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REGULAR ARTICLES

Effect of high-fibre diets supplemented with banana leaf on growth performance, meat quality, and serum cholesterol of quail

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Abstract
Bananas are one of the most extensively cultivated fruits globally, yielding substantial amounts of greenery, including their leaves. Banana leaves (BL) have notable protein content, bioactive compounds, and a significant fiber component. This study aimed to investigate the impact of incorporating dried and nutrient-determined BL along with a multienzyme complex into the diet of quails. The experiment lasted 35 days, a total of 280 one-day-old quail chicks (*Coturnix coturnix japonica*) were allocated into four groups with seven replicates. Experimental diets were formulated with the addition of dried BL at levels of 0% (C), 3% (BL3), 6% (BL6), and 9% (BL9), with the inclusion of 1,000 mg/kg multienzyme complex to the basal diet. The total fiber content of diets was determined at 2.77%, 4.28%, 5.77%, and 7.28%, respectively. The inclusion of BL in the diet did not significantly affect growth performance. However, the addition of 3% and 6% BL to the diet resulted in a significant reduction in meat oxidation. A 6% BL inclusion led to the lowest serum low-density lipoprotein and the highest high-density lipoprotein concentrations ($p < 0.05$). Meat yellowness (b*) increased with all three levels of BL in the diet compared to the basal diet ($p < 0.05$), while L* and a* values remained unaffected. A 6% BL addition to quail diets may lead to improved meat quality and higher serum HDL concentration without detrimental effects on growth performance.

Keywords Antioxidant activity · DPPH · Flavonoid · HDL · MDA · Phenolic

Introduction

In a world where the agricultural landscape is increasingly challenged by the dual imperatives of sustainable production and climate change mitigation, the quest for innovative and eco-conscious dietary solutions for livestock has gained paramount significance. Among the many potential resources in this quest, banana leaves (BL), a byproduct of the extensive global banana cultivation industry, have emerged as a promising candidate. As one of the most widely cultivated fruits on the planet, bananas generate not only succulent fruit but also an abundance of greenery, including their sizable, often underutilized, foliage. Bananas are cultivated primarily for their fruit, and consequently, producing and consuming bananas results in significant waste and by-products, which account for 80% of the entire plant's mass, including the leaves (Zou et al. 2022). Little is known about the use of green parts of banana plants in balanced poultry diets as feed material, but the phytochemical benefits of BL were reported due to its bioactive compound content and high oligosaccharides (Achilonu et al. 2018). Conversely, it has been reported that dried banana leaves without the midrib contain superior essential nutrients compared to alfalfa meal (Squibb et al. 1953) but neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents of BL are also quite high (Wadhwa et al. 2015). Considering the limited digestive system capacity of birds, it is obvious that BL cannot meet the energy and protein requirements of poultry and generally high fiber in the diet has been related to worse growth performance. In contrast, recent evidence has confirmed that an appropriate amount of dietary fiber can benefit the development of the gut, the gut microecosystem, growth performance, and overall welfare of poultry (He et al. 2021). To deal with the digestible problem of high fiber in the diet, applications such as supplementation of enzymes and fermentation may increase the incorporation levels of leaf meal into the poultry diets. The Japanese quail was chosen for the present study

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because it is considered an important experimental animal due to its early maturity, rapid life cycle, low production costs, low body weight, and high disease resistance (Nasr et al. 2017). Japanese quail are often regarded as exemplary subjects in scientific research due to their findings being transferable to various other types of poultry (Narinç and Aksoy 2014). In this study, by determining the baseline nutritional composition and bioactive compounds of BL, a comprehensive trial was structured to investigate the impact of incorporating BL into quail diets at varying levels (0%, 3%, 6%, and 9%) with the multienzyme complex supplementation. The primary objective of the study was to evaluate the effects of BL supplementation on various facets of quail performance, including growth performance, meat oxidation, meat color, pH values, and cholesterol concentrations.

Materials and methods

Ethical note The animal experiment was conducted according to the guidelines of the local ethics committee of Selcuk University, which were prepared following the "Directive 2010/63/EU is the European Union (EU) legislation". All procedures in this study complied with the ethical principles of animal welfare.

Animal management procedures A total of 280 one-day-old quail chicks (*Coturnix coturnix japonica*) were randomly allocated into four treatment groups with 7 replicates, each replicate containing 10 chicks. The average live weight of the chicks was 8.18 g and was distributed without sex differentiation. The chicks were reared in multi-layer quail cages (Cimuka -CB25 /5, Ankara, Turkey) with full heat (automatic temperature control with thermostat) and light (E 27 bulb) control. Each cage had a water tank with a capacity of 20 L and each compartment had nipples and feed manger. The experiment lasted 35 days, light was provided for 23 h/day. Humidity was kept at about 45%. The temperature was continuously lowered from 35 °C to 22 °C from day 1 to day 22 and then maintained till day 35. Feed and water were provided ad libitum.

Banana leaf and diets The banana leaves (BL) were harvested from greenhouses in the Anamur district, Mersin province, Türkiye (latitude: 36.077286, longitude: 32.832890). The fresh BL was placed on a clean concrete surface and dried in the sun until the humidity dropped to 15%. The leaves' middle thick veins were removed, then chopped into 2–5 cm pieces with a hammer mill and ground to a 2 mm size in a feed mill. Afterward, total dry matter content was detected by a laboratory oven (Elektromag-5040P, İstanbul, Türkiye), crude protein content was determined with the Carbon- Nitrogen analyzer instrument (N–C LECO, Michigan, US), crude fat content with the Soxhlet instrument (Gerhardt SOX-416, König winter, Germany), mineral content with the ICP-AES (Inductively coupled plasma atomic emission spectroscopy) instrument (Shimadzu, Kyoto, Japan), and the total fiber with automatic fiber analysis device (Gerhardt, König winter, Germany) according to AOAC (1995). The nutrient composition of dry BL is given in Table 1.

The experimental diets were formulated to be isocaloric and isonitrogenous and to meet the nutritional requirements as per NCR (1994). The diet groups were classified according to the total content of added banana leaves 0, 3, 6, and 9% BL and multienzyme complex in the basal diet (24% crude protein and 2900 kcal metabolic energy) were designated as C, BL3, BL6, and BL9, respectively. The total fiber content of the experimental diets was determined as 2.77% (C), 4.28% (BL3), 5.77% (BL6), and 7.28% (BL9). 1,000 mg of the multienzyme complex (Farmazyme®3000-proenx;. endo-1,4-beta-xylanase, endo-1,3(4)-beta-glucanase, cellulase, alpha-amylase, pectinase, protease) per kg of feed was added to each diet and homogeneously mixed. The ingredients and nutrient composition of the experimental diets are shown in Table 2.

Antioxidant activity, total flavonoid, and total phenolic contents of banana leaves and diets Antioxidant activities of BL and diets were done via DPPH (1,1-diphenyl-2-picrylhydrazyl). DPPH values were determined as a percentage of free radical scavenging activity (%), as described by Babaoğlu et al. (2022). The total phenolic contents of BL and diets were determined by using the Folin–Ciocalteu reagent method according to Yoo et al. (2004). The absorbance

Table 1 Nutrient values, metabolic energy, and mineral content of dried banana leaf

Nutrients (%)	
Dry matter	13.95
Crude protein	14.50
Ash	16.0
Crude fiber	53.0
Ether extract	2.01
Metabolizable energy (Kcal/kg)≅	1476,00
Minerals	
%	
Ca	2.90
Mg	0.41
K	1.81
mg/kg[1]	
Fe	199.36
Cu	5.94
Mn	296.72
Zn	12.97

Table 2 Feed formulation and nutrient contents of experimental diets for Japanese quail in the growth period using the gradual supplementation of dry banana leaves

Ingredients (%)	C	BL3	BL6	BL9
Corn	46.05	43.58	40.10	38.14
Soybean meal (47% CP)	46.40	45.85	45.50	44.50
Banana leaf	0.00	3.00	6.00	9.00
Soybean oil	4.30	4.40	5.30	5.30
Limestone	0.70	0.60	0.50	0.40
DCP	1.80	1.80	1.80	1.80
Salt	0.20	0.20	0.20	0.20
Premix*	0.20	0.20	0.20	0.22
Lysine	0.16	0.18	0.20	0.23
Methionine	0.19	0.19	0.20	0.21
Nutrients (%)				
Crude protein*	24.10	24.11	24.15	24.00
Total fiber*	2.77	4.28	5.77	7.28
Calcium	0.88	0.93	0.98	1.02
Available phosphorus	0.35	0.35	0.35	0.35
Lysine	1.33	1.33	1.33	1.33
Methionine	0.51	0.51	0.51	0.51
Methionine -cystine	0.83	0.83	0.83	0.83
Metabolizable energy (kcal/kg)	*2900,00*	*2900,00*	*2900,00*	*2900,00*

*Analyzed value, DCP: Dicalcium phosphate, C: Control (Basal diet), BL3: Basal diet with 3% banana leaf supplement, BL6: Basal diet with 6% Banana leaf supplement, BL9: Basal diet with 9% BL supplement, *Vitamin-mineral premix (per kilogram of diet): Vitamin A 15000 IU; Vitamin D3 1500 IU; Vitamin K 5 mg; Vitamin B1 3 mg; Vitamin B2 6 mg; Vitamin B6 5 mg; Vitamin B12 0,03 mg; Niacin 30 mg; Biotin 0,1 mg; calcium D-pantothenate 12.0 mg; folic acid 1.0 mg; choline chloride 400 mg; Manganese 80 mg; Iron 35 mg; Zinc 50 mg; Copper 5.0 mg; Iodine 2 mg; Cobalt 0.04 mg

was determined at 750 nm using a spectrophotometer. The total flavonoid contents of BL and diets were determined using the method described by Chen and Chen (2011). The results were given as mg of catechin equivalents (mg CE/100 mL).

Growth performance parameters On days 1, 7, 14, 21, 28, and 35 of the experiment, all birds in each compartment and residual feed in mangers were weighed and recorded. Body weight gain (BWG) was calculated from the weekly changes in body weight of the birds, and feed intake (FI) was determined from the amounts of feed given and remaining. The feed conversion ratio (FCR) was calculated using the feed intake/body weight gain (FI /BWG) formula. On the 35th day of the experiment, one bird from each replicate, 7 birds from each treatment, and a total of 28 birds were randomly selected and slaughtered using cervical dislocation (Genchev and Mihaylov 2008). The slaughtered birds were de-feathered and eviscerated and the carcasses were weighed and recorded. Carcass yield (CY) is determined by calculating the ratio between live weight and carcass weight.

Serum LDL and HDL concentrations 5 mL of blood was taken from the jugular vein in tubes from each slaughtered animal. Serum was collected by centrifuging the blood at 3500 rpm for 5 min at a standard ambient temperature of 25 °C. High-density lipoprotein (HDL) and low-density lipoprotein (LDL) concentrations were determined by the photometric method using the Abbot c8000 chemistry analyzer (Diamond Diagnostics Inc., Holliston, US).

Meat pH, colour, lipid oxidation (Thiobarbituric acid (TBARS) number) After slaughter, the carcasses were stored at 4 °C for 24 h and the breast meat was separated for detection of pH, colour, and MDA concentration. The pH values of the samples were measured via a pH meter (Cola-Parmer-WTW 2A20-1012, Cambridgeshire, UK) as reported by Lambooij et al. (1999). L^*, a^*, and b^* colour values of the chicken meat samples were determined via a colorimeter (Minolta CR 300, Osaka, Japan) with illuminate D65, 2° observer, Diffuse/O mode, 8 mm aperture of the instrument for illumination and 8 mm for measurement. To determine the lipid oxidation, TBARS numbers were measured at 530 nm (UV–Visible Recorder Spectrophotometer, Shimadzu, Tokyo, Japan) and given as mg malonaldehyde/kg sample according to the Tarladgis et al. (1960). Then absorbance values were multiplied by the coefficient 7.03.

Statistical analysis All data from the experiment and analyses were subjected to Bartlett's test for homogeneity of variances and then analyzed in one direction using Minitab software ANOVA. Duncan's Multiple Range Test was used to determine the differences between treatments that were found to be significantly different ($P < 0.05$).

Results

Phenolic, flavonoid content, and antioxidant activity of BL The total flavonoid and phenolic content of dry BL and BL-supplemented diets have been presented in Fig. 1. DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity of BL and BL-supplemented diets have been given in Fig. 2. The highest total flavonoid and phenolic content were found in the BL and the lowest levels were found in the basal diet (C). As the proportion of BL in the diet increased, the levels of total phenols and flavonoids in the BL-supplemented diet increased. Similarly, the antioxidant activity of the diets depended on the amount of BL in the feed. BL showed the highest free radical scavenging activity and the lower amount of BL in the diet reduced the antioxidant activity.

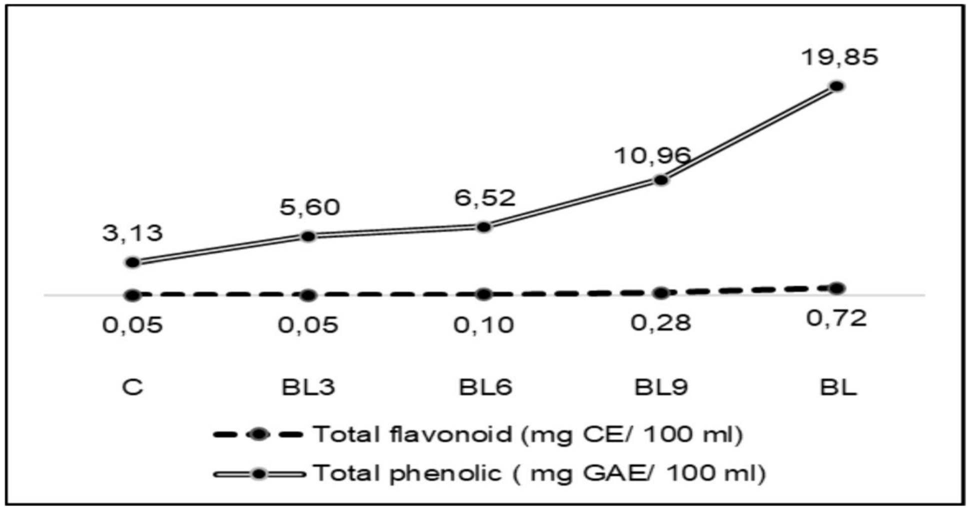


Fig. 1 Total flavonoid and total phenolic contents of dried BL and experimental diets. C: Control (Basal diet), BL: Banana leaf, BL3: Basal diet with 3% BL supplement, BL6: Basal diet with 6% BL supplement, BL9: Basal diet with 9% BL supplement

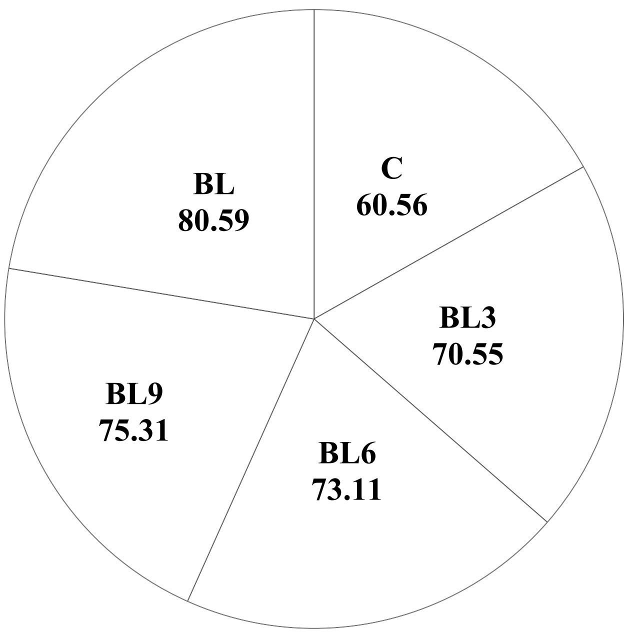


Fig. 2 DPPH (%) radical scavenging activity of dried BL and experimental diets. C: Control (Basal diet), BL: Banana leaf, BL3: Basal diet with 3% BL supplement, BL6: Basal diet with 6% BL supplement, BL9: Basal diet with 9% BL supplement

Growth performance The effects of using three different amounts of BL in quail diets on growth performance are shown in Table 3. The data for FBW, WG, FI, FCR, CW, and CY were similar between dietary treatments and the differences were insignificant. However, numerically the lowest FBW and WG were found in the control group and the highest value was determined in the BL6 group. FI of the birds increased in parallel with the amount of BL in the diet and the highest FI was in BL9 but caused higher FCR. Like FBW, CW was lower in groups C and BL9.

Meat oxidative stress, pH, and colour The TBARS number and pH values of the breast meat of quails fed different amounts of dry BL are shown in Fig. 3. The pH of the meat was not affected by the BL amount of the diets and the results were similar between the dietary treatments. The TBARS numbers of the breast meat were significantly affected by the BL amount of feed ($P < 0.05$). The TBARS number in the meat of quails fed with basal diet and %9 BL was significantly higher than in the BL3 and BL6 groups, and the 6% BL in the diet caused the least oxidative stress in the meat ($P < 0.05$). On the other hand, even the lowest level

Table 3 The effects of BL supplemented diets on growth performance parameters of quails

	C	BL3	BL6	BL9	STD	*P* value
FBW (g)	124.77	139.90	144.56	135.49	16.19	*0.21*
WG (g)	116.05	131.76	136.44	127.72	16.25	*0.19*
FI (g/bird)	395.30	450.80	461.70	466.10	52.54	*0.11*
FCR (g feed/g WG)	3.51	3.45	3.41	3.70	0.64	*0.87*
CW (g)	88.73	102.23	105.07	97.17	11.64	*0.10*
CY (%)	71.18	73.23	72.60	71.70	1.67	*0.18*

C: Control (Basal diet), BL: Banana leaf, BL3: Basal diet with 3% BL supplement, BL6: Basal diet with 6% BL supplement, BL9: Basal diet with 9% BL supplement, FBW: Final body weight, WG: Weight gain, FI: Feed intake, FCR: Feed conversion ratio, CW: Carcass weight, CY: Carcass yield, STD: Mean standard deviation

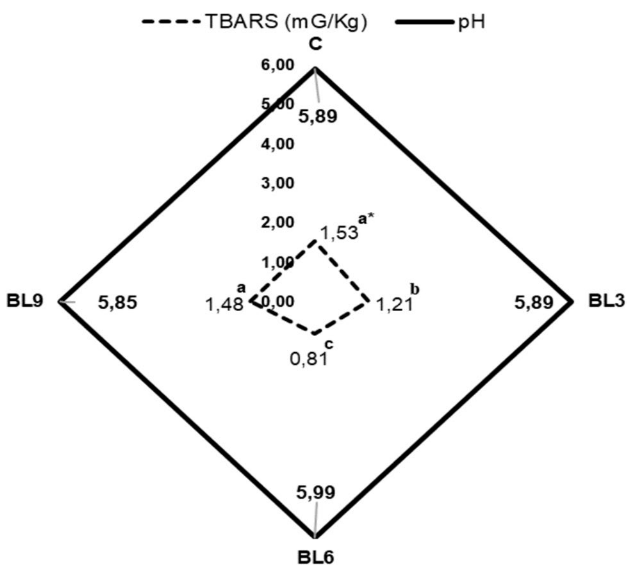


Fig. 3 The effects of BL-supplemented diets on quail meat TBARS number and pH. C: Control (Basal diet). BL: Banana leaf. BL3: Basal diet with 3% BL supplement. BL6: Basal diet with 6% BL supplement. BL9: Basal diet with 9% BL supplement. TBARS: Thiobarbituric acid number. * a. b. c letters. the differences are statistically significant at P < 0.05

of BL (3%) in the diet significantly reduced meat TBARS number than the control and BL9 groups (P < 0.05).

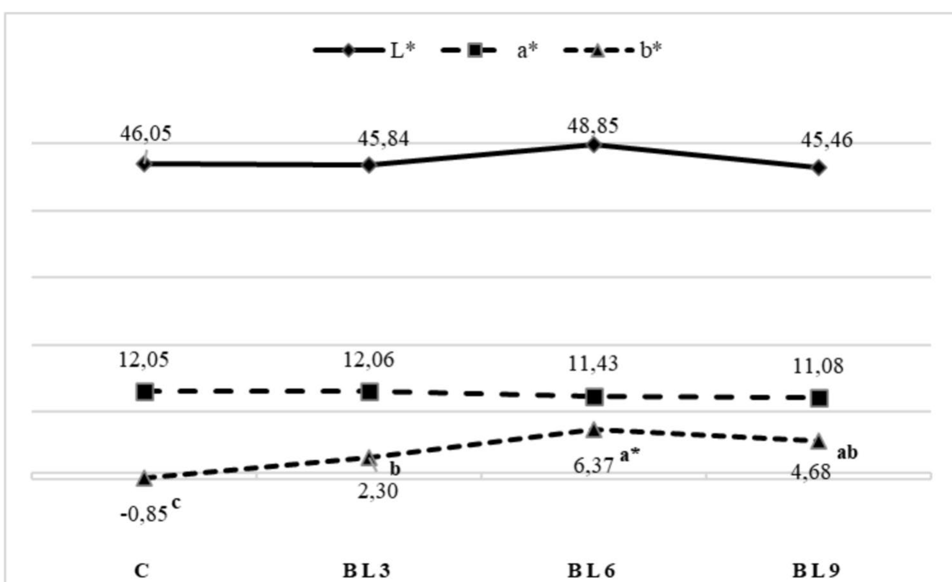
Quail breast meat colour values change with the use of the different amounts of BL in the diet have been presented in Fig. 4. Results showed that BL levels of the diet did not significantly affect the L* and a* colour values of the meat, however, depending on the proportion of BL in the diet the b* value changed and 6% BL significantly increased the b* value of the meat (P < 0.05).

Serum HDL and LDL concentrations The effects of diet BL on HDL and LDL serum concentrations of quail are shown in Fig. 5. Both quail serum HDL and LDL were affected by the presence of BL in the diet. and the differences between the diet groups were significant (P < 0.05). The serum HDL concentrations of C, BL6, and BL9 were higher than those of BL3, and the highest HDL concentration was found in BL6 (P < 0.05). On the other hand, the highest LDL concentration was found in the control group, any amount of BL in the diet reduced serum LDL concentration more than the basal diet, and the lowest LDL was found in group BL6 (P < 0.05).

Discussion

Banana leaf Phenolics are secondary metabolites that are extensively distributed across the plant kingdom. Flavonoids represent the largest group of phenolic compounds, and their positive health effects are primarily due to their direct and indirect antioxidant activities (Cosme et al. 2020). Mostafa (2021) stated that parts of the banana tree, such as the peels and leaves, have antioxidant activities and biological functions. Total polyphenols of the BL were reported as 80 g/kg in dry matter (Marie-Magdeleine et al. 2010). Another study showed that the determined total phenolic and flavonoid content of BL depends on extraction fraction and contained ranges from 7.33 to 11.06 GAE/g of total phenolics, and 59.03 to 125.99 mg QE/g total flavonoid (Handayani et al. 2021). Similarly, to previous studies, the results of the current study showed that total phenolic and flavonoid compounds have presented in considerable amounts in BL, and BL incorporation into diets increased the phenolic and flavonoid contents and antioxidant capacity of experimental diets.

Fig.4 The effects of BL supplemented diets on quail meat colour values. C: Control (Basal diet). BL: Banana leaf. BL3: Basal diet with 3% BL supplement. BL6: Basal diet with 6% BL supplement. BL9: Basal diet with 9% BL supplement. * a. b. c letters. the differences are statistically significant at P < 0.05



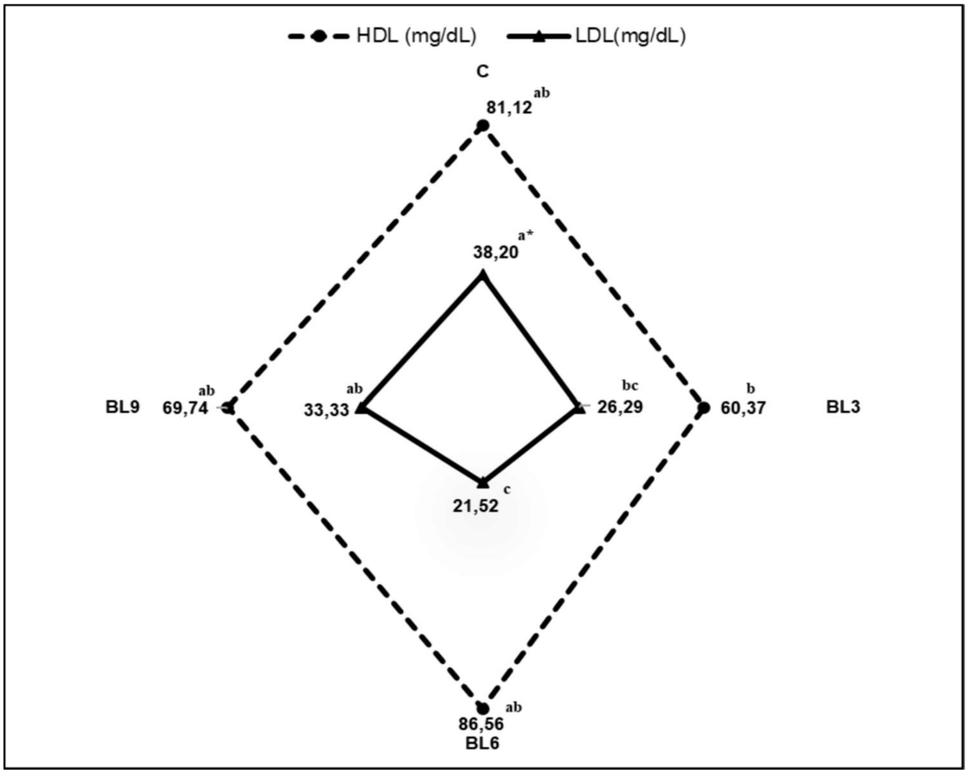


Fig. 5 The effects of BL-supplemented diets on serum LDL and HDL concentration of quails. C: control (Basal diet). BL: Banana leaf. BL3: Basal diet with 3% BL supplement. BL6: Basal diet with 6% BL supplement. BL9: Basal diet with 9% BL supplement. HDL: High-density lipoprotein. LDL: Low-density lipoprotein. *a. b. c letters. the differences are statistically significant at P < 0.05

Growth performance Previous studies on the use of plant leaves of the *Musa* genus in poultry nutrition are inadequate, however similar to the current study, it has reported that dry plantain leaves, a variety of the genus *Musa* when replaced by 10% of a basal diet in broiler, did not affect feed efficiency (Marín et al. 2003). In a related study, 5, 10, and 15% BL fermented with *Trichoderma viride* were added to broiler diets, and results showed that 10% fermented leaves increased FI and improved WG, FCR, and CY of the chickens (Mandey et al. 2015). Oleforuh-Okoleh et al. (2015) reported that 50 g/kg of banana leaf powder in broiler diets increased FBW and WG and resulted in better FCR. The mentioned studies' results have shown variability; however, it is known that the nutrient composition can vary depending on a variety of plants and the digestibility of nutrients can change depending on the amount of inclusion and, application to the leaf such as drying or fermenting. High-fiber feed usually means relatively low energy density which can reduce FI, feed conversion ratio (FCR), and poultry body weight and there is some evidence that as dietary fiber increases in diet, the feed intake and body weight reduced (Jiménez-Moreno et al. 2013). Some early studies indicated that quail consuming high-fiber diets exhibited lower body weights compared to those on low-fiber diets. It was proposed that this difference in body weight was primarily attributed to variations in energy utilization, with quail on high-fiber diets expending more energy. (Savory and Gentle 1976). However, other studies have reported that crude fiber in the diet has a growth-promoting effect on poultry, suggesting that increasing dietary fiber may enhance performance parameters (Rezaei et al. 2018), but this depends on the source and the amount. For example, Iheukwumere et al. (2007) reported that cassava leaf meal in broiler diets at the level of 10% and 15% have 9.85% and 8.80% total fiber respectively, reduced FBW, WG, and FI and increased FCR but level of 5% did not affect performance parameters negatively.

Improving gut morphology and organ development may lead to increased nutrient absorption, which converts into increased performance. Different carbohydrates from dietary fiber may have altered modes of action when ingested by the bird. Hence, to conclude the effect of dietary fiber, several factors need to be carefully considered such as the source of the fiber, particle size, intake amount, species, age, physiological status, energy and protein content of the feed, and duration of intake (Tejeda and Kim 2021). In this study growth performance was not affected significantly but FI increased numerically with an increase in BL level and fiber content of the diet. On the other hand, WG and FCR numerically changed depending on the level of the dietary fiber and BL level insignificantly. In a nutshell, neither bioactive compounds nor fiber content of diets has influenced the fattening performance significantly.

Meat MDA concentration, pH, and colour values In this study, BL inclusion to feed increased the content of the bioactive compounds and therefore DPPH scavenging effects of the diets (Figs. 1. and 2.) and resulted in TBARS numbers changing in the meat. MDA is the secondary oxidation product of polyunsaturated fatty acids and the TBARS number is an indicator of the mg of MDA per kg of meat (Salih et al. 1987). Plant sources containing polyphenols and flavonoids have been used in the form of extracts or powders for meat products to inhibit or retard lipid oxidation during storage (Choe et al. 2019). To our knowledge, there is no data on the effects of banana plant waste in poultry feed on meat quality, however, study results can be found that used high fiber plant leaves which have bioactive compounds in poultry feeding, Cui et al. (2018) reported that broilers fed moringa leaves had increased breast meat oxidative stability, and this may be related to the leaf's potential antioxidant properties. Another similar study reported that the use of moringa leaf meal as an additive in broiler diets reduced lipid oxidation in meat and maintained the quality of the broiler meat during storage (Cwayita 2014). Dietary fiber and natural antioxidants are considered two important nutritional components and could be very valuable for improving the quality and storage stability of meat products (Madane et al. 2019). High dietary fiber levels have been associated with negative impacts on nutrient and bioactive compound digestion, absorption, and utilization in avian species (Van Soest et al. 1991). The present study results have supported this statement, revealing that although the BL9 group has the highest concentration of bioactive compounds due to its high fiber content resulted in the highest level of meat oxidation (TBARS number). This situation suggests that high fiber may impede the absorption or utilization of bioactive components in quails. In this study, dietary BL was ineffective on meat pH, and the results were similar between dietary treatments. In the literature, the average pH value of quail meat was reported as 5,94 similar to the current study (Narinc et al. 2013). In this study, the lightness (L*) and redness (a*) of meat were not affected by BL inclusion in the diet but the yellowness (b*) significantly increased in all 3 additional levels of BL. It is known that the composition of the poultry diet may modulate meat colour and reported that xanthophylls cause poultry carcasses to have a desirable yellow colour (He, et al. 2021) Poultry diets based on corn-soybean have a considerable amount of carotenoid and have been reported that the total xanthophyll content of corn is 21.97 µg/g (Moros et al. 2002). On the other hand, banana leaves contain 12.8 mg/g of total carotenoids and 217.1 g/mg of total chlorophyll (Ahmadi et al. 2019). The banana leaf contains lower carotenoids and a higher chlorophyll than maize but, according to the results of the current study higher chlorophyll in the diet increased the yellowness (b*) of the quail meat. The effect of dietary BL amount on the b* value of meat has been like the effect on TBARS number of meats, and this indicates that an increase in high fiber in the diet may affect the absorption and bioavailability of bioactive components such as pigment components which may modulate of the meat colour.

Serum LDL and HDL concentrations Earlier studies have reported that dietary fiber may modulate cholesterol metabolism by preventing the absorption of cholesterol, binding bile salts, and causing sterol excretion (Sutton et al. 1981). A study reported that dietary Lignocellulose supplementation (0.5% and 1.0%) in broiler diets significantly reduced the concentration of triglycerides and LDL fractions (Bogusławska-Tryk et al. 2016). Another study reported that levels of 1 and 2% insoluble fiber addition to broiler chicken diets reduced liver and plasma total cholesterol concentration but did not affect HDL and LDL levels (Rahmatnejad and Saki 2016). Bioactive compounds like phenolics and flavonoids in the diet have been found to influence cholesterol metabolism in poultry. Studies suggest that phenolic supplementation can enhance the excretion of fecal sterols and decrease the absorption of dietary cholesterol, leading to lower levels of plasma and hepatic cholesterol (Mahfuz et al. 2021). Daramola (2019) reported that medical plants such as Bitter leaf meal and Moringa oleifera leaf meal, which contain phytochemicals, added to broiler diets reduced serum cholesterol levels. Accordingly, in the current study, increased amounts of dietary fiber and phenolic compounds have affected the serum LDL and HDL levels of quails, and 6% banana leaves in the diet decreased serum LDL but increased HDL levels more than other dietary treatments. However, the effectiveness of plant-based feed materials in reducing serum cholesterol levels may vary depending on the amounts of phytochemicals in the plant, the dosage, and the duration of supplementation. Additionally, it is important to consider the potential for other factors, such as genetics, diet, and environmental conditions, to influence serum cholesterol levels in poultry.

In conclusion, adding up to 9% BL with multienzyme complex in quail diet had a positive effect on performance parameters. However, BL diets improved antioxidant stability, colour of meat, and serum cholesterol. It was concluded BL (6%) can be used to reduce the meat's oxidative stress and serum LDL concentration and increase the yellowness of the meat in quails in the growth period. Considering these findings, conducting further research could be advantageous to explore the utilization of different levels of dry BL during poultry fattening periods, particularly without enzyme supplementation.

Author contribution G. Kanbur: *Investigation, Resources, Material obtaining, Trial designing and conducting, Samples collecting, Data collecting, Formal analysis, Writing – original draft*. R. Göçmen: *Trial designing and conducting, Data collecting, Samples collecting, Validation*. K. Ünal: *Sample analyzing, Reviewing, Editing, Validation*.

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Data availability The data that support the findings of this study are available from the corresponding author [G. Kanbur] upon reasonable request.

Declarations

Conflict of interest The authors verify that there is no financial or personal conflict of interest with any person or organization related to this manuscript.

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