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RESEARCH ARTICLE

Evaluation of the Production Performance of Two Strains of Japanese Quail Fed Diets Supplemented with Fennel Seeds, Dill Seeds and their Mixture

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Abstract

Objective: This study aimed to evaluate the effects of dietary supplementation with fennel and dill seeds, individually or in combination, on the production performance of two Japanese quail strains, brown and black.

Materials and Methods: The study was conducted at the College of Agriculture and Forestry, University of Mosul, using 320 one-day-old Japanese quails from two strains, brown and black. The birds were randomly allocated to four dietary treatments for 35 days, with each treatment comprising 40 birds distributed among four replicates of 10 birds each. The dietary treatments included an unsupplemented control diet, fennel seed supplementation at 0.4 g/kg feed, dill seed supplementation at 0.4 g/kg feed, and a combination of fennel and dill seeds at 0.2 g/kg feed each. Growth performance, feed consumption, feed conversion ratio, dressing percentage, and mortality were evaluated.

Results: The black strain had significantly greater live body weight at 1 day of age and at 3 and 5 weeks of age than the brown strain. Among the dietary treatments, fennel seed supplementation produced the most pronounced improvements in growth performance and significantly exceeded the other treatments. The interaction between strain and dietary supplementation indicated that fennel supplementation produced the greatest improvement in performance, followed by dill supplementation, whereas the fennel-dill combination also significantly improved performance compared with the control in both strains. The black strain and fennel-supplemented group recorded the greatest total weight gain. Feed consumption did not differ significantly between strains or among the supplemented groups, whereas the control and dill-supplemented groups exhibited improved feed conversion ratios. Dressing percentage was significantly higher in the black strain and fennel-supplemented groups. Mortality was significantly reduced by dill supplementation.

Conclusion: Dietary supplementation with fennel and dill seeds, particularly fennel alone, improved several production performance traits of Japanese quails. Fennel supplementation enhanced growth performance and dressing percentage, whereas dill supplementation was associated with reduced mortality and improved feed conversion. These findings indicate that fennel and dill seeds have potential as dietary phytogenic additives for improving production performance in Japanese quails.

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INTRODUCTION

The American Feed Control Officials (AAFCO) defines feed additives as "an ingredient or mixture of ingredients added to a basic feed mix to meet a specific need, usually in small quantities and requiring careful handling and mixing." The European Union officially banned the use of antibiotics as growth promoters in poultry and livestock in 2006[1], prompting researchers to seek alternatives. Among the potential alternatives reported for poultry production are plant-based additives, which include a range of natural feed additives derived from herbs, spices, or other plants, or their extracts in the form of essential oils[2]. These additives are incorporated into animal feed to enhance productivity by improving digestion and nutrient absorption and reducing intestinal pathogens[3].

Quails are fast-growing and high-producing birds, making them an important poultry species. They contribute to the poultry industry as an important source of meat and eggs rich in phosphorus[4]. The development of multiple breeds of this bird may contribute to the establishment of productive breeds that are well adapted and resistant to the environmental conditions of Iraq. Numerous studies investigating the inclusion of medicinal plant products in quail diets have reported significant improvements in the productive and physiological performance of treated birds.

Fennel seeds (*Foeniculum vulgare* Mill., family Apiaceae) contain volatile aromatic oil compounds with potential health-promoting properties, including fenchone, anethole, myrcene, limonene, chavicol, cineole, anisic aldehyde and pinene, in addition to amino acids, phenolic compounds and flavonoids. Fennel seeds possess several biological properties, including hepatoprotective, anticoagulant, antiviral, antimicrobial, antispasmodic, anti-inflammatory, antimutagenic, antipyretic, and analgesic activities[5,6]. These active components are known to have digestive, antiflatulent, and carminative properties[7]. Fennel is also considered a potential source of natural phytochemicals, particularly antioxidants[8]. Furthermore, it may be used as a therapeutic agent to alleviate heat stress and related disorders[9].

Dill (*Anethum graveolens* L.) is one of the beneficial spices and medicinal plants because of its essential oils. Essential oil is present in its leaves, stems, flowers, fruits and seeds. Therefore, improving our knowledge of its benefits based on scientific studies is essential for enhancing its potential applications in medicine. Dill is an aromatic annual herb belonging to the Apiaceae family (Umbelliferae), native to the Mediterranean Basin and western Asia. The scientific name *Anethum* is derived from the Greek word *anethon*, whereas the common name dill is derived from the Scandinavian words *dylla* or *dilla*, which likely mean "to soothe"[10].

Dill also contains several saturated and unsaturated fatty acids, including lauric acid (1.29%), stearic acid (0.9 to 3.86%), capric acid (5.97%), myristic acid (0.08 to 0.25%), palmitic acid (2.31 to 4.66%), oleic acid (36.38 to 53.87%), linolenic acid (0.26 to 0.40%), linoleic acid (5.8 to 45.13%), palmitoleic acid (0.2%), eicosenoic acid (0.04%) and arachidonic acid (0.1 to 1.32%)[11]. Several phenolic acids, including vanillic acid, caffeic acid, protocatechuic acid, picomatic acid, ferulic acid, chlorogenic acid, syringic acid, rosmarinic acid, ocomaric acid and trans-cinnamic acid, have also been identified in ethanol extracts of dill[11,12]. These active compounds have demonstrated diverse biological activities, including antimicrobial, antifungal, antioxidant, insecticidal, anti-inflammatory, anticonvulsant, antidiabetic, anticancer, anticholesterol and antibacterial activities, particularly against harmful bacteria such as *Escherichia coli*, *Salmonella* and *Clostridium*[13].

MATERIALS AND METHODS

Experimental design and birds: This research was conducted at the poultry farm of the Department of Animal Production, College of Agriculture and Forestry, University of Mosul, from September 26 to October 31, 2025. A total of 320 one-day-old Japanese quails of two strains, brown and black, were used, with 160 birds from each strain. The chicks were allocated to four dietary treatments, each comprising 40 chicks, with four replicates of 10 chicks per treatment. The treatments were administered throughout the 35-day rearing period as follows: Treatment 1 was the control, Treatment 2 was supplemented with fennel seeds at 0.4 g/kg feed, Treatment 3 was supplemented with dill seeds at 0.4 g/kg feed and Treatment 4 was supplemented with a combination of fennel and dill seeds at 0.2 g/kg feed each.

The poultry house was equipped with the necessary facilities for ventilation, temperature control and lighting. The building was cleaned and disinfected before the beginning of the experiment. A preventive health program was implemented to protect the chicks from diseases throughout the rearing period and the necessary vaccines and vitamins were administered.

Diet and management: A diet with a single level of metabolizable energy and crude protein was used during the starter and grower stages and was provided to the birds throughout the 35-day experimental period. Feed and water were provided *ad libitum* throughout the experiment. The diet contained 24.10% crude protein and 2,910 kcal/kg

Table 1: Feed Components and calculated chemical analysis

The components	Percentage	Calculated chemical analysis	Value
Yellow corn	39.00	ME(KCal/kg diet)	2910.00
Soybean meal	36.50	Crude protein (%)	24.10
Sunflower oil	2.20	Crude fiber (%)	3.68
Wheat	13.30	Ash(%)	5.99
Protein center	8.00	Ether extract (%)	4.16
Limestone	0.50	Soluble carbohydrates (%)	51.27
Vitamins and minerals	0.25	Calcium (%)	1.09
Table salt	0.25	Available phosphorus (%)	0.44
Total	100.00	Lepsin (%)	1.35
		Methionine	0.58

metabolizable energy, as shown in Table 1, according to Al-Azzawi (2004). The diets were formulated with consideration of the birds' energy and protein requirements as recommended by the NRC[14].

Measurements: The chicks were weighed at the beginning of the experiment, at the end of the third week and at the end of the fifth week to determine live body weight and body weight gain per bird. Feed consumption was determined for each replicate and the feed conversion ratio was calculated. Mortality was recorded daily throughout the experimental period. At the end of the experiment, six birds from each treatment were slaughtered to determine dressing percentage.

Statistical analysis: The data were statistically analyzed using the SAS[15] statistical software package (SAS Institute, 2000) according to a completely randomized design. The statistical model used was:

$$Y_{ijk} = \mu+H_1+T_j+(HT)_{ij}+e_{ijk}$$

Where:

Y_{ijk} : Observation of bird k belonging to strain I and treatment j
μ : Overall mean
H_i : Effect of strain i
T_j : Effect of treatment j
$(HT)_{ij}$: Interaction effect between strain I and treatment j
e_{ijk} : Random experimental error

When significant differences were detected among treatment means, Duncan's multiple range test was used to compare the means.

RESULTS AND DISCUSSION

Live body weight: Table 2 shows the effects of strain and dietary supplementation on live body weight in the two Japanese quail strains. A significant effect of strain was observed, with the black strain having a greater live body weight than the brown strain at 1 day of age and at 3 and 5 weeks of age. Regarding the effect of dietary supplementation, no significant differences were observed among treatments at 1 day of age. At 3 weeks of age, significant differences were observed among dietary treatments, with the fennel-supplemented and fennel-dill combination treatments producing greater live body weights than the control and dill-supplemented treatments. At 5 weeks of age, the fennel-supplemented treatment was significantly superior to the other dietary treatments.

The interaction between strain and dietary supplementation showed a numerical advantage for the combination of fennel supplementation and the black strain at 1 day of age, which had a greater live body weight than the other combinations. Similarly, the control and dill-supplemented treatments in the black strain were numerically greater than the corresponding treatments in the brown strain. At 3 weeks of age, the control treatment in the black strain and the fennel-supplemented treatment in both strains were significantly superior to the other treatment combinations. At 5 weeks of age, fennel supplementation produced the greatest live body weight in both strains, followed by dill supplementation and the fennel-dill combination, with these treatments generally exceeding the control treatment.

The greater live body weight observed in the black strain may be related to differences in genetic background between the two strains. Previous studies have reported differences in productive and physiological traits among quail genetic lines, although such differences may vary according to genetic background, rearing conditions and selection history[16,17]. Feather color itself is not necessarily the direct determinant of productive performance; rather, genes associated with pigmentation may be linked to genes involved in growth, metabolism and immune responses. Differences in melanin pigmentation and associated physiological processes may therefore contribute to variation in growth performance between black and brown quails. Haqani *et al.*[18] reported

Table 2: Live body weight of quails at 1 day and 3 and 5 weeks of age under different experimental treatments (mean±standard error)

Treatment		Live body weight (g/bird) 1 day	3 weeks	5 weeks
Effect of strain				
Brown quail		9.18±0.21^{b}	114.87±0.93^{b}	203.89±6.65^{b}
Black quail		10.37±0.25^{a}	116.58±1.06^{a}	213.77±2.36^{a}
The effect of adding fennel and dill seeds and their combination				
	zero	9.37±0. 73^{a}	115.34±1.45^{b}	189.94±2.07^{c}
	0.4 g fennel seeds	10.01±0.37^{a}	119.87±1.07^{a}	220.72±0.92^{a}
	0.4 g dill seeds	10.13±0 .39^{a}	113.67±0.68^{b}	211.85±1.32^{b}
	0.2 g fennel seeds + 0.2 g dill seeds	9.62±0.35^{a}	112.86±1.14^{a}	212.81±2.00^{b}
The Effect of interaction between strain and level of addition of fennel, dill seeds and their mixture				
Brown quail	Zero	9.25±0.36^{c}	112.09±0.35^{c}	198 .21±0.34^{c}
	0.4 g fennel seeds	9.50±0.37^{b}	118.06±0.63^{b}	219.67±0.70^{a}
	0.4 g dill seeds	9.35±0.83^{c}	112.48±0.24^{c}	209.22±0.32^{b}
	0.2 g fennel seeds + 0.2 g dill seeds	9.50±0.07^{b}	113.01±0.37^{c}	208.47±0.02^{b}
Black quail	Zero	10.25±0 .67^{a}	117.87±0.68^{b}	201.66±0.34^{c}
	0.4 g fennel seeds	11.00±0.34^{a}	121.62±0.06^{a}	221.79±0.37^{a}
	0.4 g dill seeds	10.50±9.63^{ab}	114.87±0.69^{c}	214.49±0.32^{b}
	0.2 g fennel seeds + 0.2 g dill seeds	9.75±0.76^{ab}	114.51±0.80^{c}	217.16±0.02^{b}

Means with different superscript letters within the same column indicate statistically significant differences at the 5% probability level ($P < 0.05$)

associations between melanin pigmentation and physiological processes related to energy metabolism and growth. Differences in behavioral activity and feed consumption between strains may also contribute to variation in productive performance. Elkhaiat *et al.*[19] reported differences among quail strains in productive and reproductive traits, including feed consumption, fertility and egg production.

The improvement in live body weight associated with fennel seed supplementation may be attributed to the nutritional and biologically active components of fennel seeds. Fennel contains protein, fat, carbohydrates and minerals such as calcium, phosphorus, iron, zinc and magnesium[20], as well as fatty acids, particularly linoleic, linolenic, oleic and palmitic acids[21]. Fennel also contains biologically active compounds and essential oils, including anethole and estragole, which may stimulate digestive activity by enhancing bile secretion and the activity of digestive enzymes such as protease, lipase, amylase and maltase[22]. These effects may contribute to improved digestion and nutrient utilization and, consequently, greater body weight.

Ragab[23], Mohammed and Abbas[24] and Lemrabt *et al.*[25] reported improvements in feed consumption, feed conversion ratio, body weight and body weight gain following the addition of fennel seeds to broiler diets. Similarly, Nassar *et al.*[26] reported that dietary supplementation with fennel seeds may be a useful nutritional strategy for enhancing poultry production.

Weight gain: Table 3 shows the effects of strain and dietary supplementation on weight gain during the different experimental periods. A comparison between the brown and black strains revealed a significant advantage for the black strain during the first period, whereas no significant differences between strains were observed during the subsequent periods.

Regarding dietary supplementation, significant improvements in weight gain were observed with fennel supplementation and the fennel-dill combination compared with the other treatments during the first period. During the second and third periods, fennel supplementation significantly increased weight gain compared with the other dietary treatments.

The interaction between strain and dietary supplementation also affected weight gain. During the first period, the black strain receiving fennel supplementation had significantly greater weight gain than the other treatment combinations. The brown strain receiving fennel supplementation and the black strain receiving the fennel-dill combination also showed greater weight gain than the dill-supplemented treatments. During the second period, fennel supplementation in the black strain resulted in significantly greater weight gain than the other treatment combinations. The black strain receiving the fennel-dill combination also exceeded the dill-supplemented treatments in both strains. During the third period, fennel supplementation in the black strain produced significantly greater weight gain than the control and dill-supplemented treatments.

Table 3: Weight gain of quails during 1 to 3, 4 to 5 and 1 to 5 weeks of age under different experimental treatments (Mean±standard error).

Treatment		Average of weight gains (g/bird)		
		1-3 weeks	4-5 weeks	1-5 weeks
Effect of strain				
Brown quail		63.92±0.51^{b}	73.76±0.61^{a}	153.60±0.92^{a}
Black quail		65.98±0.75^{a}	74.06±74.38^{a}	158.20±1.16^{a}
The effect of adding fennel and dill seeds and their combination				
	Zero	64.02±0.83^{bc}	72.84±0.66^{bc}	153.08±0.78^{b}
	0.4 g fennel seeds	67.76±0.88^{a}	77.05±0.42^{a}	161.01±1.12^{a}
	0.4 g dill seeds	62.55±0.39^{c}	71.68±0.47^{c}	154.45±134^{b}
	0.2 g fennel seeds + 0.2 g dill seeds	65.44±0.75^{b}	74.03±0.74^{b}	155.07±1.85^{b}
The Effect of interaction between strain and level of addition of fennel, dill seeds and their mixture				
Brown quail	Zero	62.44±0.06^{c}	72.48±0.65^{bc}	151.99±0.64^{d}
	0.4 g fennel seeds	66.21±0.32^{b}	76.89±0.63^{a}	158.85±1.02^{ab}
	0.4g dill seeds	62.52±0.33^{c}	72.04±0.70^{c}	152.32±0.32^{cd}
	0.2g fennel seeds + 0.2 g dill seeds	64.49±0.83^{bc}	73.30±0.37^{bc}	151.24±0.62^{d}
Black quail	Zero	65.59±0.17^{b}	73.25±0.68^{bc}	154.16±0.34^{cd}
	0.4 g fennel seeds	69.31±0.24^{a}	77.21±0.66^{a}	163.15±0.37^{a}
	0.4 g dill seeds	62.57±0.33^{c}	71.32±0.69^{c}	156.59±0.32^{cb}
	0.2 g fennel seeds + 0.2 g dill seeds	66.47±0.46^{b}	74.86±0.70 ^{ab}	158.88±0.02 ^{ab}

Means with different superscript letters within the same column indicate statistically significant differences at the 5% probability level (P < 0.05)

Table 4: Feed consumption of quails during 1 to 3, 4 to 5 and 1 to 5 weeks of age under different experimental treatments (mean±standard error).

Treatment		Weekly feed intake (g/bird)		
		1-3 weeks	4-5 weeks	1-5 weeks
Effect of strain				
Brown quail		162.21±3.32^{a}	287.32±1.75^{a}	409.43±1.43^{a}
Black quail		159.04±0.58^{a}	268.62±1.12^{b}	381.42±1.76^{a}
The effect of adding fennel and dill seeds and their combination				
	Zero	164.69±1.24^{a}	280.72±1.15^{a}	412.35±1.79^{a}
	0.4 g fennel seeds	159.29±0.87^{a}	278.33±0.27^{a}	403.19±1.22^{a}
	0.4 g dill seeds	164.94±1.04^{a}	280.43±0.47^{a}	414.50±1.92^{a}
	0.2 g fennel seeds+0.2 g dill seeds	158.44±0.93^{a}	279.54±0.67 ^{a}	409.18±1.83 ^{a}
The Effect of interaction between strain and level of addition of fennel, dill seeds and their mixture				
Brown quail	Zero	163.61±0.96^{a}	283.80±0.25^{a}	410.36±0.64^{a}
	0.4g fennel seeds	160.94±0.80 ^{a}	281.44±0.83^{a}	406.52±0.42^{a}
	0.4 g dill seeds	159.64±0.73^{a}	282.34±0.80^{a}	411.32±0.22^{a}
	0.2 g fennel seeds + 0.2 g dill seeds	158.21±0.76^{a}	283.54±0.37^{a}	409.61±0.52^{a}
Black quail	Zero	158.69±0.67^{a}	274.71±0.71^{a}	396.88±0.64^{a}
	0.4 g fennel seeds	157.72±0.94^{a}	273.47±0.56^{a}	392.31±0.37^{a}
	0.4 g dill seeds	159.84±0.33^{a}	274.52±0.09^{a}	392.48±0.82^{a}
	0.2 g fennel seeds + 0.2 g dill seeds	159.91±0.03 ^{a}	274.08±0.30^{a}	395.30±0.42^{a}

Means with different superscript letters within the same column indicate statistically significant differences at the 5% probability level (P < 0.05)

The greater weight gain associated with fennel supplementation may be related to the presence of essential oils and other phytochemicals that can influence digestive function and nutrient utilization. The observed response is consistent with previous reports of improved growth performance following the incorporation of fennel into poultry diets[23-26].

Feed consumption: Table 4 shows the effects of strain and dietary supplementation on feed consumption. A significant effect of strain was observed, with the brown strain having greater feed consumption than the black strain. No significant differences were detected among the dietary treatments. Similarly, no significant interaction was observed between strain and dietary supplementation.

Table 5: Feed conversion ratio (kg feed/kg weight gain) of quails during 1 to 3, 4 to 5 and 1 to 5 weeks of age under different experimental treatments (Mean±standard error)

		Feed conversion efficiency (kg feed intake/ kg weight gain)		
Treatment		1-3 weeks	4-5 weeks	1-5 weeks
Effect of strain				
Brown quail		2.570±0.06^{b}	3.71±0.05^{a}	2.66±0.03^{b}
Black quail		2.440±0.03^{a}	3.67±0.04^{a}	2.41±0.02^{a}
The effect of adding fennel and dill seeds and their combination				
	Zero	2.620±0.03^{b}	3.89±0.05^{b}	2.72±0.02^{c}
	0.4 g fennel seeds	2.470±0.01^{a}	3.65±0.04^{a}	2.55±0.03^{a}
	0.4 g dill seeds	2.640±0.07^{b}	3.86±0.01^{b}	2.66±0.05^{b}
	0.2 g fennel seeds + 0.2 g dill seeds	2.59±0.06^{b}	3.68±0.01^{a}	2.63±0.03^{b}
The Effect of interaction between strain and level of addition of fennel, dill seeds and their mixture				
Brown quail	Zero	2.64±0.04^{b}	3.80±0.02^{a}	2.69±0.07^{c}
	0.4 g fennel seeds	2.56±0.02^{ab}	3.63±0.01^{a}	2.60±0.06^{b}
	0.4 g dill seeds	2.65±0.03^{b}	3.78±0.07^{a}	2.66±0.05^{c}
	0.2 g fennel seeds + 0.2 g dill seeds	2.62±0.06^{b}	3.69±0.03^{a}	2.64±0.02^{c}
Black quail	Zero	2.53±0.05^{ab}	3.78±0.08^{a}	2.56±0.08^{b}
	0.4 g fennel seeds	2.45±0.06^{a}	3.66±0.06^{a}	2.48±0.07^{a}
	0.4 g dill seeds	2.54±0.03^{ab}	3.76±0.05^{a}	2.53±0.04^{ab}
	0.2 g fennel seeds + 0.2 g dill seeds	2.51±0.06^{ab}	3.67±0.07^{a}	2.52±0.04^{ab}

Means with different superscript letters within the same column indicate statistically significant differences at the 5% probability level ($P < 0.05$)

The greater feed consumption of the brown strain, despite its lower live body weight compared with the black strain, indicates that differences in feed intake alone may not explain the differences in growth performance between the two strains. The absence of significant differences among dietary treatments suggests that the improvements in body weight and weight gain observed with fennel supplementation were not necessarily attributable to increased feed consumption, but may have resulted from improved nutrient utilization and digestive efficiency.

Feed conversion ratio: Table 5 shows the effects of strain and dietary supplementation on feed conversion ratio in the two Japanese quail strains. Regarding the effect of strain, the brown strain exhibited a significantly improved feed conversion ratio compared with the black strain during the first and third periods, whereas no significant difference was observed between strains during the second period.

Regarding dietary supplementation, the control and dill-supplemented treatments showed significantly improved feed conversion ratios during the first and second periods compared with the other treatments. During the third period, the control treatment produced the most favorable feed conversion ratio, followed by the fennel-dill combination and dill-supplemented treatments, whereas the fennel-supplemented treatment had the least favorable feed conversion ratio.

The interaction between strain and dietary supplementation was also significant during some experimental periods. During the first period, the control, dill-supplemented and fennel-dill combination treatments in the brown strain showed significantly improved feed conversion ratios compared with the fennel-supplemented treatment in the black strain. No significant differences were observed among the treatment combinations during the second period. During the third period, the control, dill-supplemented and fennel-dill combination treatments produced significantly improved feed conversion ratios compared with the remaining treatment combinations.

The improved feed conversion observed with dill supplementation may be associated with the biologically active compounds present in dill. Dill contains essential oils, fatty acids, flavonoids and phenolic compounds that may influence digestive processes, nutrient utilization and intestinal microbial activity[11-13]. Its volatile compounds, including carvone and limonene, may stimulate digestive secretions and enhance feed utilization. Alagawany *et al.*[27] reported that aromatic plants and their bioactive compounds can influence digestive enzyme activity and intestinal health in poultry.

Mortality rate and dressing percentage: Table 6 shows the effects of strain and dietary supplementation on mortality rate and dressing percentage. A significant effect of strain was

Table 6: Mean final body weight and mortality rate of quails at 5 weeks of age under different experimental treatments (mean±standard error)

Treatment		Dressing percentage	Mortality percentage
Effect of strain			
Brown quail		65.71±0.73^{b}	2.43±0.05^{a}
Black quail		68.51±0.84^{a}	2.32±0.09^{a}
The effect of adding fennel and dill seeds and their combination			
	Zero	62.20±0.74^{c}	2.44±0.07^{b}
	0.4 g fennel seeds	67.65±0.98^{a}	2.31±0.04^{a}
	0.4 g dill seeds	65.25±0.42^{b}	2.59±0.07^{c}
	0.2 g fennel seeds + 0.2 g dill seeds	65.81±1.20^{b}	2.36±0.02^{b}
The Effect of interaction between strain and level of addition of fennel, dill seeds and their mixture			
Brown quail	Zero	63.69±0 .40^{d}	2.43±0.09^{b}
	0.4 g fennel seeds	69.45±1.32^{b}	2.31±0.07^{b}
	0.4 g dill seeds	64.80±0.56^{cd}	2.67±0.09^{c}
	0.2 g fennel seeds + 0.2 g dill seeds	65.91±0.72^{c}	2.34±0.02^{bc}
Black quail	Zero	64.33±0.40^{cd}	2.75±0.09^{c}
	0.4g fennel seeds	73.40±0.29^{a}	2.07±0.07^{a}
	0.4 g dill seeds	66.55±0.97^{c}	2.19±0.09^{a}
	0.2 g fennel seeds + 0.2 g dill seeds	69.75±0.85^{b}	2.28±0.04^{b}

Means with different superscript letters within the same column indicate statistically significant differences at the 5% probability level ($P < 0.05$)

observed for dressing percentage, with the black strain having a higher dressing percentage than the brown strain. However, strain had no significant effect on mortality rate.

Regarding dietary supplementation, dressing percentage was significantly higher in the fennel-supplemented treatment than in the other treatments. Mortality rate was significantly lower in the dill-supplemented treatment than in the control, fennel-supplemented and fennel-dill combination treatments. The interaction between strain and dietary supplementation significantly affected the measured traits. Dressing percentage was higher in both the brown and black strains receiving fennel supplementation than in the other treatment combinations. Mortality rate was significantly lower in the brown strain receiving dill supplementation and in the black strain receiving the control diet than in the other treatment combinations.

The favorable effects of dill supplementation on feed conversion ratio and mortality may be associated with its diverse bioactive constituents. Dill contains saturated and unsaturated fatty acids, including lauric acid (1.29%), stearic acid (0.9 to 3.86%), capric acid (5.97%), myristic acid (0.08 to 0.25%), palmitic acid (2.31 to 4.66%), oleic acid (36.38 to 53.87%), linolenic acid (0.26 to 0.40%), linoleic acid (5.8 to 45.13%), palmitoleic acid (0.2%), eicosenoic acid (0.04%) and arachidonic acid (0.1 to 1.32%)[11]. Several phenolic acids, including vanillic, caffeic, protocatechuic, picomatic, ferulic, chlorogenic, syringic, rosmarinic, ocomaric and trans-cinnamic acids, have also been identified in ethanol extracts of dill[11,12]. These compounds may contribute to the biological activity of dill and may influence metabolic processes and productive performance[13].

The addition of dill to quail diets may improve growth performance through several potential mechanisms. Its active compounds, including carvone, limonene, flavonoids, phenolic compounds and volatile oils, may improve digestion and feed utilization efficiency. Volatile oils and aromatic compounds can stimulate digestive secretions and intestinal enzyme activity. Studies in quail and other poultry have indicated that aromatic plants can increase the activities of digestive enzymes such as amylase, lipase and protease and may contribute to improved intestinal health[27]. The active compounds in dill may also act as appetite stimulants, enhance nutrient absorption and inhibit potentially harmful microorganisms in the gastrointestinal tract[28].

Dill is also rich in flavonoids and phenolic compounds with antioxidant activity. These compounds can scavenge free radicals, reduce lipid peroxidation and help protect cellular membranes. Such antioxidant activity may contribute to maintaining hepatic function and, consequently, supporting growth and productive performance[29]. In addition, dill may influence the intestinal microbial community. Its volatile compounds have demonstrated antibacterial activity against microorganisms such as *Escherichia coli* and *Salmonella*[30]. By potentially reducing the proliferation of harmful bacteria and competition for nutrients in the intestine, these compounds may support intestinal health and nutrient absorption. Studies involving aromatic plants in quail have reported reductions in intestinal bacterial load and improvements in the intestinal microbial environment[31].

Furthermore, essential oils in dill, particularly carvone and limonene, may improve feed palatability and influence feed

intake, potentially contributing to body weight gain and daily weight gain[28]. However, these proposed mechanisms should be interpreted cautiously because the present study did not directly measure digestive enzyme activity, intestinal microbiota, antioxidant status, or nutrient digestibility. Therefore, further studies measuring these physiological and microbiological parameters are needed to establish the mechanisms underlying the observed effects of fennel and dill supplementation.

CONCLUSION

The present study demonstrated clear differences between the two Japanese quail strains and among dietary treatments in growth performance and carcass characteristics. The black strain generally exhibited greater live body weight, weight gain and dressing percentage, whereas the brown strain consumed more feed and showed a more favorable feed conversion ratio during some periods. Dietary fennel supplementation consistently improved live body weight and weight gain, particularly at 3 and 5 weeks of age, although it was associated with a less favorable feed conversion ratio. The fennel treatment also resulted in the highest dressing percentage. Dill supplementation reduced mortality rate and, together with the fennel-dill combination, generally produced better feed conversion than fennel alone. Overall, fennel supplementation showed potential for enhancing growth and carcass performance, whereas dill supplementation appeared beneficial for feed efficiency and survivability in Japanese quails.

RECOMMENDATIONS

Based on the findings of the present study, the black strain may be considered for breeding programs because of its superior live body weight, weight gain and dressing percentage compared with the brown strain. Dietary supplementation with fennel and dill seeds may also be considered as a nutritional strategy for improving growth performance and carcass characteristics. In particular, fennel supplementation enhanced live body weight, weight gain and dressing percentage, whereas dill supplementation was associated with improved feed conversion ratio during certain production periods and reduced mortality. Further studies are recommended to determine the optimal inclusion levels and combinations of fennel and dill seeds and to evaluate their effects under different production conditions.

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