

Effects of sex and bay laurel (*Laurus nobilis* L.) supplementation on growth performance, carcass characteristics, digestive organs, and biochemical parameters in japanese quails (*Coturnix coturnix japonica* Temminck & Schlegel)

Efectos del sexo y la suplementación con laurel (*Laurus nobilis* L.) sobre el rendimiento de crecimiento, características de la canal, órganos digestivos y parámetros bioquímicos en codornices japonesas (*Coturnix coturnix japonica* Temminck & Schlegel)

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ABSTRACT

This study explores the incorporation of bay laurel into the diet of Japanese quails as a natural alternative to synthetic additives. The aim is to promote quail growth while evaluating the effects of bay laurel supplementation on carcass traits, digestive organs, and blood biochemistry results. Initially, 208 unsexed chicks were fed a standard diet without bay laurel for seven days. They were then divided into four groups: 0%, 1%, 2%, and 3% bay laurel, with each group having four replicates of 13 quails. The study found that 3% bay laurel supplementation increased body weight at 42 days ($P = 0.019$) and average daily gain during the finishing phase ($P = 0.002$). Groups fed 2% and 3% bay laurel showed a decrease in feed intake ($P = 0.022$) and feed conversion ratio during the growth phase ($P = 0.01$) and higher carcass yield ($P = 0.013$). Additionally, 3% bay laurel increased intestine weight ($P = 0.006$) and cecal length ($P < 0.0001$). All bay laurel supplementation levels (1%, 2%, and 3%) produced reductions in blood glucose, triglycerides, and total cholesterol ($P < 0.0001$). bay laurel addition did not have an effect on other biochemical parameters ($P > 0.05$). Sex effects were significant throughout the experimental period, with females demonstrating superior body weight and average daily gain ($P < 0.0001$). Males exhibited higher carcass yield ($P < 0.0001$) and heart proportion ($P < 0.0001$), while females showed higher triglycerides ($P < 0.0001$), total protein ($P = 0.007$), and calcium levels ($P < 0.0001$). The bay laurel \times sex interactions revealed differences in total cholesterol ($P = 0.004$), heart proportion ($P = 0.013$), and intestine weight ($P = 0.010$). The addition of 3% bay laurel to quail feed results in better growth performance, carcass yield, intestinal development, and biochemical parameters.

Key words: Feed additive; digestive health; blood metabolites

RESUMEN

Este estudio explora la incorporación de laurel de bahía en la dieta de codornices japonesas como una alternativa natural a los aditivos sintéticos. El objetivo es promover el crecimiento de las codornices mientras se evalúan los efectos de la suplementación con laurel de bahía sobre las características de la canal, los órganos digestivos y los resultados de la bioquímica sanguínea. Inicialmente, 208 pollitos sin sexar fueron alimentados con una dieta estándar sin laurel de bahía durante siete días. Luego se dividieron en cuatro grupos: 0%, 1%, 2% y 3% de laurel de bahía, con cada grupo teniendo cuatro réplicas de 13 codornices. El estudio encontró que la suplementación con 3% de laurel de bahía aumentó el peso corporal a los 42 días ($P = 0,019$) y la ganancia diaria promedio durante la fase de finalización ($P = 0,002$). Los grupos alimentados con 2% y 3% de laurel de bahía mostraron una disminución en el consumo de alimento ($P = 0,022$) y en el índice de conversión alimenticia durante la fase de crecimiento ($P = 0,01$) y un rendimiento de canal mayor ($P = 0,013$). Además, el 3% de laurel de bahía aumentó el peso del intestino ($P = 0,006$) y la longitud cecal ($P < 0,0001$). Todos los niveles de suplementación con laurel de bahía (1%, 2% y 3%) produjeron reducciones en la glucosa sanguínea, los triglicéridos y el colesterol total ($P < 0,0001$). La adición de laurel de bahía no tuvo un efecto sobre otros parámetros bioquímicos ($P > 0,05$). Los efectos del sexo fueron durante todo el período experimental, con las hembras demostrando un peso corporal y ganancia diaria promedio superiores ($P < 0,0001$). Los machos exhibieron un mayor rendimiento de canal ($P < 0,0001$) y proporción de corazón ($P < 0,0001$), mientras que las hembras mostraron mayores niveles de triglicéridos ($P < 0,0001$), proteína total ($P = 0,007$) y calcio ($P < 0,0001$). Las interacciones laurel de bahía \times sexo revelaron diferencias en el colesterol total ($P = 0,004$), la proporción de corazón ($P = 0,013$) y el peso del intestino ($P = 0,010$). La adición de 3% de laurel de bahía al alimento de las codornices resulta en un mejor rendimiento de crecimiento, rendimiento de canal, desarrollo intestinal y parámetros bioquímicos.

Palabras claves: Aditivo alimenticio; salud digestiva; metabolitos sanguíneos

INTRODUCTION

The Japanese quail (*Coturnix coturnix japonica* Temminck & Schlegel) farming industry represents a new development in poultry production [1, 2, 3]. The birds demonstrate excellent suitability for international poultry operations because they serve as essential meat producers in Europe and egg producers in Japan and dual-purpose animals throughout Asia [4].

The provision of animal protein through quail farming helps sub-Saharan Africa enhance its food security [5]. The Japanese quail stands as one of the smallest bird species which offers multiple benefits for commercial farming operations. The fast growth rate of quail birds combined with their short breeding period and high egg production makes them suitable for commercial purposes [2, 3].

The requirements for quail feed and housing space are lower than those of other poultry species [6] and they possess natural disease resistance [7]. The quail farming industry operates at a low cost because of reduced production expenses [4, 6] which has led to business expansion [4].

Growing health awareness has increased consumer preference for natural and safe food [8]. The European Union responded by prohibiting antibiotic growth promoters in poultry production in 2006 [9] to combat antibiotic resistance and toxicity and residue accumulation and pollution issues [10].

Scientists started searching for natural alternatives after the ban [9, 10]. The promising natural feed additives known as phytobiotics show promise because they derive from plants and possess minimal toxicity [11]. The process of adding these ingredients to feed remains simple.

The addition of these ingredients results in improved feed efficiency, enhanced digestion and nutrient absorption, improved immune function, and a reduced risk of antibiotic resistance development. The additives help decrease oxidative stress and inflammation levels in the body [12].

The natural substance Bay laurel (*Laurus nobilis*) (BL) also known as sweet bay or Roman laurel or noble laurel [13] shows potential as a natural alternative. The This Mediterranean evergreen shrub belongs to the Lauraceae family [13, 14] and grows commercially in Asia and Europe and America [13].

The leaves from BL served as symbols of peace and victory which ancient cultures used to crown their military and athletic champions [14]. The plant has been used in traditional medicine for treating various health issues including gastrointestinal problems and respiratory infections and amenorrhoea and colic and different types of pain [13].

Today, BL maintains an important role in both cuisine and health. Its leaves remain essential in Mediterranean gastronomy [14]. The leaves of BL serve dual purposes in food preparation by enhancing flavor and offering health benefits, such as improved digestion, reduced stress, and strengthened immune function [15].

Bay laurel therapeutic effects come from phenolic compounds and flavonoids with antioxidant activity [16]. The plant shows

antimicrobial, hypoglycemic, and anti-inflammatory properties, plus emetic, stimulant, and diuretic effects [13, 15], and protects against gastrointestinal damage [15].

This study evaluated sex and dietary BL influence growth, carcass characteristics, digestive organs, and biochemical parameters in Japanese quail, to provide a natural alternative to antibiotic growth promoters and consequently mitigate antimicrobial resistance.

MATERIALS AND METHODS

Animals and diets

The study was conducted at the Institute of Veterinary Sciences, University Frères Mentouri-Constantine 1, in Algeria. Fertile quail eggs were incubated (Pouss Afric, capacity: 2,500 eggs, Algeria), and the chicks were initially fed a standard growing diet without BL for seven days (d) to prevent potential negative effects from anti-nutritional factors. At 7 d old, 208 unsexed Japanese quails were individually weighed, identified, and randomly assigned to four dietary treatment groups supplemented with BL at 0 (control), 1, 2, and 3%.

Each treatment consisted of four replicates of 13 quails. At 21 d of age, sex determination was performed based on plumage appearance and cloacal structure, revealing 112 females and 96 males. The sex ratio was relatively balanced across all experimental groups (females: 28, 26, 30, 28; males: 24, 26, 22, 24 for 0, 1, 2, and 3% BL, respectively). The quails were housed in galvanized cages and raised in a controlled environment with continuous lighting and unrestricted access to food and water to promote uniform growth. The rearing process adhered to local guidelines and ethical standards, ensuring compliance with established norms for animal care and welfare throughout the study.

The BL used in the study was sourced from local markets. It was carefully dried in the shade to preserve its properties, then ground into a fine powder before being incorporated into the quail feed. Feed formulations were made using the Windows User-Friendly Feed Formulation tool (WUFFDA ver. 1.02, 2004), according to the standards established by the National Research Council (NRC) [17]. The specific dietary compositions for each experimental group are displayed in TABLE I, whereas the chemical composition of the BL is provided in TABLE II.

Performance measurement

Body weight was recorded weekly before morning feeding using a precision digital scale (Princeton instruments, model YP601N, accuracy: 0.1 g, maximum capacity: 600 g, USA). Daily feed consumption per cage enabled calculation of feed intake (FI) and feed conversion ratio (FCR) at the group level. Average daily gain (ADG) was determined for males, females, and combined populations during growing and finishing periods. Daily mortality was recorded and incorporated into performance index calculations.

Slaughter and post-mortem analyses

At 42 d of age, 5 males and 5 females were randomly drawn from each experimental group and individually weighed. These quails were isolated and subjected to a 12-h water-only diet. Euthanasia was performed by cutting the jugular vein. Plumage,

TABLE I
Ingredients and nutrient composition of diets during grower and finisher periods

Ingredients (g·kg ⁻¹ of feed)	Starter				Finisher			
	0% BL	1% BL	2% BL	3% BL	0% BL	1% BL	2% BL	3% BL
Yellow corn	51.25	50.85	50.30	49.50	59.50	56.35	55.41	55.00
Soybean meal (48 %)	41.13	40.40	40.40	40.35	26.50	30.92	30.87	30.85
Wheat bran	5.87	6.00	5.55	5.40	12.25	9.98	9.97	9.40
Limestone (%)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Dicalcium Phosphate (%)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
MV premix* (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Bay leaf powder (%)	0	1	2	3	0	1	2	3
Total	100	100	100	100	100	100	100	100
Dry matter (%)	88.1	88.14	88.29	88.22	87.96	88.04	88.15	88.12
ME (Kcal·kg ⁻¹)	2800	2800	2800	2800	2800	2800	2800	2800
Proteins (%)	24	24	24.01	24.01	20.01	20	20	20
Fat (%)	2.53	3.54	3.53	3.51	2.89	3.69	3.68	3.67
Crude fiber (%)	3.38	3.44	3.47	3.53	3.69	3.63	3.70	3.72

ME: Metabolized Energy. *MV premix: Mineral-Vitamin supplement provided per kg of diet: Vitamin A: 3750.75 IU, Vitamin D3: 1249.875 IU, Vitamin E: 7.5 mg, Vitamin K3: 0.8 mg, Vitamin B1: 0.6425 mg, Vitamin B2: 0.0175 mg, Vitamin B6: 1.5 mg, Vitamin B12: 0.004675 mg, Niacin: 17.8 mg, Folic acid: 0.3125 mg, Pantothenic acid: 3.55 mg, Biotin: 0.05 mg, Choline: 150.4125 mg, Betaine: 87.4925 mg, Fe: 12.65 mg, Cu: 3.45 mg, Mn: 25.325 mg, Zn: 16.9 mg, Se: 0.1025 mg, Iode: 0.515 mg, Butylated hydroxyanisole (BHA): 0.05 mg, Ethoxyquin: 0.05 mg, Sepiolite: 7.5075 mg, DL Methionine: 413 mg, L-Lysine: 0.0125%

TABLE II
Chemical composition of bay laurel (g·kg⁻¹ dry matter)

Component	Content (%)
Moisture	18.1
Mineral matter	3.9
Crude protein	8.1
Crude fat	8
Crude fiber	9
Ca	0.89
Phosphore	0.1
Metabolised Energy (Kcal·kg ⁻¹)	2811.1

heads, viscera, and legs were discarded. Eviscerated carcasses were subsequently weighed, and the carcass yield was computed following the method of Brake *et al.* [18]:

$$\text{Dressing perc}\% = \left(\frac{\text{Empty carcass weight}}{\text{Live body weight}} \right) \times 100$$

The heart and abdominal fat, as well as various digestive organs, including the liver, gizzard, proventriculus, and intestine, were weighed using an analytical balance (KERN, model PLS, precision: 0.0001 g, capacity: 510 g, Germany). The relative weights of these organs were expressed as a percentage of total body weight. In addition, the lengths of the entire intestine and cecum were measured using a standard measuring tape and recorded to the nearest millimeter.

Blood samples were collected immediately post-euthanasia via the jugular vein using a glass funnel directly into heparinized tubes. Plasma was isolated by centrifugation at 0,805 G for 10 min (Sigma, model 1–6P, maximum speed: 2.837 G, Germany), and plasma samples were stored at –20°C until analysis (ENIEM,

model CF 1301, 350 L capacity, Algeria). The levels of glucose, triglycerides, albumin, total protein, aspartate aminotransferase, alanine aminotransferase, total cholesterol, urea, creatinine, and calcium were determined using a colorimetric method with commercial kits (Bio Lab®, France and Spinreact®, Spain) and a semi-automatic spectrophotometer (Mindray BA–88A, China).

Statistical analysis

Data were analyzed using the General Linear Model (GLM) procedure in Statistical Package for the Social Sciences version 25 (SPSS Inc., Chicago, IL, USA). Individual-level traits (body weight, ADG, absolute and relative organ weights, intestine and cecum lengths, and blood biochemical parameters) were subjected to a two-way analysis of variance, with dietary treatment (0%, 1%, 2%, and 3% BL) and sex (male and female) as the main effects. The Treatment × Sex interaction was included in the model to assess whether the effect of BL supplementation differed between sexes. The statistical model used was as follows:

$$Y_{ijk} = \mu + T_i + S_j + (T \times S)_{ij} + e_{ijk}$$

Where:

Y_{ijk} : Observed value in the *i*-th treatment of the *j*-th sex of the *k*-th individual,

μ : Overall mean,

T_i : Effect of treatment (*i*: 1 to 4),

S_j : Effect of sex (*j*: 1 and 2),

$(T \times S)_{ij}$: Interaction between treatment and sex,

e_{ijk} : Random error term.

Means were tested using Duncan's multiple range test [19]. Group-level parameters (FI and FCR), measured at the cage level, were analyzed using one-way ANOVA with treatment as the main factor. Statistical significance was declared at $P < 0.05$. Data are presented as means \pm standard deviation.

RESULTS AND DISCUSSION

Productive performance

TABLE III shows how quail body weight and ADG progress through different ages and BL dietary concentrations. The body weight measurements between d 7 and 35 showed no differences ($P > 0.05$) between treatment groups. The 3% BL group showed an increase in body weight compared to controls at d 42 ($P = 0.019$).

The growth phase showed no treatment effects ($P > 0.05$) for ADG, but the finishing phase showed improvements in ADG for both 2 and 3% BL groups compared to controls ($P = 0.002$). Similar results were obtained in research studies with Japanese quail [20, 21] and broiler chickens [22, 23] in which BL supplemented poultry had higher live weights and higher weight gains than those on control diets.

The experimental results also showed that female quails outperformed male quails in body weight and ADG measurements throughout both experimental phases ($P < 0.0001$). Chimezie *et al.*

[24] and Ibrahim *et al.* [25] confirm that female quails outperform male quails in terms of growth performance. Nariç and Genç [26] suggest that genetic elements and hormonal factors may also impact a bird's nutrient utilization, as well as its body growth.

Evaluation of the BL supplementation \times sex interaction revealed no statistical differences ($P > 0.05$).

Data presented in TABLE IV demonstrate that during the growth period, birds fed 2 and 3% BL diets exhibited lower FI and FCR values compared to controls ($P = 0.022$ and $P = 0.01$, respectively). The FI and FCR measurements between treatments showed no differences ($P > 0.05$) during the finishing phase.

In contrast to the findings of the present study, there are studies on broiler chickens that have documented that while higher doses of BL produce increases in FI, there are no changes to FCR across the entire rearing period [22]. Similarly, other studies document increases in FI without affecting FCR values [23]. The differences presented by these studies may be the result of differences in species, genetic lines, rearing environments and methods of BL administration.

Carcass traits

The research findings about BL dietary supplementation effects on carcass characteristics and abdominal fat and heart and liver weights appear in TABLE V. The experimental treatments did not produce any significant changes in either slaughter weight,

TABLE III
Impact of bay laurel dietary supplementation on the live body weight and average daily gain of quail across different ages

Treatments	Sex	Body weight (g)						ADG (g·d ⁻¹ ·bird ⁻¹)	
		Growing period			Finishing period			Growing period	Finishing period
		7 days old	14 days old	21 days old	28 days old	35 days old	42 days old		
0% BL	M	24.55 \pm 0.97	60.98 \pm 3.28	107.95 \pm 9.98	145 \pm 17.63	171.14 \pm 18.71	186.57 \pm 19.06 ^b	5.93 \pm 0.58	2.96 \pm 1.02
	F	25.22 \pm 3.00	71.22 \pm 2.48	116.64 \pm 11.07	161.09 \pm 19.72	188.04 \pm 26.26	228.78 \pm 26.53	6.32 \pm 0.58	4.83 \pm 1.01
1% BL	M	24.40 \pm 1.65	61.09 \pm 3.26	105 \pm 12.35	146.88 \pm 21.23	177.55 \pm 27.65	193.04 \pm 23.22 ^{ab}	5.89 \pm 0.79	3.29 \pm 0.59
	F	25.77 \pm 1.61	69.97 \pm 5.75	117.83 \pm 14.57	164.52 \pm 18.57	191.99 \pm 27.08	235.19 \pm 20.83	6.53 \pm 0.94	5.04 \pm 0.87
2% BL	M	24.21 \pm 1.03	62.78 \pm 4.59	108.10 \pm 11.20	149.53 \pm 13.50	175.99 \pm 16.94	197.98 \pm 16.94 ^a	5.99 \pm 0.77	3.46 \pm 0.46
	F	25.21 \pm 1.13	70.47 \pm 1.36	120.04 \pm 12.11	162.53 \pm 21	193.68 \pm 27.23	237.88 \pm 21.51	6.65 \pm 0.79	5.38 \pm 0.66
3% BL	M	23.50 \pm 1.43	62.07 \pm 2.37	111.25 \pm 11.03	155.11 \pm 14.83	181.78 \pm 13.02	202.96 \pm 17.11 ^a	6.26 \pm 0.70	3.41 \pm 0.63
	F	25.80 \pm 0.78	71.60 \pm 2.59	122.50 \pm 13.48	160.29 \pm 13.91	194.70 \pm 16.96	238.53 \pm 20.90	6.79 \pm 0.91	5.58 \pm 1.00
0% BL		24.88 \pm 2.23	66.10 \pm 5.92	112.29 \pm 11.32	153.05 \pm 20.22	179.59 \pm 31.26	207.68 \pm 31.26 ^b	85.80 \pm 8.57	6.13 \pm 0.61 ^b
1% BL		25.08 \pm 1.75	65.53 \pm 6.44	111.42 \pm 14.85	155.71 \pm 21.65	184.77 \pm 28.03	214.12 \pm 30.49 ^{ab}	87.04 \pm 12.93	6.22 \pm 0.92 ^{ab}
2% BL		24.65 \pm 1.18	66.15 \pm 5.22	113.33 \pm 12.95	155.23 \pm 18.20	183.73 \pm 23.52	215.44 \pm 27.49 ^{ab}	87.95 \pm 11.78	6.28 \pm 0.84 ^a
3% BL		24.49 \pm 1.65	66.19 \pm 5.36	116.11 \pm 13.32	157.35 \pm 14.51	187.37 \pm 16.03	218.32 \pm 25.77 ^a	90.93 \pm 11.69	6.49 \pm 0.83 ^a
M		24.16 \pm 1.33 ^b	61.77 \pm 3.53 ^b	108.14 \pm 11.23 ^b	149.23 \pm 17.05 ^b	176.64 \pm 19.64 ^b	195.33 \pm 19.77 ^b	84.35 \pm 10.16 ^b	6.02 \pm 0.72 ^b
F		25.49 \pm 1.89 ^a	70.79 \pm 3.51 ^a	119.05 \pm 12.81 ^a	162.17 \pm 18.38 ^a	191.90 \pm 24.73 ^a	234.80 \pm 22.67 ^a	91.88 \pm 11.44 ^a	6.56 \pm 0.81 ^a
Source of variation									
BL		0.576	0.292	0.149	0.653	0.318	0.019	0.081	0.002
Sex		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
BL \times Sex		0.098	0.338	0.853	0.358	0.954	0.863	0.821	0.658

M: male, F: female, BL: bay laurel, ADG: Average Daily Gain, BWG: Body Weight Gain. ^{a, b}: Means within a column with different superscript letters differ significantly ($P < 0.05$)

TABLE IV
Effects of different levels of bay laurel on quails' FI and FCR during growing and finishing periods

Treatments	FI (g·d ⁻¹)		FCR	
	Growing period	Finishing period	Growing period	Finishing period
0% BL	10.52 ± 0.39 ^b	27.31 ± 1.85	2.60 ± 0.09 ^b	10.41 ± 1.16
1% BL	9.94 ± 0.88 ^{ab}	27.95 ± 2.52	2.47 ± 0.22 ^{ab}	9.32 ± 1.19
2% BL	9.29 ± 0.11 ^a	27.07 ± 2.27	2.32 ± 0.10 ^a	9.64 ± 1.84
3% BL	9.42 ± 0.32 ^a	26.09 ± 1.90	2.23 ± 0.12 ^a	9.37 ± 2.21
P values	0.022	0.68	0.01	0.77

FI: Feed Intake (g·bird⁻¹), FCR: Feed Conversion Ratio, ^{a,b}: Means within a column with different superscript letters differ significantly ($P < 0.05$)

carcass weight, abdominal fat deposition, or heart and liver weights (absolute and relative), according to statistical analysis ($P > 0.05$), regardless of the supplementation levels tested.

However, the dressing percentage of quails receiving 2 and 3% BL supplementation was higher than the control group ($P = 0.013$). The 1% BL treatment group showed dressing percentage values that were statistically comparable ($P > 0.05$) to the control group and the 2 and 3% BL treatment groups.

The research results support Al Rubaei [21] who studied quails and found that 2% BL powder supplementation leads to better

carcass weight, yield, and major edible muscle proportions (breast, drumstick, and thigh), which is attributed to the strong positive correlation between live body weight and dressing percentage. Research has demonstrated that feeding quails medicinal plants and natural spices leads to better carcass attributes and meat quality [27].

The results of this study indicated that there were numerous differences in carcass measurement results determined by sex. The female quail carcasses had higher slaughter and carcass weights ($P < 0.0001$ and $P = 0.003$, respectively), as well as higher absolute and relative liver weights ($P < 0.0001$), compared to male quail carcasses. The male quail carcasses have higher carcass yield and heart proportion than the female quail carcasses ($P < 0.0001$). This supports Toriki *et al.* [28], indicating that male quail have more carcass efficiency than females because they tend to have lower body weights. Males in both cages and on the floor show greater efficiency in converting nutrients into lean tissue. The abdominal fat weight and weight percentage were similar for each sex ($P > 0.05$). This is consistent with Narinç and Genç's [26] findings on Japanese quail raised in typical farming conditions, which suggested that males and females would have equal abdominal fat accumulation.

Evaluation of the BL supplementation × sex interaction affects heart proportion ($P = 0.013$). BL supplementation increased relative heart weight in females, while no such effect was observed in males, indicating a sex-dependent response to dietary BL supplementation.

TABLE V
Effects of dietary bay laurel supplementation on carcass traits, abdominal fat, heart, and liver weights in Japanese quails

Treatments	Sex	Slaughter		Carcass		Abdominal fat		Heart		Liver	
		weight (g)	weight (g)	yield (%)	weight (g)	%	weight (g)	yield (%)	weight (g)	yield (%)	
0% BL	M	185.04 ± 13.08	131.24 ± 12.05	70.84 ± 2.06	0.52 ± 0.43	0.28 ± 0.24	1.62 ± 0.10	0.88 ± 0.09	3.88 ± 0.38	2.10 ± 0.26	
	F	227.40 ± 16.45	145.38 ± 12.16	63.97 ± 3.82	0.64 ± 0.38	0.28 ± 0.16	1.44 ± 0.15 ^b	0.63 ± 0.04 ^b	6.26 ± 0.76	2.76 ± 0.38	
1% BL	M	194.64 ± 17.03	142.58 ± 12.17	73.26 ± 1.13	0.75 ± 0.72	0.36 ± 0.35	1.60 ± 0.15	0.81 ± 0.07	4.02 ± 1.02	2.07 ± 0.63	
	F	227.78 ± 13.83	150.38 ± 9.80	66.03 ± 2.05	0.97 ± 0.90	0.43 ± 0.39	1.70 ± 0.12 ^a	0.78 ± 0.04 ^a	5.56 ± 0.80	2.59 ± 0.40	
2% BL	M	190.58 ± 12.59	138.86 ± 9.67	72.85 ± 0.74	0.79 ± 0.49	0.42 ± 0.27	1.64 ± 0.11	0.86 ± 0.05	3.66 ± 0.71	1.93 ± 0.41	
	F	227.00 ± 16.39	155.68 ± 11.28	68.62 ± 3.05	0.62 ± 0.64	0.26 ± 0.26	1.72 ± 0.19 ^a	0.76 ± 0.05 ^a	6.32 ± 1.56	2.77 ± 0.57	
3% BL	M	197.16 ± 26.25	144.92 ± 20.20	73.48 ± 1.33	0.69 ± 0.49	0.36 ± 0.27	1.64 ± 0.20	0.84 ± 0.06	3.62 ± 0.66	1.85 ± 0.28	
	F	228.24 ± 13.42	158.08 ± 9.40	69.38 ± 4.76	0.63 ± 0.39	0.28 ± 0.18	1.74 ± 0.18 ^a	0.76 ± 0.10 ^a	5.76 ± 0.50	2.54 ± 0.33	
0% BL		206.22 ± 26.35	138.31 ± 13.63	67.41 ± 4.63 ^b	0.58 ± 0.39	0.28 ± 0.19	1.53 ± 0.15	0.75 ± 0.14	5.07 ± 1.37	2.43 ± 0.46	
1% BL		211.21 ± 22.78	146.48 ± 11.20	69.64 ± 4.12 ^{ab}	0.86 ± 0.78	0.40 ± 0.35	1.65 ± 0.14	0.79 ± 0.06	4.79 ± 1.18	2.33 ± 0.57	
2% BL		208.79 ± 23.63	147.27 ± 13.29	70.74 ± 3.05 ^a	0.70 ± 0.55	0.34 ± 0.26	1.68 ± 0.15	0.81 ± 0.07	4.99 ± 1.81	2.35 ± 0.64	
3% BL		212.70 ± 25.58	151.50 ± 16.39	71.43 ± 3.93 ^a	0.66 ± 0.42	0.32 ± 0.22	1.69 ± 0.19	0.80 ± 0.09	4.69 ± 1.25	2.19 ± 0.46	
	M	191.8 ± 17.25 ^b	139.40 ± 13.98 ^b	72.6 ± 1.67 ^a	0.68 ± 0.51	0.35 ± 0.27	1.62 ± 0.14	0.85 ± 0.07 ^a	3.79 ± 0.69 ^b	1.99 ± 0.40 ^b	
	F	227.60 ± 13.85 ^a	152.38 ± 11.05 ^a	67.00 ± 3.94 ^b	0.71 ± 0.58	0.31 ± 0.25	1.65 ± 0.19	0.73 ± 0.08 ^b	5.97 ± 0.96 ^a	2.66 ± 0.41 ^a	

Source of variation

BL	0.832	0.143	0.013	0.754	0.822	0.112	0.319	0.750	0.674
Sex	< 0.0001	0.003	< 0.0001	0.879	0.625	0.621	< 0.0001	< 0.0001	< 0.0001
BL × Sex	0.883	0.876	0.423	0.880	0.824	0.155	0.013	0.531	0.875

M: male, F: female, BL: bay laurel. ^{a, b}: Means within a column with different superscript letters differ significantly ($P < 0.05$)

Digestive organs

The results in TABLE VI indicate that BL supplementation did not affect ($P>0.05$) the weights of proventriculus and gizzard organs. The intestinal weight of quails increased when they received 3% BL compared to 1% BL and control groups ($P = 0.006$) but not when compared to 2% BL ($P>0.05$).

These findings align with previous research on broiler chickens, which showed that BL supplementation led to increased villus length, crypt depth, and the villus-to-crypt depth ratio [22] and ileum and jejunum weight [23]. The beneficial morphological changes in the intestine result from multiple possible mechanisms.

The bioactive compounds in BL containing polyphenols, flavonoids and terpenes function as antioxidants, antimicrobials and anti-inflammatory agents [16, 29]. These compounds protect intestinal epithelial cells from oxidative stress which enables better tissue development and maintenance. Nafea *et al.* [30] found that adding 2–6 g·kg⁻¹ BL to broiler chicken feed reduced total bacterial counts and coliform counts in the chickens' feces. Intestinal health is largely determined by the appropriate number and distribution of gut-related bacteria within each species of chicken [31], with optimal gut health and microbiota balance being associated with greater feed utilization.

Increased absorptive surface area results in greater nutrient uptake, and balanced gut microbiota optimize nutrient digestibility and reduce the energy requirements for the control of pathogenic organisms [17, 31]. The polyphenols in the diet stimulate digestive

enzyme production [10], which leads to better nutrient absorption and results in better growth rates and lower FCR values for quails receiving 3% BL.

The study found that digestive organ development between male and female quails showed significant differences. The gizzard and proventriculus weights of female quails exceeded those of male quails ($P = 0.008$ and $P<0.0001$, respectively). The analysis of gizzard and proventriculus weights as a proportion of body weight showed no sex-related differences ($P>0.05$). Regarding the intestine, the absolute weight, relative weight, and length were highly higher ($P<0.0001$) in females compared to males.

The study found no variation ($P>0.05$) between males and females regarding their cecal length measurements. These findings align with previous studies by Alamuoye and Ojo [32] and Wegner *et al.* [33], who reported identical sex-related variations in organ dimensions. The reproductive needs of females lead to different organ development patterns because their bodies need to produce vitellogenin and they require more digestive power to support egg production. The study found a significant interaction between BL incorporation × sex only for intestinal weight measurements ($P = 0.010$), with females in the 3% BL group developing significantly larger intestines than males, indicating a sex-dependent response to dietary BL inclusion.

Biochemical parameters

The blood biochemical results from Japanese quails who received BL dietary supplements appear in TABLE VII. The

TABLE VI
Effects of dietary bay laurel supplementation on digestive tract organs in Japanese quails

Treatments	Sex	Gizzard		Proventriculus		Intestinal		Caecal	
		weight (g)	yield (%)	weight (g)	yield (%)	weight (g)	yield (%)	length (cm)	length (cm)
0% BL	M	3.70 ± 0.90	1.99 ± 0.45	1.40 ± 0.23	0.76 ± 0.14	6.30 ± 0.45	3.42 ± 0.39	59.60 ± 5.41	9.06 ± 0.95
	F	3.90 ± 0.12	1.71 ± 0.08	1.84 ± 0.55	0.80 ± 0.23	9.44 ± 1.02 ^b	4.14 ± 0.24	71.40 ± 4.03	8.80 ± 0.68
1% BL	M	3.74 ± 0.79	1.89 ± 0.32	1.52 ± 0.16	0.78 ± 0.14	6.66 ± 1.00	3.40 ± 0.57	58.80 ± 7.98	8.76 ± 0.53
	F	4.40 ± 0.88	2.03 ± 0.24	1.64 ± 0.46	0.75 ± 0.18	9.38 ± 2.68 ^b	4.33 ± 1.06	71.40 ± 4.66	8.88 ± 1.58
2% BL	M	3.64 ± 0.27	1.91 ± 0.11	1.48 ± 0.30	0.77 ± 0.12	7.04 ± 1.78	3.66 ± 0.73	57.00 ± 6.44	8.70 ± 1.49
	F	4.40 ± 0.32	1.94 ± 0.13	2.10 ± 0.26	0.92 ± 0.07	9.86 ± 1.37 ^b	4.33 ± 0.38	70.80 ± 4.65	8.78 ± 0.58
3% BL	M	3.86 ± 0.55	1.98 ± 0.22	1.58 ± 0.21	0.82 ± 0.07	6.70 ± 0.84	3.44 ± 0.35	59.60 ± 4.61	10.36 ± 1.86
	F	4.38 ± 0.39	1.92 ± 0.19	2.06 ± 0.15	0.90 ± 0.09	13.56 ± 1.50 ^a	4.38 ± 0.39	75.40 ± 4.82	12.40 ± 2.17
0% BL		3.80 ± 0.61	1.85 ± 0.34	1.62 ± 0.46	0.78 ± 0.18	7.87 ± 1.81 ^b	3.78 ± 0.48	65.50 ± 7.67	8.93 ± 0.79 ^b
1% BL		4.07 ± 0.86	1.96 ± 0.28	1.58 ± 0.33	0.77 ± 0.15	8.02 ± 2.39 ^b	3.86 ± 0.94	65.10 ± 9.06	8.82 ± 1.11 ^b
2% BL		4.02 ± 0.49	1.92 ± 0.11	1.79 ± 0.42	0.84 ± 0.12	8.45 ± 2.11 ^{ab}	3.99 ± 0.65	63.90 ± 8.99	8.74 ± 1.07 ^b
3% BL		4.12 ± 0.53	1.95 ± 0.20	1.82 ± 0.30	0.86 ± 0.09	10.13 ± 3.79 ^a	3.91 ± 0.60	67.50 ± 9.44	11.38 ± 2.19 ^a
	M	3.73 ± 0.62 ^b	1.94 ± 0.28	1.49 ± 0.22 ^b	0.78 ± 0.11	6.67 ± 1.07 ^b	3.48 ± 0.50 ^b	58.75 ± 5.82 ^b	9.22 ± 1.39
	F	4.27 ± 0.52 ^a	1.90 ± 0.20	1.91 ± 0.40 ^a	0.84 ± 0.16	10.56 ± 2.41 ^a	4.29 ± 0.57 ^a	72.25 ± 4.58 ^a	9.71 ± 2.05
Source of variation									
	BL	0.654	0.777	0.271	0.367	0.006	0.870	0.530	< 0.0001
	Sex	0.008	0.599	< 0.0001	0.173	< 0.0001	< 0.0001	< 0.0001	0.262
	BL × Sex	0.747	0.315	0.381	0.577	0.010	0.936	0.858	0.242

M: male, F: female, BL: bay laurel. ^{a, b}: Means within a column with different superscript letters differ significantly ($P<0.05$)

TABLE VII
Impact of dietary bay laurel supplementation on blood biochemical parameters in 42-day-old quails

Treatments	Sex	GLU (g·l ⁻¹)	TG (g·l ⁻¹)	ALB (g·dl ⁻¹)	TP (g·dl ⁻¹)	AST (U·l ⁻¹)	ALT (U·l ⁻¹)	TC (mg·dl ⁻¹)	Urea (g·l ⁻¹)	Creat (g·l ⁻¹)	Ca (mg·l ⁻¹)
0% BL	M	3.78±0.59	2.55±0.53	21.02±3.61	42.12±3.66	54.60±24.77	14.81±5.58	3.76±0.37	0.04±0.01	4.29±0.70	99.00±14,97
	F	3.54±0.41	3.95±0.05	18.28±1.25	42.42±7.28	54.40±25.65	11.20±2,88	4.39±0.63 ^a	0.07±0.01	4.02±1,43	201.53±39,60
1% BL	M	3.06±0.63	1.91±0.31	20.36±1.39	37.06±4.02	70.60±11.23	9.74±2,28	3.80±0.30	0.06±0.05	3.06±0.16	128.97±34,83
	F	2.90±0.36	2.65±0.89	19.56±1.33	45.86±3.75	64.40±18.66	13.83±4,61	3.12±0.44 ^b	0.04±0.03	3.28±1,17	153.33±38,66
2% BL	M	2.82±0.58	1.44±0.42	20.56±2.65	42.98±1.35	68.20±12.87	14.41±6,16	3.72±0.53	0.03±0.02	2.76±0.58	99.45±50,99
	F	2.59±0.44	2.66±0.47	20.98±4.07	47.70±6.46	49.20±10,73	13.60±5,68	2.96±0.51 ^b	0.05±0.02	3.64±1,09	195.40±30,35
3% BL	M	2.46±0.40	1.59±0.44	20.50±3.18	39.58±4.95	67.20±11,90	10.41±2,35	3.05±0.32	0.07±0.02	2.83±1,54	98.82±92,30
	F	2.60±0.17	2.43±0.11	19.58±1.13	43.32±4.39	62.20±10,68	16.09±5,34	3.06±0.33 ^b	0.03±0.04	3.53±1,30	198.05±19,30
0% BL		3.66±0.49 ^a	3.25±0.81 ^a	19.65±2.93	42.27±5.43	54.50±23,77	13.01±4,60	4.07±0.59 ^a	0.059±0.02	4.16±1,07	150.26±60,96
1% BL		2.98±0.49 ^b	2.28±0.74 ^b	19.96±1.35	41.46±5.91	67.50±14,88	11.78±4,05	3.46±0.51 ^b	0.05±0.04	3.17±0.80	141.15±36,99
2% BL		2.70±0.50 ^b	2.05±0.77 ^b	20.77±3.24	45.34±5.05	58.70±15,00	14.00±5,60	3.34±0.63 ^b	0.04±0.02	3.20±0.95	147.43±64,20
3% BL		2.53±0.30 ^b	2.01±0.53 ^b	20.04±2.30	41.45±4.83	64.70±10,98	13.25±4,91	3.05±0.31 ^b	0.05±0.03	3.18±1,39	148.43±81,77
M		3.03±0.71	1.87±0.59 ^b	20.61±2.61	40.43±4.17	65.15±16,16	12.34±4,72	3.58±0.48	0.05±0.03	3.24±1,04	106.56±53,10
F		2.91±0.52	2.92±0.77 ^a	19.60±2.33	44.82±5.62	57.55±17,29	13.68±4,70	3.38±0.75	0.05±0.03	3.62±1,18	187.07±36,35
Source of variation											
BL		< 0.0001	< 0.0001	0.799	0.238	0.325	0.755	< 0.0001	0.676	0.138	0.973
Sex		0.413	< 0.0001	0.226	0.007	0.165	0.366	0.167	0.733	0.280	< 0.0001
BL × Sex		0.786	0.365	0.598	0.283	0.642	0.111	0.004	0.071	0.648	0.149

GLU: glucose, TG: triglycerides, ALB: albumin, TP: total protein, AST: aspartate aminotransferase, ALT: alanine aminotransferase, TC: total cholesterol, Creat: creatinine, Ca: calcium.

^{a, b}: Means within a column with different superscript letters differ significantly ($P < 0.05$)

addition of BL to the diet at any tested concentration (1, 2 or 3%) led to decreases ($P < 0.0001$) in glucose and triglyceride and total cholesterol blood levels when compared to control groups. The study did not detect any changes in the measured biochemical parameters when BL was added to the diet ($P > 0.05$).

These hypoglycemic, hypocholesterolemic, and hypotriglyceridemic effects are consistent with those of Ali [34], who showed that broiler chickens fed 2–3 g·kg⁻¹ BL experienced substantial decreases in their glucose and cholesterol and triglyceride levels. Similarly, Hamody *et al.* [35] demonstrated that female breeder quails who received 0.5–1.5% BL supplementation showed decreased triglyceride levels.

Research findings about BL oil effects (100–400 mg·kg⁻¹) on blood biochemical parameters in Japanese quails have produced conflicting results. Gölcü and Duru [23] found glucose reduction but no changes in cholesterol or triglycerides while Bulbul *et al.* [36] detected no significant effects.

The different results between studies might stem from variations in BL dosage levels, form (powder or oil), and treatment duration and the use of different poultry species. The metabolic improvements in BL-supplemented quails can be attributed to several bioactive compounds in BL. Polyphenols lower blood sugar through their ability to control pancreatic β -cell operation and their protective effects against cell damage from inflammation and oxidative stress [23, 37].

Additionally, polyphenols and flavonoids reduce oxidative stress through their antioxidant properties, thereby improving blood lipid profiles [38, 39]. The combination of naringenin flavonoids with eugenol essential oils leads to decreased hepatic triglyceride production and enhanced lipolysis [35, 38, 39], which results in lower glucose and cholesterol and triglyceride levels in BL-supplemented quails.

The metabolic results between males and females produced different patterns of response. The female quails in this study showed elevated triglyceride and calcium levels ($P < 0.0001$) and elevated total protein concentrations ($P = 0.007$) compared to male quails. The research findings from Udoh *et al.* [40] support these results because his study showed that female birds had elevated total protein and lipid and hepatic enzyme levels.

The laying period brings about physiological changes which lead to increased hepatic production of triglycerides and cholesterol and phospholipids for lipoprotein formation and oocyte incorporation. Additionally, elevated estrogen production stimulates vitellogenin and lipoprotein synthesis, resulting in higher concentrations of total proteins, triglycerides, and cholesterol in females compared to males. The BL supplementation × sex interaction proved statistically significant only for total cholesterol ($P = 0.004$) which indicated females obtained better cholesterol reduction from BL supplements than males. This sex-specific response could be related to differences in lipid metabolism and hormonal influences between sexes.

CONCLUSIONS

The addition of 3% BL to the Japanese quail diet improved growth performance, carcass yield, feed efficiency, intestinal morphology, and reduced blood glucose, triglycerides, and cholesterol levels. These results suggest that BL may be used as a natural feed additive in commercial quail production.

Conflicts of interest

The authors declare no conflicting interests.

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