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The effects of goji berry (*Lycium barbarum* L.) leaves on performance, meat lipid oxidation, digestive tract parts, and some blood parameters of broiler chickens

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ABSTRACT: This study aimed to investigate the effects of supplementing diets with goji berry (*Lycium barbarum* L.) leaves (GBL) on performance, meat lipid oxidation, meat chemical composition, carcass traits, some internal organs, digestive tract parts, and some blood parameters in broiler chickens. A total of 144 d-old mixed-sex chicks (Ross-308) were weighed and randomly allocated to four experimental groups with three replicates of 12 chickens each. Treatments were as follows: (i) basal diet (control), (ii) basal diet+1 g/kg GBL, (iii) basal diet + 5 g/kg GBL, and (iv) basal diet+ 10 g/kg GBL. After analysis by one-way ANOVA, the results revealed that 10 g/kg GBL improved body weight (0-6 weeks) ($p<0.01$), body weight gain (4-6 weeks), and feed intake (4-6 and 0-6 weeks) ($p<0.05$). The feed conversion ratio did not significantly improve with GBL treatment ($p>0.05$). In addition, 10 g/kg GBL of the diet increased heart weight and proventriculus length ($p<0.05$), however, it decreased breast meat lipid oxidation on d 21 ($p<0.05$). Experimental treatments did not affect the total cholesterol, HDL, glucose, and triglycerides ($p<0.05$) but decreased LDL ($p<0.05$). In conclusion, supplementing 10 g/kg GBL to a broiler chicken diet may improve performance and decrease breast meat lipid oxidation and blood serum LDL.

Keywords: Goji berry leaves, broiler, performance, lipid oxidation, blood parameters.

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INTRODUCTION

Chicken meat production is a necessary animal activity for fulfilling essential amino acids of people's health (Hanusová *et al.*, 2015). The immune system needs a variety of amino acids to function actively and continuously in people (Alam *et al.*, 2019). It becomes even more important to feed with functional foods to increase body immunity against Covid-19, which is on the agenda all over the world, and other infectious diseases. Food safety and functional foods have become progressively important matters for the poultry and livestock industry worldwide.

Goji berry (or wolfberry) is a perennial plant and a common name for *Lycium barbarum* L., *Lycium chinense* L., and *Lycium ruthenicum* L. species of the *Lycium species*, belongs to the family of *Solanaceae* (eggplants), is commonly found in the arid and semi-arid regions of China, Tibet, Himalayas, Mongolia, Southeast Europe, and the Mediterranean countries (Levin and Miller, 2005; Potterat, 2010; Bucheli *et al.*, 2011; Wang *et al.*, 2015). Goji berry has been used in conventional Chinese medicine since the first century A.D. and in other Asian countries for centuries (Potterat, 2010; Anonymous, 2021). Goji berries have been cultivated and largely grown in Northwest China for more than six hundred years (Chen *et al.*, 2013). Goji berry has the highest oxygen radical absorbance capacity values than other vegetables and fruits consumed as food (Chen *et al.*, 2013; USDA, 2010). Foods with high oxygen radical absorbance capacity levels protect cells and cell components from oxidative damage (Prior *et al.*, 1999). Goji berry fruit contains vitamins, mineral elements, monosaccharides, polysaccharides, essential oils, amino acids, carotenoids, betaine, and flavonoids (Zhang *et al.*, 2012; Endes *et al.*, 2015; Shen *et al.*, 2016). Flavonoids are antioxidant compounds that deactivate harmful impacts of formerly consumed substances in the body (Kanti Dey *et al.*, 2012; Khalili *et al.*, 2016). In folk medicine, goji berry has been used for life-enhancing effects and many benefits in China for years (Gündüz *et al.*, 2015). In addition, goji berry has been reported in studies that strengthen the immune system, increase muscle mass, balance blood sugar, prevent chronic diseases such as hypercholesterolemia, prevention of diabetic retinopathy, lowering cholesterol, antimicrobial activity, effective in Alzheimer's disease, anti-tumor effect, aphrodisiac effect, spatial learning behavior, anti-anxiolytic, preventing loss of vision, anti-cancer, anti-bacterial and memory enhancer (Chao *et al.*, 2006; Thomson, 2010;

Amagase and Fransworth, 2011; Hu *et al.*, 2012; Tang *et al.*, 2012; Kulczynski and Gramza-Michalowska, 2016; Pehlivan Karakaş *et al.*, 2016; Soares de Sousa *et al.* 2016; Hempel *et al.* 2017; Protti *et al.* 2017; Sun *et al.*, 2019; Meng *et al.*, 2020; Shahrajabian, *et al.*, 2020). In recent years, positive results have been obtained in studies on broiler nutrition with medicinal plants. All the features of the goji berry are generally related to the fruit, and no study has been found in the search on the use of the leaves in broilers. However, there are many studies conducted with leaves of herbal sources rich in bioactive compounds in broilers (Ebrahim *et al.*, 2015; Alnidawi *et al.*, 2016; Olorun-tola *et al.*, 2019).

This study was conducted to determine the effects of goji berry (*Lycium barbarum* L.) leaves (GBL) on growth performance, carcass yield, thiobarbituric acid value (TBARS) in breast meat, meat composition, and some blood parameters of broilers. Moreover, it is aimed to provide functional food production by using goji berry leaves in broiler nutrition.

MATERIALS AND METHODS

This experimental protocol was approved by the local ethical commission (No: 2019/01-03).

Broiler management and experimental design:

A total of 144-day-old mixed-sex chickens (Ross-308) were weighed and randomly divided into four experimental groups with three replicates of 12 chickens each. According to us, there is no GBL study in broilers in the literature. Considering both the high cost of feed and the previous studies with other leaves, doses of 1, 5, and 10 g/kg were used in the experiment. Treatments were as follows: (i) basal diet (control), (ii) basal diet+1 g/kg GBL, (iii) basal diet + 5 g/kg GBL and (iv) basal diet+ 10 g/kg GBL. Control and treatment diets did not include any additives. Birds fed on a starter diet for three weeks (0-21 days) and a finisher diet for three weeks (22-41 days). The starter and finisher diets were formulated to meet the requirements of the broiler chicks are in line with NRC (1994). The chemical composition and ingredients of the starter and finisher diet were presented in Table 1.

Water and experimental diets were provided *ad-libitum* throughout the six weeks. Chicks were reared in-group cages with continuous 1/23 hours dark/light and were exposed to standard temperature regimes which by stages decreased from 33 to 25 °C. Body weight and feed intake of broilers were monitored

Table 1. Chemical composition and ingredients of basal diets

Feed Ingredients, %	Starter Diets (0-3 weeks)	Finisher Diets (4-6 weeks)
Corn (CP 8%)	39.2	50.7
Full fat soya (CP 36 %)	29	30
Soybean meal (CP 42 %)	13	5
Corn gluten meal (CP 42 %)	6.9	3.8
Boncalite (CP 15 %)	-	3.0
Fish meal (CP 53 %)	4.5	-
Vegetable oil	3.0	3.0
DCP	1.8	2.1
Lysine	0.4	0.1
Methionine	0.4	0.3
CaCO ₃	0.5	0.7
NaCl	0.4	0.3
NaHCO ₃	0.4	0.5
Vitamin premix*	0.3	0.2
Mineral premix**	0.2	0.3
Calculated Composition		
ME (kcal kg ⁻¹)	3108	3224
Lysine, %	1.67	1.07
Methionine + cystine, %	1.19	0.92
Ca, %	1.10	0.89
P (available), %	0.55	0.44
Analyzed Values, %		
Dry matter	90.60	89.54
Crude protein	23.91	22.89
Ether extract	8.59	11.73
Crude fiber	1.18	1.70
Crude ash	5.45	4.16

* Provides per kg of diet: Vitamin A 8000 IU, Vitamin D₃ 800 IU, Vitamin E 15 mg, Vitamin K₃ 2 mg, Vitamin B₁ 2 mg, Vitamin B₂ 4 mg, Vitamin B₁₂ 10 mg,

** Provides per kg of diet: Mn 80 mg, Zn 60 mg, Fe 25 mg, Cu 15 mg, Co 0.25 mg, I 1 mg, Se 0.2 mg, Mo 1 mg, Mg 50 mg.

weekly. Feed conversion ratio (FCR) and body weight gain (BWG) was calculated at the end of wk 0-3, 4-6, and 0-6 for each replication.

$$\text{BWG} = \text{Body weight} - \text{Initial weight}$$

$$\text{FCR} = \text{Total feed intake} / \text{Total body weight gain}$$

Goji berry leaves preparation and analyses

Goji berry leaves (in air-dried form) were obtained from a goji berry producer in Denizli, Turkey. The goji berry leaves were ground in a 1 mm sieve and their chemical composition was analyzed according to AOAC (1990). GBL was added to the starter and finisher diets at different levels homogeneously and no other additives were added. Total phenolic compounds, total flavonoid contents, and antioxidant activity of GBL used as an additive in the study were

determined. The antioxidant activity was assayed according to the method reported by Villano *et al.* (2007). The total phenolic compounds of the goji berry leaves were analyzed using the method stated by Elzaawely and Tawata (2012) and the total flavonoid contents were tested by the aluminum chloride colorimetric method (Chang *et al.*, 2002).

Body components and digestive tract parts

On the 42nd day, four birds from each sub-group were weighed and slaughtered for determination of body organs (thigh, wing, breast, liver, heart, pancreas, abdominal fat, proventriculus, gizzard weight, gizzard length, gizzard width, crop weight, crop length) and digestive tract parts (duodenum weight, duodenum length, ileum+jejunum weight, ileum+jejunum length, colon weight, colon length, caecum weight, and caecum length).

Meat lipid oxidation and chemical composition

Breast and thigh meat samples collected from slaughtered birds were analyzed for TBARS (lipid oxidation in meat) on the 3rd day (after keeping at +4 °C) and on the 21st day (after being kept at -18 °C in the deep freezer) (Tarladgis *et al.*, 1960).

Crude protein, crude ash, and dry matter contents of breast and thigh meat of birds and feeds used during the experiment (starter and finisher) were determined as reported by AOAC (1990).

Blood parameters

Blood samples were collected from the brachial vein of eight birds from each treatment on 42-d of the experiment using heparinized syringes. The serum was separated by centrifugation for 5 min. at 10,000 rpm and were kept at -18 °C. The total cholesterol, total triglycerides, total glucose, high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL) concentration of these serum samples were analyzed using commercial kits.

Statistical analyses

The one-way Analyses of Variance (ANOVA) procedure was used to determine the statistical differences in the parameters to evaluate the effect of different doses of GBL supplementation on broiler chickens. Duncan's Multiple Comparison Test was used to determine significant differences between experimental groups means using SPSS Version 16.01 (SPSS, 2007). Statistical significance was considered at $p < 0.05$.

RESULTS

Chemical evaluation of experimental GBL

Dry matter, crude protein, and crude ash of GBL are given in Table 2. Total phenolic contents, total flavonoid compounds, and antioxidant capacity of GBL are shown in Table 3 and Table 4, respectively.

Table 2. Dry matter, crude protein, and crude ash contents of GBL

Parameters	GBL
Dry matter, %	96.21
Crude protein, % DM	16.06
Crude Ash, % DM	14.49

Table 3. Total flavonoid and total phenolic contents of GBL

Parameters	GBL
Total Phenolic (mg GA EQ / 1 g)	7.756
Total Flavonoid (TFC mg CATECEQ/1 g)	3.468

Table 4. Inhibition of GBL

Parameters	Inhibition (%)
Ascorbic Acid	96.818
GBL	93.209

Results from chemical analysis stated that GBL contains 7.756 mg GA EQ / 1 g total phenolic and 3.468 TFC mg CATECEQ/1 g total flavonoid, 96.21 % dry matter, % 16.06 crude protein, and 14.49 % crude ash. Also, inhibition of it is 93.209 %.

Growth performance

The effects of goji berry leave on body weight, body weight gain, feed intake, and feed conversion ratio (FCR) of broiler chicks are presented in Table 5.

At 0-3 and 4-6 weeks, it was observed that the body weight of birds increased numerically, especially with 5 and 10 g/kg GBL treatment ($p > 0.05$). But, when the experiment was evaluated overall, a significant increase in body weight was detected with 10 g/kg GBL supplementation compared to the control and 1 g/kg GBL ($p < 0.05$). GBL had no significant effect on body weight gains of broilers at 0-3 and 0-6 weeks ($p > 0.05$). However, body weight gain increased statistically at 4-6 weeks, especially with the supplementation of 10 g/kg GBL ($p < 0.05$). When the groups were compared in terms of feed intake, no effect of GBL was found in 0-3 weeks. ($p > 0.05$). However, at 4-6 and 0-6 weeks, feed intake at 10 g/kg GBL was again statistically significantly increased compared to control and 1 g/kg GBL ($p < 0.05$).

It was concluded that the effect of GBL on the FCR throughout the experiment was not significant ($p > 0.05$). Also, mortality was not observed during the experiment.

Body components and digestive tract parts

The data regarding body components and digestive tract parts of birds are summarized in Table 6.

When the effect of GBL on body components was evaluated, it was concluded that heart weight and proventriculus length increased with 10 g/kg GBL supplementation ($p < 0.01$). Differences in other body parameters were not found to be significant ($p > 0.05$). According to Table 5, duodenum, ileum + jejunum weights and duodenum, ileum + jejunum and colon lengths were not affected by GBL treatment, but, it was determined that 5 and 10 g/kg GBL treatment increased the colon weight of broiler chickens com-

Table 5. The effects of GBL on the performance of broiler chickens

Parameters	Goji Berry Leaves, g/kg				P
	Control	1	5	10	
BW, g/bird	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
0-3. weeks	788.00±16.18	744.92±23.63	789.49±15.70	806.64±25.72	0.08
4-6. weeks	1436.86±66.21	1474.35±17.29	1562.63±57.66	1635.92±52.63	0.09
0-6. weeks	2224.86 ^b ±67.01	2219.29 ^b ±39.22	2353.37 ^{ab} ±55.05	2444.56 ^a ±67.48	0.01
BWG, g/bird	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
0-3. weeks	743.00±16.11	699.97±23.70	743.80±15.86	763.64±14.68	0.16
4-6. weeks	1436.86 ^b ±66.21	1469.03 ^b ±17.29	1563.89 ^{ab} ±57.66	1653.92 ^a ±52.63	0.04
0-6. weeks	2179.86±66.60	2174.32±39.34	2306.43±54.86	2399.56±67.31	0.07
FI, g/bird	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
0-3. weeks	1133.61±34.50	1061.81±24.69	1111.27±42.46	1177.65±36.45	0.21
4-6. weeks	2476.67 ^b ±34.09	2518.48 ^b ±49.76	2599.66 ^{ab} ±48.30	2794.17 ^a ±94.98	0.03
0-6. weeks	3580.29 ^b ±53.63	3610.28 ^b ±74.23	3710.93 ^{ab} ±24.29	3971.82 ^a ±129.23	0.03
FCR	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
0-3. weeks	1.52±0.03	1.52±0.04	1.49±0.04	1.54±0.02	0.76
4-6. weeks	1.73±0.06	1.71±0.02	1.67±0.03	1.71±0.01	0.61
0-6. weeks	1.66±0.03	1.65±0.02	1.61±0.03	1.65±0.01	0.59
Mortality %	-	-	-	-	

^{a-b}: The differences between the means indicated by different letters on the same line are statistically significant ($p < 0.05$). $\bar{X} \pm S.E.$: Mean±Standard Error

BW: Body weight; BWG: Body Weight Gain; FI: Feed Intake; FCR: Feed Conversion Ratio.

Table 6. The effects of GBL on body components and digestive tract parts of broiler chickens

Parameters	Goji Berry Leaves, g/kg				P
	Control	1	5	10	
Body components	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
Carcass, g	1655.83±25.06	1690.83±34.53	1667.92±30.26	1752.08±39.09	0.18
Thigh, g	477.08±7.03	500.00±15.30	467.08±8.15	480.00±12.09	0.22
Wing, g	169.58±3.23	185.00±6.00	169.17±6.79	183.58±5.96	0.09
Breast, g	544.17±18.11	534.58±15.61	568.33±17.55	613.75±16.07	0.09
Liver, g	42.19±4.46	40.82±1.17	40.82±1.17	46.76±1.35	0.30
Heart, g	8.75 ^b ±0.49	9.23 ^b ±0.25	9.23 ^b ±0.56	11.43 ^a ±0.76	0.01
Pancreas, g	4.20±0.45	4.29±0.33	3.99±0.33	4.30±0.82	0.94
Abdominal fat, g	44.77±1.95	47.18±1.88	47.86±2.97	45.08±3.06	0.72
Proventriculus, cm	5.08 ^b ±0.27	5.33 ^b ±0.31	5.16 ^b ±0.44	7.44 ^a ±0.27	0.01
Gizzard, g	20.80±1.01	22.96±0.96	18.93±1.21	21.33±1.92	0.12
Gizzard length, cm	5.83±0.28	6.00±0.21	5.12±0.10	5.53±0.30	0.10
Gizzard width cm	4.08±0.08	4.25±0.31	3.36±0.25	3.95±0.34	0.13
Crop, g	9.53±0.49	10.41±1.00	8.73±0.46	11.08±1.06	0.22
Crop, cm	17.33±0.60	18.00±0.47	19.51±0.91	19.00±1.01	0.23
Digestive Tract Parts					
Duodenum, g	6.25±0.34	6.62±0.34	6.44±0.42	7.01±0.32	0.52
Duodenum, cm	29.25±0.48	32.17±0.83	31.67±0.88	30.00±1.67	0.07
Ileum + Jejunum, g	28.84±2.10	30.09±1.27	33.90±0.82	32.54±2.26	0.15
Ileum + Jejunum, cm	144.20±2.97	145.33±2.63	142.94±3.90	148.10±5.92	0.78
Colon, g	1.57 ^b ±0.09	1.91 ^{ab} ±0.02	2.27 ^a ±0.16	2.23 ^a ±0.27	0.01
Colon, cm	8.92±0.58	9.17±0.17	10.25±0.26	10.34±0.67	0.06
Caecum, g	5.38 ^b ±0.42	6.77 ^a ±0.29	6.70 ^a ±0.20	6.83 ^a ±0.18	0.04
Caecum, cm	16.91 ^b ±0.55	19.00 ^a ±0.52	19.56 ^a ±0.89	20.88 ^a ±0.54	0.03

^{a-c}: The differences between the means indicated by different letters on the same line are statistically significant ($p < 0.05$). $\bar{X} \pm S.E.$: Mean±Standard Error

pared to the control group ($p < 0.05$). Also, the caecum length and weight of broilers increased statistically with GBL compared to the control group ($p < 0.05$).

Meat lipid oxidation and chemical composition

Data on the chemical composition of the thigh and breast meat of broilers are given in Table 7.

GBL treatment on breast crude ash and crude protein did not affect ($p > 0.05$), but birds fed 10 g/kg GBL had lower breast dry matter than compared to the control group ($p < 0.05$). The thigh dry matter and crude protein were not affected by supplementing the basal diet with GBL ($p > 0.05$). In addition, supplementing the diet with 10 g/kg GBL increased thigh crude ash ($p < 0.01$).

The effects of GBL on d 3 and d 21 TBARS values of the thigh and breast meat of birds were presented in Table 8.

TBARS values obtained showed that the addition of GBL to the basal diets had no effect on breast meat lipid oxidation on d 3 ($p > 0.05$), but significantly decreased meat lipid oxidation d 21 ($p < 0.05$). It was found that GBL had no statistically significant effect on thigh meat lipid oxidation ($p > 0.05$). Thigh meat TBARS values at 10 g/kg GBL were numerically lower compared to the control group on the d 3 and d

21. The data stated that there is no significant effect of GBL on thigh TBARS.

Some blood serum parameters

The effects of GBL on cholesterol, triglycerides, glucose, high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL) of broiler chicks were presented in Table 9.

According to Table 9, the total cholesterol, triglycerides, glucose, and high-density lipoprotein cholesterol (HDL) were not affected by the GBL treatment ($p > 0.05$). Supplementing of 10 g/kg GBL decreased low-density lipoprotein cholesterol (LDL) compare to other all treatments.

DISCUSSION

Goji berry leaves have many health benefits, such as immune system, kidney, liver, longevity-related functions, and activities but studies on GBL are very limited. According to our knowledge, there is no study on chemical composition and the possible effects of goji berry leaves on broilers. But, there are many previous studies conducted with different dietary leaf meals similar to the current study. In the present study, it was hypothesized that the beneficial contents of goji berry leaves may enhance the health status of broilers reflecting performance, meat lipid

Table 7. The effects of GBL on some chemical composition of breast and thigh meat of broiler chickens

Parameters, %	Goji Berry Leaves, g/kg				P
	Control	1	5	10	
	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
Breast Dry Matter	30.88 ^a ±1.91	29.30 ^{ab} ±0.39	28.15 ^{ab} ±0.49	25.92 ^b ±0.10	0.04
Breast Crude Protein	32.45±1.82	33.82±4.91	32.09±2.05	25.33±0.25	0.13
Breast Crude Ash	1.31±0.03	1.42±0.12	1.58±0.10	1.54±0.09	0.23
Thigh Dry Matter	26.66±0.61	26.97±0.80	27.29±0.29	25.09±0.57	0.12
Thigh Crude Protein	23.75±0.47	23.98±0.89	21.95±0.73	21.36±0.56	0.06
Thigh Crude Ash	1.28 ^b ±0.08	1.41 ^b ±0.10	1.22 ^b ±0.24	1.79 ^a ±0.04	0.01

^{a-b}: The differences between the means indicated by different letters on the same line are statistically significant ($p < 0.05$). $\bar{X} \pm S.E.$: Mean±Standard Error

Table 8. The effects of GBL on TBARS values of thigh and breast meat of broiler chickens

Parameters	Goji Berry Leaves, g/kg				P
	Control	1	5	10	
	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
Breast TBA, d 3	0.13±0.01	0.17±0.09	0.12±0.07	0.10±0.05	0.25
Breast TBA, d 21	0.15 ^a ±0.02	0.09 ^{ab} ±0.09	0.03 ^b ±0.01	0.05 ^b ±0.03	0.04
Thigh TBA, d 3	0.07±0.02	0.09±0.01	0.07±0.04	0.06±0.05	0.12
Thigh TBA, d 21	0.57±0.14	0.54±0.10	0.53±0.26	0.50±0.30	0.59

^{a-b}: The differences between the means indicated by different letters on the same line are statistically significant ($p < 0.05$). $\bar{X} \pm S.E.$: Mean±Standard Error

Table 9. The effects of GBL on some blood serum parameters of broiler chickens

Parameters (mg/dL)	Goji Berry Leaves, g/kg				P
	Control	1	5	10	
	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	$\bar{X} \pm S.E.$	
Total cholesterol	133.0	129.5	141.0	140.8	0.47
Triglycerides	42.0	40.0	38.25	40.0	0.92
Glucose	249.25	239.25	230.75	253.0	0.29
HDL	35.75	40.0	37.60	38.0	0.70
LDL	40.0 ^a	40.0 ^a	40.13 ^a	38.0 ^b	0.02

^{a-b}: The differences between the means indicated by different letters on the same line are statistically significant. ($P < 0.05$). $\bar{X} \pm S.E.$:

Mean \pm Standard Error

HDL: High-density lipoprotein cholesterol; LDL: Low-density lipoprotein cholesterol.

oxidation, some body components, some digestive tract, parts, and some blood parameters. A limited number of studies have been conducted on the chemical composition, antioxidant activity, total phenolic and total flavonoid contents of goji berry leaves. In the current study, it was found that GBL contained 96.21 % dry matter, 16.06 % crude protein, and 14.49 % crude ash. Potterat (2010) reported that GBL has 13 % crude protein. Systems that destroy the effects of free radicals are called antioxidants. It has demonstrated by studies that herbal sources are beneficial against reactive oxygen species due to natural compounds such as ascorbic acid (vitamin C), flavonoids, and phenolic acids (Halvorsen *et al.*, 2002; Ogwuegbu *et al.*, 2021; Seidavi *et al.*, 2022). It is determined that GBL is opulent in phytochemicals (Table 3) and has a high antioxidant capacity (Table 4). By adding GBL to diets, the bioactive components it contains can be exploited to improve broiler growth performance, health, well-being, and meat quality. Due to these properties, it is considered to have the potential to be used in poultry nutrition.

In the present study, it was concluded that GBL did not have a negative effect on the performance and mortality of broilers. With the GBL treatment, the feed intake increased and similar increases were observed in body weight and body weight gains. These similar increases were reflected in the FCR and therefore, no change was found. Also, it can be said that the muscle mass increasing effect of GBL may have increased the carcass weight and breast meat weights, and therefore it may have increased the body weight and body weight gain of broiler chickens. Arslan Duru (2019) stated that supplementation of laying hens fed with GBL did not change initial and final body weight, body weight gain, feed intake, and FCR in comparison with the control group. Alnidawi *et al.* (2016) suggested that supplementation of *Moringa*

oleifera leaf meal enhances the growth performance of broilers; Kharde and Soujanya (2014) have reported that neem leaves treatment improved body weight gain and FCR of broilers and Tesfaye *et al.* (2013) found that inclusion of 10-20 % of *Moringa oleifera* leaf meal in diets reduced growth performance of broilers. The differences observed in the performance of broilers in previous studies may be due to the types and their effectiveness of phytochemicals used as feed additives in diets. In addition, the concentration of active substances contained in different types of phytochemical herbs and their biological activities may be another reason for the variable findings.

In the current study, GBL had significantly no impact on the body components of broilers except for proventriculus and heart. It was noted that the proventriculus length and heart weight increased. In addition, GBL treatment was observed to increase in caecum length, colon, and caecum weight of birds. It can be said that the increase in feed intake reflected in the finishing phase is the reason for the prolongation of the proventriculus and large intestine parts (Table 2). Corduk *et al.* (2013) indicated that the relative weight of the proventriculus of broilers fed oregano and red pepper was significantly decreased by delaying access to diet and water for 24 h post-hatch. The increase in heart weights observed in experimental birds may be a result of the possible high concentration of anti-nutritional factors in the diet containing 10 g/kg GBL. Because the heart may be performing above-normal metabolic activities due to the relatively high concentration of anti-nutritional factors (Gemedé and Ratta, 2014). Besides, GBL treatment, the rapid growth of birds may have made growth hormones work faster and may even have triggered heart enlargement by increasing blood pressure. As a result, it is understood that birds that consume GBL-supplemented diets do not have a negative effect on body components and

digestive tract parts. It has been reported that mistletoe and *Moringa oleifera* leaf meal treatment in diets did not affect the carcass characteristics of broilers (Ologhobo *et al.*, 2017; Rama Rao *et al.*, 2019).

The breast dry matter content was slightly lower while the thigh meat crude ash content was higher in the 10 g/kg GBL group compared to the control group. The content of breast crude protein, breast crude ash, thigh dry matter, and thigh crude protein did not change with GBL supplementation. Feeding with GBL has been found to improve the product quality of broilers. The addition of 10 g/kg GBL to the diet increased the breast meat juiciness of broiler chickens. However, the dry matter content of thigh meat increased statistically significantly with 10 g/kg GBL supplementation compared to all other treatments. Usually, meats are stored or frozen before consumption, so these processes observe negative changes in lipid fraction in meat. Lipid oxidation leads to the formation of potentially toxic compounds that negatively affect meat quality and reduce shelf life. Malondialdehyde (MDA) is accepted as the oxidative rancidity index. Therefore, the most common and sensitive method used to evaluate lipid oxidation in animal tissues is considered to be 2-thiobarbituric acid (TBA). As shown in Table 8, after 21 d of storage, TBARS values of breast meat from broilers fed on the control diets, especially 5 and 10 g/kg GBL, significantly decreased whilst decreasing numerically in all other treatments. The phenolic compounds and antioxidant activity of GBL seem to be responsible for the reduces these phenomena. It has been found that GBL treatment does not have any adverse effects on the health of the chicks, as well as improving the product quality of broilers. The improvement in meat composition and TBARS values with the increase of GBL supplementation in diets supports these findings. As a result, lipid oxidation in meat can be delayed by the use of natural antioxidants in diets. Natural antioxidants are important both in protecting human and animal health and affecting meat quality. Mustafa (2019) observed that eucalyptus leaves improved the juiciness of the thigh and breast meats of broilers. Also, the feeding treatment with eucalyptus leaves improved hardness and TBARS values in the thigh and breast meats of the broiler. Ebrahimi *et al.* (2015) stated that the inclusion of papaya leaves in the diet reduced lipid peroxidation and increased the antioxi-

dant activity of broiler breast meat.

In the present study, experimental treatments significantly did not affect the total cholesterol, triglycerides, glucose, and high-density lipoprotein cholesterol (HDL) except the low-density lipoprotein cholesterol (LDL). GBL possesses multiple pharmacological effects, including hypocholesterolemic and anti-diabetic effects. Due to these effects of GBL, it can be said that there was no significant increase in glucose, total cholesterol, triglycerides, and HDL compared to the control group. Feeding broiler on diets added with GBL had a significant decrease in LDL. Mocan *et al.* (2017) and Gong *et al.* (2016) reported that GBL is a powerful antibacterial and antioxidant. Also, it has a cholesterol-lowering effect. Decreased LDL may reflect the hypocholesterolemic effects in the fiber-rich portion of GBL and may be due to blocking cholesterol absorption in the intestinal. Arslan Duru (2019) declared that the cholesterol concentration of egg yolk decreased with the treatment of GBL in the laying hen's diets. Khalaji *et al.* (2011) found that supplementation of *Artemisia* leaves in diets had no effect on plasma triglyceride, cholesterol, HDL, and LDL while Oloruntola *et al.* (2019) stated that lower serum cholesterol, triglycerides, and cholesterol in broilers fed a diet supplemented with neem leaves, pawpaw leaves, and bamboo leaves. Ghazalah and Ali (2008) had previously recorded lower LDL concentrations in broilers fed a diet added with rosemary leaves.

CONCLUSION

The current study discovered that GBL, a potent bioactive source, had a favorable impact on broiler feed. It was observed that with the addition of 5-10 g/kg GBL, there was an improvement in many performance parameters of birds, especially in body weight and lipid oxidation in meat, and a decrease in LDL value, further studies are needed. However, the effect of using different forms and/or higher doses of GBL or extracts obtained by different methods on the performance of broilers can be seen more clearly.

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