ± 0.58^{a}	9.32 ± 0.67^{a}	6.05 ± 0.25^{ab}	6.20 ± 0.38^{a}	2.83 ± 0.26
T4	11.68 ± 0.52	26.15 ± 0.83^{a}	8.24 ± 0.64^{ab}	5.48 ± 0.34^{ab}	5.10 ± 0.40^{ab}	2.44 ± 0.29

$^{a–b}$ Values with different superscripts column wise differ significantly (P < 0.05). T0: Control group, and T1-T4: Treatment groups.

Table 8
Effect of diet supplemented with peppermint and eucalyptus essential oils on economics in Japanese quails

Parameters	T0	T1	T2	T3	T4
Starter phase (week 1–2)					
Average Feed intake (g/bird)	152.52 ± 1.51^{b}	148.15 ± 0.63^{a}	147.59 ± 0.35^{a}	147.20 ± 0.11^{a}	146.11 ± 1.96^{a}
Total feeding cost (Rs)	5.49 ± 0.06^{b}	5.93 ± 0.02^{a}	5.87 ± 0.01^{a}	5.87 ± 0.00^{a}	5.55 ± 0.08^{b}
Average weight gain (g)	71.25 ± 0.64^{c}	81.10 ± 1.17^{a}	78.56 ± 0.95^{b}	82.74 ± 0.40^{a}	78.09 ± 0.43^{b}
Feed cost (Rs.)/kg weight gain	77.06 ± 0.09^{a}	73.12 ± 0.75^{bc}	74.76 ± 0.93^{ab}	70.98 ± 0.38^{c}	71.01 ± 1.17^{c}
Finisher phase (week 3–5)					
Average Feed intake (g/bird)	452.97 ± 2.11^{b}	433.14 ± 4.53^{a}	432.18 ± 0.76^{a}	416.71 ± 8.95^{a}	425.03 ± 3.77^{a}
Total feeding cost (Rs)	15.86 ± 0.07^{c}	16.90 ± 0.18^{a}	16.76 ± 0.03^{ab}	16.21 ± 0.35^{bc}	15.71 ± 0.14^{c}
Average weight gain (g)	121.83 ± 1.29^{c}	144.99 ± 5.15^{a}	139.17 ± 3.78^{ab}	148.19 ± 1.18^{a}	132.29 ± 2.42^{b}
Feed cost (Rs.)/kg weight gain	130.15 ± 0.79^{a}	116.78 ± 3.18^{b}	120.59 ± 3.04^{b}	109.37 ± 1.89^{c}	118.75 ± 1.36^{b}
Overall (week 1–5)					
Average Feed intake (g/bird)	605.49 ± 3.04^{c}	581.29 ± 4.83^{b}	579.77 ± 0.61^{ab}	563.91 ± 8.99^{a}	571.13 ± 2.53^{ab}
Total feeding cost (Rs)	21.35	22.83	22.63	22.08	21.25

$^{a–c}$ Values with different superscripts column wise differ significantly ($P < 0.05$). Cost of starter diet = Rs. 36/kg, and finisher diet = Rs. 35/kg

Parameters					
	T0	T1	T2	T3	T4
	± 0.11[c]	± 0.19[a]	± 0.02[ab]	± 0.35[b]	± 0.09[c]
Average weight gain (g)	193.07	226.09	217.73	230.93	210.39
	± 1.67[d]	± 5.13[ab]	± 4.49[bc]	± 1.14[a]	± 2.14[c]
Feed cost (Rs.)/kg weight gain	110.56	101.04	104.02	95.62	101.01
	± 0.40[a]	± 1.57[b]	± 2.03[b]	± 1.11[c]	± 0.59[b]

[a–c] Values with different superscripts column wise differ significantly (P < 0.05). Cost of starter diet = Rs. 36/kg, and finisher diet = Rs. 35/kg

Essential oils and their potency

Essential oils are highly potent; thus, they need to be combined with a carrier oil. A carrier oil that is unscented or lightly scented, like almond, jojoba, or coconut oil can be made use of. This not only functions as a carrier but also helps to dilute the essential oil. Here, in this trial coconut oil was used as a carrier for combining the essential oil in the diet. Pure virgin coconut oil of food grade was used in half the concentration of peppermint and eucalyptus essential oils in the various treatment groups. The feed of the control group was incorporated with a carrier oil, but it was devoid of both essential oils.

Statistical analysis

All data on various parameters were analysed statistically by running ANOVA using SPSS 19 software. Significant mean differences between the treatments were determined at a 5% significance level (P < 0.05) using Duncan's Multiple Range Test (DMRT) as modified by Kramer (1957).

Ethical approval

All experimental procedures involving live birds were reviewed and approved by the Institutional Animal Ethics Committee (IAEC). All methods were carried out in accordance with the relevant guidelines and regulations for the care and use of laboratory animals, including national and institutional guidelines for animal welfare.

Results

Data on performance indices are summarized in Tables 3 to 6. Mean body weight (BW) gains at different intervals in different experimental groups are given in Table 3. During the first week of the trial, a significant (P□0.05) variation in body weight gain was observed. The birds belonging to the supplemental groups T1, T2, T3, and T4 showed the highest weight gain (28.94 ± 0.59 g, 27.66 ± 0.85 g, 29.25 ± 0.34 g,

and 28.16 ± 1.01 g, respectively), whereas the group T0 (control) showed the least (25.05 ±0 .59 g) weight gain. In the second week of the trial, the maximum weight gain was recorded in the T3 group which was significantly (P≤0.05) higher (53.49 ± 0.74 g) than group T0 (control). In the fourth week, significantly (P≤0.05) higher weight gain was seen in group T3 (37.78 ± 0.51 g) which was supplemented with a combination of 0.1% each of peppermint and eucalyptus essential oil while the lowest (29.81 ± 1.13 g) weight gain was recorded in the group T0 (control) i.e., 29.81±1.13 g. During the fifth week of the trial, the body weight gain of the Japanese quails was significantly (P≤0.05) higher in groups T1 and T3, *i.e.,* 48.49 ± 3.27 g and 47.90 ± 0.92 g, respectively. In the finisher phase (weeks 3-5), the highest body weight gain was observed in the Japanese quails belonging to the group T1 (144.99 ± 5.15 g) and T3 (148.19 ± 1.18 g) which were significantly (P≤0.05) higher than the control group (T0).

The means of feed consumption measured at different intervals in different experimental groups are given in Table 4. During the first week of the trial, birds of the treatment group T4 had the least (50.95 ± 0.87 g) and significantly (P<0.05) lower feed consumption, whereas the highest (54.39 ± 1.07 g) feed consumption of Japanese quails was recorded in the T0 (control) group. In the second week, a significant (P≤0.05) difference in feed consumption was seen between the control and essential oil-supplemented groups. Japanese quails of the T0 group consumed the highest amount of feed (98.12±0.52g). While considering the starter phase (1-2 weeks), a similar trend in feed consumption was seen as that of the second week. Birds belonging to groups supplemented with essential oils recorded significantly (P≤0.05) lower feed consumption than the group T0 (control) *i.e.,* 152.52 ± 1.51 g. During the third week, a significantly (P≤0.05) lower amount of feed consumption was noticed in the Japanese quails of group T3 (131.83 ± 3.54 g) while the birds of group T0 (control) consumed the highest amount of feed (141.33 ± 0.93 g). In the fifth week of the trial *i.e.,* in the last week, a significant (P≤0.05) variation in the feed consumption was observed among the supplemental groups and the control. The highest (182.42 ± 0.64 g) feed consumption among the Japanese quails was recorded in group T0 (control) whereas group T3 recorded the least (161.79 ± 2.61 g) amount of feed consumption. During the finisher phase (3-5 weeks) of the feeding trial, Japanese quails of the T0 (control) group consumed the highest (452.97 ± 2.11 g) amount of feed while the groups T1, T2, T3, and T4 recorded significant (P≤0.05) lower feed consumption *i.e.,* 433.14 ± 4.53 g, 432.18 ± 0.76 g, 416.71 ± 8.95 g, and 425.03 ± 3.77 g respectively.

The means of feed conversion ratio (FCR) measured at different intervals in different experimental groups are given in Table 5. During the first week of the feed trial, it was observed that group T0 (control) showed a significantly (P≤0.05) higher feed conversion ratio (2.17 ± 0.02) than all the essential oil-supplemented groups. In the second week, Japanese quails of group T3 supplemented with 0.1% of peppermint and eucalyptus essential oils recorded the significantly (P≤0.05) lowest (1.76 ± 0.03) FCR while the group T0 (control) showed the highest FCR *i.e.,* 2.12 ± 0.01. The feed conversion ratio during the starter period *i.e.,* 1-2 weeks, was significantly (P≤0.05) lower in the Japanese quails of group T3 (1.78 ± 0.01) compared to all the other groups. The group T2 and T4 also showed significantly (P≤0.05) lower FCR (1.88 ± 0.02 and 1.87 ± 0.03, respectively) than the control (T0) group, which recorded the highest FCR of 2.14 ± 0.00. During the third week, significant (P≤0.05) differences in the feed conversion

ratio of Japanese quails were seen. The lowest and best result was found in groups T3 (2.11 ± 0.03) and T2 (2.17 ± 0.05), whereas the highest feed conversion ratio was observed in birds of group T0 (2.39 ± 0.05). In the fourth week of the feeding trial, significant (P≤0.05) results were seen. The birds of group T0 (control) showed the highest feed conversion ratio of 4.35 ± 0.15, while group T3, which was supplemented with 0.1% each of peppermint and eucalyptus essential oil, showed the lowest FCR (3.26 ± 0.09). A significant (P≤0.05) difference in the feed conversion ratios of Japanese quails was again observed during the fifth week of the feeding trial. The feed conversion ratio was significantly (P≤0.05) lowest in group T3 (3.38 ± 0.11) and highest in group T0 (5.56 ± 0.21). During the finisher period of the feeding trial (3-5 weeks), a similar pattern in FCR was noticed as that of the starter phase. A significantly (P≤0.05) highest (3.72 ± 0.02) feed conversion ratio was seen in Japanese quails belonging to the control (T0). While group T3 (2.81 ± 0.05) supplemented with 0.1% peppermint essential oil and eucalyptus essential oil showed the significantly (P≤0.05) lowest FCR.

The dressing yield without giblets (Table 6) was significantly (P≤0.05) improved in the groups T1, T2, T3, and T4 (68.84 ± 1.75, 67.08 ± 0.89, 69.96 ± 0.33, and 68.04 ± 1.10% respectively), whereas the minimum (63.18 ± 0.20%) weight was noted in the group T0 (control). The highest dressed yield with giblet was noted in group T3 (supplemented with 0.1% each of peppermint and eucalyptus essential oils) and T4 (supplemented with 0.05% each of peppermint and eucalyptus essential oils) *i.e.,* 76.21 ± 1.12 and 76.62 ± 0.16% respectively. The group T0 showed the minimum (72.47 ± 1.25%) dressed yield weight with giblet.

Results regarding the effect of peppermint and eucalyptus essential oils supplementation on cut-up parts are presented in Table 7. The birds belonging to the group T0 (control) had lower (7.49 ± 0.16%) thigh weight while the group T2 and T3 supplemented with peppermint and eucalyptus essential oils had higher (9.29 ± 0.2 and 9.29 ± 0.21%, respectively) thigh weights. The Japanese quails belonging to the group T2 (0.2% eucalyptus essential oil), T3 (0.1% of each peppermint eucalyptus essential oil), and T4 (0.05% of each peppermint and eucalyptus essential oils) recorded the higher (27.30 ± 0.22, 26.53 ± 0.58 and 26.15 ± 0.83 %) breast weight followed by T2 (25.26 ± 0.99%). The group T0 (control) had the least (23.24 ± 0.53%) breast weight of all the groups. A significant (P≤0.05) impact was seen on the drumstick weight in the Japanese quails supplemented with essential oils. The results of dietary supplementation of the essential oils in the Japanese quails were positive in terms of the drumstick weight and wing weight. T1, the group supplemented with 0.2% of peppermint essential oil showed the highest (6.32 ± 0.30%) drumstick weight, while the lowest (5.02 ± 0.38%) weight of drumstick was noted in group T0. The drumstick weight of the groups T2, T3, and T4 were 5.70 ± 0.36, 6.05 ± 0.25, and 5.48 ± 0.34% respectively. Significantly higher wing weight was seen in group T3 (6.20 ± 0.38%), which was supplemented with 0.1% each of peppermint and eucalyptus essential oils, and T1 (6.17 ± 0.41%) supplemented with 0.2% peppermint essential oil.

The effects of peppermint and eucalyptus essential oils supplementation in terms of feed cost in Rs. (Including the cost of essential oil and the carrier oil) per kg of weight gain in the starter, finisher, and during the overall period of the trial on the economics of Japanese quail production have been presented

in Table 8. During the starter phase *i.e.,* 1-2 weeks of trial, the group T0 (control) showed a significantly (P≤0.05) higher (Rs. 77.06 ± 0.09) feed cost per kg weight gain whereas the group T3 (Rs. 70.98 ± 0.38) supplemented with a combination of 0.1% each of peppermint and eucalyptus essential oils followed by T4 (Rs. 71.01 ± 1.17) supplemented with a combination of 0.05% each of peppermint and eucalyptus essential oils showed the minimum feed cost per kg weight gain. In the finisher phase (3-5 weeks), the Japanese quails belonging to group T0 showed the maximum (Rs. 130.15 ± 0.79) feed cost per kg weight gain. The significant (P≤0.05) minimum (Rs. 109.37 ± 1.89) feed cost per kg weight gain was seen in T3, whereas the other essential oil-supplemented groups showed feed cost per kg weight gain higher than that of T3 but lower than the control.

Discussion

The overall body weight gain during the entire period of the trial was significantly (P≤0.05) affected by the supplementation of the essential oils either as a single or in combination. The total body weight gain of the T3 group was around 230.93 ± 1.14 g, which was significantly (P≤0.05) higher than T0 (control), which recorded the lowest (193.07 ± 1.67 g) overall weight gain followed by the T4 group (210.39 ± 2.14 g). The overall results showed that the group supplemented with 0.1% each of peppermint and eucalyptus essential oil had the maximum average body weight gain. The control group which did not receive any essential oil had the minimum average body weight gain. Therefore, it can be concluded that the supplementation of essential oils had a significant (P≤0.05) impact on the average weight gain in Japanese quails.

These results are similar to the study conducted by Aminzade *et al.* (2012), who found that there was a significant increase in body weight gain in peppermint-supplemented Japanese quails. Asadi *et al.* (2016) also found that although there was no significant increase in weight gain, groups supplemented with peppermint leaves showed higher body weight gain than the control group. Similar results were found by Ocak *et al.* (2018), Hasan and Sadeq (2020), and Hassan (2019). Also, Sorour *et al.* (2021) found that there was an increase in body weight gain of *Clostridium perfringes* challenged broilers when supplemented with peppermint and its microemulsion. Kwiecieñ and Winiarska-Mieczan (2009) noted that there was a marked positive effect of peppermint on broiler body weight gain. Farhadi *et al.* (2015) reported that eucalyptus essential oil significantly increased body weight gain in broilers when compared to the control. Ghasemi and Hajkhodadadi (2018) noted that the addition of an essential oil mixture (*Zataria multiflora, Mentha piperita, Foeniculum vulgare,* and *Eucalyptus globulus*) into drinking water significantly increased body weight gain compared to control. Mustafa (2019) recorded that with the increasing concentration of eucalyptus essential oil in the diet of broilers there was a significant increase in body weight gain.

The increase in body weight gain by eucalyptus may be due to the growth of beneficial bacteria at the expense of harmful bacteria inside the gastrointestinal tract, thus increasing the number of beneficial bacteria, especially Lactobacillus bacteria, which improves the digestion and absorption coefficient by increasing the secretion of digestive enzymes. Peppermint also helps in increasing average daily weight

gain by decreasing the effects of gastrointestinal disorders, thus strengthening the digestive system and improving feed efficiency. Also, the phenylpropanoids and flavonoids in eucalyptus support digestion. Moreover, the antiseptic property of peppermint prevents harmful bacterial growth in the digestive system, which led to better digestion and absorption.

A significant (P≤0.05) variation in the feed consumption was seen among the groups for the overall period *i.e.,* from the 1-5 weeks of the experimental trial. Japanese quails belonging to group T0 (control), which did not receive any supplementation, had the highest (605.49 ± 3.04 g) feed consumption. On the other hand, group T3 recorded the significantly (P≤0.05) lowest feed consumption i.e., 563.91 ± 8.99 g. All the supplemental groups recorded the least consumption, especially the one that was supplemented with the combination of 0.1% of each of the peppermint and the eucalyptus essential oils.

These results are supported by Ahmed *et al*. (2005), who showed that the dietary addition of *Eucalyptus globulus* leaves in 36 White New Zealand (NZW) weaned male rabbits significantly reduced the feed intake. Ahmed *et al.* (2016) found that with the increase in the levels of peppermint essential oils, there was a decrease in the amount of feed intake in broiler chicken. Abbas *et al.* (2017) found that the feed intake in Japanese quails was significantly reduced with the increasing levels of peppermint essential oil. Alallawee *et al.* (2020) noted that the dietary supplementation of different levels of peppermint leaves powder (*Mentha piperita*) significantly reduced the overall feed intake. In contrast, Khurshid *et al.* (2016) reported no significant changes in the feed intake in broilers when supplemented with raw mint leaves. Kaur *et al.* (2021) found no significant difference in feed intake with eucalyptus powder supplementation in laying hens. Mashayekhi *et al.* (2018) and Mohebodini *et al.* (2020) found that there was no significant difference in feed intake with the supplementation of eucalyptus leaf powder in broilers. Al-Kassie (2010) showed a significant increase in feed consumption with the supplementation of dry peppermint leaves when compared to the control. A significant decrease in the feed intake in the peppermint and eucalyptus essential oil-supplemented group may be due to the improved utilization of nutrients, which in turn may be due to the enhanced gut morphology and enzyme secretion.

A significant (P≤0.05) improvement in the FCR was noticed in the essential oil-supplemented groups when compared to the control during the overall period, *i.e.,* from 1-5 weeks of feeding trial. The birds of the control group, which were not supplemented with any essential oil, had the poorest (3.14 ± 0.01) feed conversion ratio, whereas the group supplemented with a combination of 0.1% each of peppermint and eucalyptus essential oils (T3) had the best (2.44 ± 0.03) feed conversion ratio.

This is corroborated by Mohebodini *et al.* (2021) who recorded that with the increasing concentration of eucalyptus oil in the broiler diet there was a significant improvement in the FCR. Asadi *et al.* (2016) found that there was a decrease in FCR with the increasing concentration of peppermint powder in the broiler diet. A similar result was found by Al-Kassie (2010). Awaad *et al.* (2015) noted that the supplementation of peppermint and eucalyptus essential oils in VVND-infected chickens improved its FCR. Hussein (2021) found that in coccidian-challenged broiler chicken, better FCR was seen due to the use of antibiotics and peppermint powder. Mashayekhi *et al.* (2018) found that the lowest FCR was seen in the

broilers with antibiotics and 0.5% eucalyptus leaves powder. Fathi *et al.* (2020) found that supplementation of eucalyptus leaves to the laying hens increased the FCR. Witkowska *et al.* (2019) did not find any significant difference in FCR with the use of peppermint mist broiler chickens. Farhadi *et al.* (2015) also did not find any significant difference in the FCR in the broilers which were supplemented with the eucalyptus powder and its essential oil. The active compounds like carvacrol, menthol, thymol, ρ-cymene, 1,8-cineol, menthone, γ-terpinene and α-pinene present in peppermint and eucalyptus essential oil stimulate and enhance the secretion of saliva and endogenous enzymes like amylase and enhance the synthesis of bile acid in the liver and the excretion of bile acids which will improve the digestion and absorption of lipids. The beneficial effects of these essential oils on the performance of the birds could be due to the improvement of feed digestibility and nutrient absorption especially lipids. Tunica muscularis is responsible for intestinal motility and contraction which plays a vital role in the passage rate of digesta and ultimately nutrient absorption, whose thickness was increased with the use of peppermint in poultry. It was also found to increase mucous production, increase enzymatic secretions, and change the morphology of the intestine.

There was a remarkable impact of the supplementation of peppermint and eucalyptus essential oils on the dressed yield of the Japanese quails, which is supported by Al-Kassie (2010), who showed a significant increase in the dressing percentage of the broilers with the supplementation of dry peppermint leaves when compared to the control. Mashayekhi *et al.* (2018) found that the carcass yield was significantly increased in the broilers with the feeding of antibiotics and 0.5% eucalyptus leaves powder. Asadi *et al.* (2016) also found that there was a significant increase in the carcass yield of broilers when supplemented with peppermint leaves compared to the control group. But the above findings are contradicted by Srivastava *et al.* (2021) who recorded a non-significant variation in the dressing percentage when Japanese quails were supplemented with peppermint essential oil. Hassan (2019) found that there was no significant difference in the dressing percentage in the broiler chickens supplemented with peppermint oil. Ahmed *et al.* (2016) also found that with the increase in the levels of peppermint essential oils, there was no significant variation in the carcass yield in broiler chickens. Ameri *et al.* (2016) found no significant variation in the carcass yield with the supplementation of peppermint powder in broilers. Veselin *et al.* (2021) showed that supplementation of peppermint powder in the broilers did not significantly affect the carcass weight in broilers. Ocak *et al.* (2008) found no significant variation in the carcass weight in the broilers when supplemented with dry peppermint leaves. Khempaka *et al.* (2013) found that the dried peppermint leaves supplementation in broilers did not affect the eviscerated carcass weight.

Peppermint and eucalyptus essential oil supplementation in the diet of the Japanese quails resulted in significant (P□0.05) changes in the thigh weight and breast weight. The findings of the present trial are corroborated by Mashayekhi *et al.* (2018), who found that the breast weight was significantly increased in broilers with antibiotics and 0.5% eucalyptus leaf powder. Aminzade *et al.* (2012) found a significant difference in breast weight in the Japanese quails supplemented with the Mentha piperita plant. Adibnezhad *et al.* (2014) recorded that supplementation of peppermint and thyme powder in broilers significantly increased thigh weight, but the back and neck were not affected. Contrastingly, Srivastava *et*

al. (2021) recorded a non-significant variation in the thigh, drumstick, back, and neck weights when Japanese quails were supplemented with peppermint essential oil while the breast and wing weights were significantly increased. Ameri *et al.* (2016) found no significant variation in the thigh and breast weight with the supplementation of peppermint powder in broilers. Veselin *et al.* (2021) showed that supplementation of peppermint powder in the broilers did not significantly affect the thigh, breast, drumsticks, and wing weights in broilers. Khempaka *et al.* (2013) found that the dried peppermint leaves supplementation in broilers did not affect the thigh and breast weight. Ghazaghi *et al.* (2014) found that the mint powder supplementation in Japanese quails did not produce a significant difference in thigh and breast weight.

The feed cost per kg weight gain was significantly (P□0.05) lowest in group T3 (Rs. 95.62 ± 1.11) during the overall trial period, *i.e.,* from 1-5 weeks, while the control (Rs. 110.56 ± 0.40) had the highest feed cost per kg weight gain. Other groups, T1, T2, and T3 also had significantly (P□0.05) lower feed cost per kg gain than the control. Thus, from the present trial, it can be concluded that supplementation of peppermint and eucalyptus essential oils can help to reduce the cost of production of Japanese quails, especially at the concentration of 0.1% each of peppermint and eucalyptus essential oils. The results of this study are supported by Ahmed *et al.* (2019) who found that the supplementation of peppermint leaves increased the profit or net economic return in broilers. Osman *et al.* (2004) observed that dietary inclusion of 0.1% eucalyptus in broilers resulted in better performance and higher profit returns. Gole *et al.* (2020) also noted that the addition of peppermint essential oil in combination with an organic acid in the diet of broilers resulted in the best performance and higher profits.

Conclusion

The results of the present study indicated that supplementation of 0.1% of peppermint and eucalyptus essential oils in combination significantly reduced the overall feed intake and augmented the average body weight gain resulting in better feed conversion ratio and dressed yield in treated groups, demonstrating the beneficial effect of peppermint and eucalyptus essential oils in combination through improved feed efficiency and more edible yield. It is therefore suggested, that peppermint and eucalyptus essential oils in combination are used as feed additive in quails to obtain higher profitability.

Declarations

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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Use of Generative AI and AI-assisted Technologies Statement

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the conception, design, data collection, analysis, interpretation of data, or writing of this manuscript.

Data availability

The datasets generated during this study are available from the corresponding author upon reasonable request

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