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Dietary fig seeds improve growth performance and antioxidant capacity of quail

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Abstract

The aim of this study was to determine the effect of the addition of fig seed (FS) as a feed additive in quail rations on growth performance, carcass parameters, and antioxidant status. A total of 2000 one-day-old quail chicks were allocated to a control diet (C; n = 400) or diets supplemented with 0.25% ($FS^{0.25}$; n = 400), 0.50% ($FS^{0.50}$; n = 400), 0.75% ($FS^{0.75}$; n = 400), and 1.00% ($FS^{1.00}$; n = 400) FS. There were five replicates of 80 chicks for each treatment. At the end of the study, the highest body weights and average daily live weight gains were observed in the $FS^{1.00}$ group, whereas the lowest BW was observed in the control group. There was no statistical difference between the groups in terms of feed consumption, but the feed conversion ratios of all experimental groups were higher than the control group. The addition of FS had a marked effect on slaughter, hot, and cold carcass weights; and leg, chest, and wing weights compared to the control. Addition of FS to the ration increased total protein and albumin levels, whereas it decreased total oxidant status and alkaline phosphatase. Glucose and uric acid values showed a variable trend. As a consequence, it was concluded that the addition of fig seed as a feed additive at 0.50–1.00% of quail rations could be beneficial based on growth performance, carcass characteristics, and blood parameters.

Keywords: antioxidant, carcass, fattening performance, fig seeds, Japanese quail
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Introduction

The use of antibiotics in animal feeds as an additive has been forbidden since 2006 in EU countries because of residues in the animal tissues and concerns about the development of antibacterial resistance (Abdel-Moneim *et al*., 2020; Bartkiene *et al*., 2020). Various plants and their seeds, as well as their derived products (primarily medicinal and aromatic plants), have found a wide usage area in alternative medicine because they contain several precious pharmacological agents such as linalool, α-pinene, γ-terpinene, geranyl acetate, camphor, and geraniol (Ait Mbarek *et al*., 2007; Khani & Rahdari 2012; Khader & Eckl 2014). Scientists have focused new studies on phytobiotics such as fig, date palm, grape seed, sumac, nigella, and peppermint, which have good characteristics: i) they are natural, ii) absence of any side effects, iii) easy accessibility, and iv) alternative to antibiotics (Tufan *et al*., 2015; Cakmak *et al*., 2017; Kırar *et al*., 2020; Orak, 2020; Bolacali *et al*., 2021; Turcu *et al*., 2021). Fig and its products are among the important phytobiotics emphasized by researchers in recent years.

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Fig (*Ficus carica)* is a fruit belonging to *Ficus* genus of the family, Moraceae. It grows particularly well in South America and on Mediterranean coasts that have a climate with dry and hot summers and warm and rainy winters (Jeong & Lachance 2001; Gül & Özrenk 2019). Fig, which is accepted as one of the healthiest foods on the Mediterranean coast and is associated with long life expectancy, is an important component of the Mediterranean diet (Trichopoulou *et al*., 2006). The largest fatty acid component of fig seed, which has a rich nutrient composition, is linolenic acid (40–42%) as an omega-3 fatty acid derivative. Besides linolenic acid, fig seed also contains linoleic acid (30–31%), oleic acid, palmitic acid, and stearic acid (at lesser rate) (Kolesnik *et al*., 1986; Duman & Yazıcı 2018). Fig seed which has a rich content of minerals and vitamins (primarily calcium, potassium, pantothenate, vitamins B1 and B6), also contains high levels of several polyphenols that show extremely high antioxidant activity (Vinson 1999; Solomon *et al*., 2006; Amessis-Ouchemoukh, 2017; Duman & Yazıcı, 2018). Approximately 1.1 g of phenolic compounds are found in 100 g of fig fruit. Antioxidant phenolic compounds such as rutin, catechin, chlorogenic acids, gallic acid, and epigallocatechin have been found in fig and particularly fig seeds (Vinson 1999; Solomon *et al*., 2006; Duman & Yazıcı 2018).

It has been reported that the phytochemicals (including phenolic compounds, anthocyanins, phytosterols, amino acids, organic acids, and fatty acids) in the leaf, root, latex (*Ficus carica* latex= fig milk), and fruit of fig have primarily antioxidant (Solomon *et al*., 2006), antibacterial (Batiha *et al*., 2020), anticarcinogenic, antineoplastic (Vinson 1999; Solomon *et al*., 2006; Duman & Yazıcı 2018), hypolipidaemic (Asadi *et al*., 2006), anti-diabetic (Perez *et al*., 2003), and anti-inflammatory (Yang *et al*., 2009) properties. The antioxidant capacity increases as the amount of anthocyanins in the fig fruit increases (Solomon *et al*., 2006). The antioxidants in the fig fruit can protect plasma lipoproteins from oxidation and markedly elevate plasma antioxidant capacity for 4 h following consumption (Vinson *et al*., 2005).

Fig seeds can be used as a potential feed additive in poultry because of their beneficial bioactive components. It has been reported that fruits and seeds with high phenolic content, such as fig seeds, may have a positive effect on fattening performance due to their strong inhibitory effect against intestinal pathogens, high antioxidant content, and positive effect on digestion (Jeong & Lachance 2001; Ismail *et al*., 2003; Soni *et al*., 2014; Tufan *et al*., 2015; Farahat *et al*., 2017; Opyd *et al*., 2017; Mopuri *et al*., 2018; Bolacali *et al*., 2021).

Even though there are studies in the literature that have investigated the effects of the extracts obtained from medicinal and aromatic plants in poultry rations on growth performance, the number of the studies that have examined their effects on particularly antioxidant capacity and oxidative stress parameters along with growth performance are limited. In the literature review, no study on the addition of fig seed to the quail rations has been encountered. This study aimed to determine the effects of the addition of fig seed (FS) at different rates as a feed additive in quail rations on growth performance, carcass parameters, blood protein, serum biochemistry, antioxidant, and oxidant status.

Material and Methods

Fig seeds were obtained from a private enterprise (Egesia Company, Aydın/Nazilli, Turkey). Commercially available dried fig seeds were ground and added to the ration. The nutrient content of fig seeds used in the study is given in Table 1.

Table 1 The nutritional content of the fig seed used in the study (%)

Nutrients	%
Dry matter**	95.76
Energy, kcal/kg*	4070
Crude protein**	14.00
Ether extract**	27.56
Carbohydrate*	0.16
Crude fibre**	51.06
Crude ash**	2.98

* Merrill & Watt (1973); ** AOAC (2000)

This study was conducted with the approval of the Animal Experiments Local Ethics Committee of the Siirt University Experimental Animals Application and Research Centre (No: 2020/05/02).

A total of 2000 one-day-old quail chicks were allocated to a control diet (C; n = 400) or diets supplemented with 0.25% ($FS^{0.25}$; n = 400), 0.50% ($FS^{0.50}$; n = 400), 0.75% ($FS^{0.75}$; n = 400), and 1.00% ($FS^{1.00}$; n = 400) FS. There were five replicates of 80 chicks for each treatment. The quail were fed a basic ration, which was prepared according to the norms recommended for quail by Council (1994) and whose nutrient composition and content is presented in Table 2. The findings of the performance

parameters in the research were obtained by weekly weighing and evaluated at 1–21, 22–42, and 1–42 days of age. After the fig seed was ground, it was added to the ration by replacing it with the basic ration in the amount to be added to the ration. The chicks of all replicate groups were housed in cages measuring 45.5 × 68.8 × 30.0 cm for 42 d. The required heating and 24-h lighting were applied during the study. The feed and water (nipple drinkers) were provided *ad libitum*.

The total phenolic compound content of the FS was calculated using the Folin–Ciocalteu method as 617.87 mg gallic acid/100 g.

Table 2 Composition and nutrient content of the basal diet fed to quail from 1–42 days of the study (%)

Items		**Chemical composition (Analysed contents; DM basis)**	
Ingredients	%	Nutrients	%
Corn	41.90	Dry matter	90
Wheat	9.00	Metabolizable energy, kcal/kg**	2904
Vegetable oil	2.60	Crude protein	23.90
Soybean meal, 48% CP	33.00	Ether extract	4.11
Sunflower meal, 32% CP	10.20	Crude fibre	4.85
Di-calcium phosphate	0.80	Crude ash	6.35
Limestone	1.35	Threonine	1.03
L-Lysine	0.10	Lysine	1.37
L- Threonine	0.15	Methionine + Cystine	0.80
Sodium bicarbonate	0.20		
Salt	0.35		
Vitamin-mineral premix *	0.35		

Supplying per kilogram of diet: 13.000 IU vitamin A, 3.500 IU vitamin D3, 100 mg vitamin E, 3 mg vitamin K3, 3 mg vitamin B1, 8 mg vitamin B2, 6 mg vitamin B6, 30 mg vitamin B12, 30 mg niacin, 8 mg calcium-D-pantothenate, 2 mg folic acid, 70 mg vitamin C, 70 mg D-biotin, 200 mg choline chloride, 2 mg canthaxanthin, 0.75 mg apo carotenoic acid ester, 120 mg Mn, 100 mg Zn, 90 mg Fe, 16 mg Cu, 1,5 mg I, 0.75 mg Co, 0.30 mg Se
** Metabolizable energy is provided by calculation according to NRC (1994)

The body weights (BW, g) of the chicks were recorded at hatching and then once weekly throughout the study. Overall weekly net feed consumption was calculated by measuring the daily leftover feed. Using this data, average daily live weight gain (ADG), daily feed intake (FI), and feed conversion ratio (FCR) were calculated.

On the 42 d of the study, six birds (three male and three female) from each subgroup, which were the closest-to-average BW from each subgroup (24 birds from each main group), giving a total of 120 birds, were slaughtered for determination of slaughter and carcass traits. In total, 60 male and 60 female quail were slaughtered. The processes of slaughtering and the separation into carcass parts were performed according to the method of Genchev & Mihaylov (2008).

On day 42, anti-coagulant tubes were used to obtain blood samples from 12 quail with the closest-to-average BW from each subgroup in each dietary group of both sexes. Blood samples were centrifuged at 3,000 rpm for 10 min, and the resulting sera were stored at -20 ˚C until further analysis. Aspartate aminotransferase (AST), alkaline phosphatase (ALP), total protein (TP), albumin (Alb), glucose (GLUO) cholesterol (CHOL), and uric acid (UA) content in the serum were determined using an autoanalyzer (ADVIA 1800 Chemistry System). Total antioxidant status (TAS) and total oxidant status (TOS), which are oxidative stress parameters, were assessed using kits (Rel Assay Diagnostics, Gaziantep, Turkey) and spectrophotometric methods.

The TAS levels were measured using commercially available kits (Rel Assay, Turkey). The novel automated method is based on the bleaching of the characteristic colour of a more stable ABTS (2,2′-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radical cation by antioxidants. The assay has excellent precision values that are lower than 3%. The results were expressed as mmol Trolox equivalent/L (Erel, 2004). The TOS levels were measured using commercially available kits (Relassay, Turkey). In the new method, oxidants present in the sample oxidize the ferrous ion-o-dianisidine complex to ferric ions. The oxidation reaction is enhanced by glycerol molecules abundantly present in the reaction medium. The ferric ion produces a coloured complex with xylenol orange in an acidic medium. The colour intensity, measured spectrophotometrically, is then related to the total amount of oxidant molecules present in the sample. The assay was calibrated with hydrogen peroxide and the results were expressed in terms of micromolar hydrogen peroxide equivalent per litre (μmol H_2O_2 equivalent/L) (Erel, 2005).

The data were analysed with a factorial model of the general linear model procedure using SPSS software (SPSS version 23.0; IBM Corp., Armonk, NY, USA). Growth performance parameters were tested using simple linear regression analysis. If Y is a dependent variable (BW, ADG, FI, FCR) and X is an independent variable (dietary level of FS) then the regression equation of Y is $Y = a + bx$, where Y is the value of growth performance parameters (BW, ADG, FI, FCR), x is the dietary level of FS in diets (%0.00, 0.25, 0.50, 0.75, 1.00), and a and b are the parameters that define the shape of the curve.

The interaction of feed supplementation and sex on slaughter and carcass weight/percentage, blood parameters, and oxidative stress parameters were determined using the PROC GLM procedure.

$$Y_{ijk} = \mu + FS_i + G_j + (FS \times G)_{ij} + e_{ijk}$$

where Y_{ijk} is the response variable (slaughter and carcass weight/percentage, blood parameters, and oxidative stress parameters); μ is the overall mean common to all observations; FS_i is the fixed effect of dietary level of FS ($i = 5$); G_j is the fixed effect of sex ($j = 2$), $(FS \times G)_{ij}$ is the first order interaction, and e_{ijk} is the random residual error.

The growth performance parameters were analysed both within experimental periods (i.e., 1–21 d and 22–42 d) and over the whole period (1–42 d). Statistical significance was set at $P < 0.05$. Post hoc tests were performed using Duncan's Multiple Range Test.

Results

The results of the regression model established to test the effect of FS supplementation on BW, ADG FI, and FCR at different periods are presented in Table 3. BWs at 1 and 21 d were not affected by FS addition to the ration ($F = 0.850$, $P > 0.05$; $F = 4.124$, $P > 0.05$, respectively), whereas BW at 42d was affected by FS addition ($F = 29.665$, $P < 0.05$). As the FS addition to the ration increased, the BW at day 42 increased positively. FS addition to the ration explained 56.3% of the BW at day 42 ($R^2 = 0.563$). It was determined that the FS rates added to the ration did not affect the ADG in the 1–21d period ($F = 3.984$, $P > 0.05$); however, the ADG in the 22–42-d and 1–42-d periods was affected by the addition of FS to the ration ($F = 18.127$, $P < 0.05$; $F = 29.775$, $P < 0.05$, respectively). The ADG increased positively in the period 22–42 d and 1–42 d when the FS addition to the ration increased. FS addition to the ration explained 44.1% and 56.4% of the ADG in the 22–42-d and 1–42-d periods ($R^2 = 0.441$ and 0.564, respectively). FS addition did not affect the FI in the 1–21-d, 22–42-d, and 1–42-d periods ($F = 0.092$, $P > 0.05$; $F = 3.757$, $P > 0.05$; $F = 2.649$, $P > 0.05$, respectively). The FCR in the 1–21-d period was not affected by FS addition ($F = 3.683$, $P > 0.05$); however, the FCR in the 22–42-d and 1–42-d periods was affected by FS addition ($F = 21.859$, $P < 0.05$; $F = 30.229$, $P < 0.05$, respectively). Increasing the FS supplementation improved the FCR in the 22–42-d and 1–42-d periods. The addition of FS to the diet explained 48.7% and 56.8% of the FCR in the 22–42-d and 1–42-d periods ($R^2 = 0.487$ and 0.568, respectively).

Table 3 Effects of fig fruit seed supplementation on growth performance of quail

Items[1]	Treatments[2]					F-value	*P*-value (Model)	R^2
	Control	$FS^{0.25}$	$FS^{0.50}$	$FS^{0.75}$	$FS^{1.00}$			
BW, g								
1 d	8.75±0.003	8.78±0.025	8.81±0.029	8.78±0.025	8.78±0.025	0.850	0.366	0.036
21 d	90.86±1.417	91.19±0.799	91.37±1.120	91.75±1.769	94.64±1.220	4.124	0.054	0.152
42 d	189.08±1.687^{c}	195.55±1.340^{b}	194.56±2.551^{bc}	199.69±2.422^{ab}	203.38±1.112^{a}	29.665	0.000	0.563
ADG, (g/d)								
1–21 d	3.91±0.067	3.92±0.039	3.93±0.054	3.95±0.084	4.09±0.058	3.984	0.058	0.148
22–42 d	4.68±0.062^{b}	4.97±0.062^{a}	4.92±0.159^{ab}	5.14±0.031^{a}	5.18±0.059^{a}	18.127	0.000	0.441
1–42 d	4.29±0.039^{c}	4.45±0.033^{b}	4.42±0.060^{bc}	4.55±0.058^{ab}	4.63±0.026^{a}	29.775	0.000	0.564
FI, g								
1–21 d	10.25±0.266	10.37±0.207	10.03±0.064	10.02±0.093	10.33±0.234	0.092	0.764	0.004
22–42 d	23.73±0.176^{bc}	25.06±0.307^{a}	23.92±0.148^{b}	22.90±0.213^{c}	23.60±0.489^{bc}	3.747	0.065	0.140
1–42 d	16.99±0.084^{b}	17.72±0.236^{a}	16.97±0.053^{b}	16.46±0.150^{b}	16.96±0.356^{b}	2.649	0.117	0.103
FCR, (g/g)								
1–21	2.62±0.076	2.64±0.040	2.55±0.045	2.54±0.049	2.53±0.035	3.683	0.067	0.138
22–42	5.08±0.040^{a}	5.05±0.097^{a}	4.89±0.181^{a}	4.46±0.034^{b}	4.56±0.099^{b}	21.859	0.000	0.487
1–42	3.96±0.043^{a}	3.98±0.040^{a}	3.84±0.064^{a}	3.62±0.039^{b}	3.66±0.061^{b}	30.229	0.000	0.568

[1] Body weight (BW); Average daily gain (ADG); Average daily feed intake (FI); Feed conversion ratio (FCR)
[2] FS: fig seeds; $FS^{0.25}$: 0.25% fig seeds; $FS^{0.50}$: 0.50% fig seeds; $FS^{0.75}$: 0.75% fig seeds; $FS^{1.00}$: 1.00% fig seeds
^{a,b,c}: According to Duncan's test, the values with different letters in the same row are statistically different (P <0.05)

The effects of the addition of FS as a feed additive and sex on carcass weights and percentages are summarized in Table 4. The addition of FS had an effect on some carcass parameters except for leg percentage, wing percentage, neck weight-percentage, and other-weight-percentage, compared to the control group (P <0.05). The highest values for all carcass parameters (except for neck weight) were detected in the $FS^{1.00}$ group. Sex had an effect on carcass characteristics; female quail were heavier than males in all carcass characteristics (P <0.001). In addition, female quail had higher hot carcass, cold carcass, chest, and wing weights than males (P <0.05). The FS × sex interaction had no effect on carcass yield parameters except for hot carcass and leg percentage (P >0.05). The highest hot carcass and leg ratios were determined in the $FS^{0.50}$♂ and $FS^{1.00}$♂ groups, respectively, whereas the lowest hot carcass and leg ratios were observed in the C♀ and $FS^{0.25}$♀ groups, respectively.

Table 5 shows the heart, liver, gizzard, intestine, abdominal fat weights and percentages in the quail. The FS × sex interaction did not affect all internal organ and abdominal fat weights (P >0.05). There was an effect of sex on internal organ weights (P <0.01); female quail had higher internal organ weights. The females had higher liver and intestine rates compared to male quail, and male quail had a higher heart percentage than female quail (P <0.001).

Table 6 shows serum AST, ALP, TP, Alb, GLUO, CHOL, UA, TAS, and TOS values of the quail. The addition of FS to the ration increased the content of TP and Alb (P <0.01), whereas it decreased TOS (P <0.01); ALP, GLUO, and UA levels fluctuated (P <0.01), and CHOL and TAS contents increased (P >0.05). The female quail had higher ALP, TP, Alb, and GLUO values compared to male quail; AST, CHOL, TAS, and TOS were lower in female quail than in male quail. The FS × sex interaction affected TP, Alb, GLUO, CHOL, UA, and TAS parameters (P <0.05), and the highest values were obtained in $FS^{0.25}$♀, $FS^{0.25}$♀, $FS^{0.50}$♀, $FS^{1.00}$♂, C♂, and $FS^{0.25}$♂, respectively. The lowest values were observed in $FS^{0.75}$♂, $FS^{0.75}$♂, $FS^{0.75}$♂, $FS^{0.50}$♀, $FS^{0.75}$♂, and $FS^{0.25}$♀, respectively.

Table 4 Effect of dietary fig seed (FS) supplementation on slaughter and carcass traits of quail

Items		Slaughter	Hot Carcass		Cold Carcass		Leg		Breast		Wing		Neck		Other *	
Parameters		Weight, g	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%
Control	♂	170.30	120.71	70.80^{bc}	118.81	69.71	28.51	24.00^{b}	43.70	36.77	10.48	8.83	8.52	7.18	27.60	23.22
	♀	199.70	130.85	65.62^{e}	129.86	65.13	31.37	24.15^{b}	49.78	38.31	10.93	8.42	8.96	6.90	28.82	22.22
FS$^{0.25}$	♂	170.90	121.39	71.02^{b}	120.72	70.63	30.18	24.98^{ab}	44.17	36.64	10.31	8.56	9.03	7.46	27.03	22.36
	♀	212.90	142.33	67.08^{e}	139.77	65.86	33.49	23.95^{b}	53.20	38.11	11.83	8.49	9.40	6.72	31.86	22.73
FS$^{0.50}$	♂	172.60	126.91	73.53^{a}	125.38	72.64	30.85	24.63^{b}	47.99	38.29	10.73	8.57	7.64	6.09	28.16	22.43
	♀	209.90	139.48	66.48^{e}	138.33	65.93	34.54	25.00^{ab}	52.20	37.66	11.31	8.19	9.54	6.87	30.74	22.29
FS$^{0.75}$	♂	178.40	129.79	72.74^{ab}	128.61	72.07	31.63	24.59^{b}	49.46	38.46	10.86	8.44	8.57	6.64	28.10	21.87
	♀	214.00	144.66	67.55^{de}	143.94	67.22	35.69	24.83^{ab}	56.64	39.26	11.65	8.12	9.19	6.40	30.77	21.40
FS$^{1.00}$	♂	181.80	130.64	71.90^{ab}	129.97	71.53	33.45	25.73^{a}	49.75	38.26	10.86	8.37	8.14	6.28	27.77	21.36
	♀	217.20	149.62	69.02^{cd}	148.54	68.52	35.69	24.01^{b}	58.25	39.21	12.21	8.23	9.87	6.64	32.52	21.92
	SEM	4.907	3.205	0.651	3.146	0.622	0.869	0.330	1.490	0.566	0.252	0.142	0.462	0.292	0.963	0.483
	Control	185.00^{b}	125.78^{c}	68.21^{c}	124.34^{c}	67.42^{c}	29.94^{d}	24.08	46.74^{d}	37.54^{b}	10.71^{b}	8.62	8.74	7.04	28.21	22.72
	FS$^{0.25}$	191.90^{ab}	131.86^{bc}	69.05^{bc}	130.25^{bc}	68.24^{bc}	31.84^{cd}	24.47	48.68^{cd}	37.37^{b}	11.07^{ab}	8.52	9.21	7.09	29.45	22.55
	FS$^{0.50}$	191.25^{ab}	133.20^{b}	70.00^{ab}	131.85^{b}	69.28^{ab}	32.70^{bc}	24.81	50.10^{bc}	37.97^{ab}	11.02^{ab}	8.38	8.59	6.48	29.45	22.36
	FS$^{0.75}$	196.20^{a}	137.23^{ab}	70.15^{ab}	136.27^{ab}	69.65^{a}	33.66^{ab}	24.71	53.05^{ab}	38.86^{a}	11.25^{ab}	8.28	8.88	6.52	29.44	21.63
	FS$^{1.00}$	199.50^{a}	140.13^{a}	70.46^{a}	139.25^{a}	70.02^{a}	34.57^{a}	24.87	54.00^{a}	38.74^{a}	11.54^{a}	8.30	9.00	6.46	30.15	21.64
	SEM	3.470	2.267	0.460	2.225	0.440	0.614	0.233	1.054	0.400	0.178	0.101	0.327	0.207	0.681	0.341
	♂	174.80	125.89	72.00	124.70	71.32	30.92	24.79	47.01	37.68	10.65	8.55	8.38	6.73	27.73	22.25
	♀	210.74	141.39	67.15	140.09	66.53	34.16	24.39	54.01	38.51	11.58	8.29	9.39	6.71	30.94	22.11
	SEM	2.194	1.433	0.291	1.407	0.278	0.389	0.148	0.666	0.253	0.113	0.064	0.207	0.131	0.431	0.216
	FS	0.048	0.000	0.005	0.000	0.000	0.000	0.113	0.000	0.028	0.025	0.078	0.705	0.056	0.383	0.070
	Sex	0.000	0.000	0.000	0.000	0.000	0.000	0.060	0.000	0.024	0.000	0.004	0.001	0.895	0.000	0.654
	FS × Sex	0.791	0.431	0.027	0.656	0.071	0.852	0.005	0.499	0.319	0.147	0.671	0.279	0.089	0.275	0.496

FS: fig seeds; FS$^{0.25}$: 0.25% fig seeds; FS$^{0.50}$: 0.50% fig seeds; FS$^{0.75}$: 0.75% fig seeds; FS$^{1.00}$: 1.00% fig seeds
* Other: According to Genchev and Mihaylov (2008)
^{a,b,c,d}: According to Duncan's test, the values with different letters in the same row are statistically different (P <0.05)

Table 5 The effects of adding fig seeds to quail rations on the visceral organs (g and %)

Items		Heart		Liver		Gizzard		Intestine		Abdominal Fat	
Parameters		Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%	Weight, g	%
Control	♂	1.60	0.94	3.59	2.11	3.24	1.91	5.31	3.12	1.87	1.10
	♀	1.70	0.86	5.04	2.53	4.35	2.17	6.65	3.35	2.62	1.32
$FS^{0.25}$	♂	1.67	0.98	3.53	2.06	3.43	2.00	5.03	2.94	2.15	1.26
	♀	1.89	0.90	6.00	2.79	4.09	1.92	7.53	3.54	2.26	1.04
$FS^{0.50}$	♂	1.65	0.96	3.90	2.26	3.48	2.02	5.07	2.94	2.05	1.16
	♀	1.60	0.76	5.97	2.85	3.96	1.90	6.89	3.30	1.66	0.80
$FS^{0.75}$	♂	1.58	0.88	3.63	2.04	3.22	1.81	5.00	2.81	1.48	0.83
	♀	1.73	0.80	6.48	3.04	4.05	1.89	7.13	3.34	2.30	1.07
$FS^{1.00}$	♂	1.66	0.92	3.89	2.15	3.53	1.93	5.03	2.76	1.57	0.85
	♀	1.83	0.84	5.77	2.66	3.82	1.78	7.22	3.33	1.90	0.86
	SEM	0.064	0.035	0.316	0.146	0.207	0.197	0.301	0.139	0.278	0.140
	Control	1.65	0.90	4.31	2.32	3.80	2.04	5.98	3.23	2.24	1.21
	$FS^{0.25}$	1.78	0.94	4.77	2.43	3.76	1.96	6.28	3.24	2.21	1.15
	$FS^{0.50}$	1.63	0.86	4.93	2.56	3.72	1.96	5.98	3.12	1.86	0.98
	$FS^{0.75}$	1.65	0.84	5.06	2.54	3.63	1.85	6.07	3.07	1.89	0.95
	$FS^{1.00}$	1.74	0.88	4.83	2.41	3.67	1.85	6.12	3.04	1.73	0.86
	SEM	0.045	0.025	0.224	0.103	0.146	0.069	0.213	0.098	0.196	0.099
	♂	1.63	0.94	3.71	2.12	3.38	1.93	5.09	2.91	1.82	1.04
	♀	1.75	0.83	5.85	2.78	4.05	1.93	7.09	3.37	2.15	1.02
	SEM	0.029	0.016	0.142	0.065	0.093	0.043	0.135	0.062	0.124	0.063
	FS	0.077	0.072	0.181	0.475	0.937	0.239	0.849	0.486	0.264	0.078
	Sex	0.004	0.000	0.000	0.000	0.000	0.987	0.000	0.000	0.070	0.779
	FS × Sex	0.232	0.287	0.227	0.332	0.331	0.179	0.375	0.638	0.185	0.137

FS: fig seeds; $FS^{0.25}$: 0.25% fig seeds; $FS^{0.50}$: 0.50% fig seeds; $FS^{0.75}$: 0.75% fig seeds; $FS^{1.00}$: 1.00% fig seeds

Table 6 Effects of fig seed supplementation in quail diets on certain serum constituents

Item		AST, U/L	ALP, U/L	TP, g/dl	Alb, g/dl	GLUO, mg/dl	CHOL, mg/dl	UA, mg/dl	TAS, mmol trolox Equiv./L	TOS, µmol H_2O_2 equiv./L
Control	♂	244.75	743.25	2.33^{b}	1.08^{b}	339.00^{ab}	235.00^{abc}	7.94^{a}	1.28^{bcd}	17.64
	♀	195.00	858.00	2.13^{b}	0.98^{b}	306.50^{c}	204.50^{c}	5.61^{cd}	1.19^{cd}	15.90
FS$^{0.25}$	♂	254.25	865.17	2.38^{b}	1.03^{b}	300.25^{c}	224.50^{abc}	7.42^{ab}	1.56^{a}	13.19
	♀	198.25	848.00	3.23^{a}	1.50^{a}	342.75^{ab}	249.75^{ab}	7.43^{ab}	1.10^{d}	11.69
FS$^{0.50}$	♂	236.50	694.00	2.15^{b}	0.95^{b}	310.00^{c}	244.25^{abc}	6.85^{ab}	1.31^{bcd}	11.94
	♀	187.25	793.75	3.15^{a}	1.45^{a}	357.75^{a}	204.00^{c}	7.37^{ab}	1.37^{abc}	12.78
FS$^{0.75}$	♂	239.50	597.75	2.08^{b}	0.90^{b}	289.50^{c}	220.75^{abc}	3.68^{e}	1.26^{bcd}	16.81
	♀	208.50	794.25	3.15^{a}	1.45^{a}	319.00^{bc}	225.00^{abc}	6.25^{bc}	1.40^{abc}	15.75
FS$^{1.00}$	♂	226.75	626.25	2.35^{b}	1.05^{b}	297.75^{c}	259.75^{a}	6.43^{bc}	1.42^{ab}	16.67
	♀	191.00	778.25	3.00^{a}	1.35^{a}	302.25^{c}	205.75^{bc}	5.03^{d}	1.27^{bcd}	11.27
	SEM	12.258	47.991	0.117	0.065	9.662	13.714	0.398	0.068	1.346
	Control	219.88	800.63^{ab}	2.23^{b}	1.03^{b}	322.75^{ab}	219.75	6.77^{a}	1.24	16.77^{a}
	FS$^{0.25}$	226.25	856.58^{a}	2.80^{a}	1.26^{a}	321.50^{ab}	237.13	7.43^{a}	1.33	12.44^{b}
	FS$^{0.50}$	211.88	743.88^{b}	2.65^{a}	1.20^{a}	333.88^{a}	224.13	7.11^{a}	1.34	12.36^{b}
	FS$^{0.75}$	224.00	696.00^{b}	2.61^{a}	1.18^{a}	304.25^{bc}	222.88	4.97^{b}	1.33	16.28^{a}
	FS$^{1.00}$	208.88	702.25^{b}	2.68^{a}	1.20^{a}	300.00^{c}	232.75	5.73^{b}	1.34	13.97^{ab}
	SEM	8.668	33.935	0.083	0.046	6.832	9.697	0.282	0.048	0.952
	♂	240.35	705.28	2.26	1.00	307.30	236.85	6.46	1.36	15.25
	♀	196.00	814.45	2.93	1.35	325.65	217.80	6.34	1.26	13.48
	SEM	5.482	21.462	0.052	0.029	4.321	6.133	0.178	0.030	0.602
	FS	0.557	0.006	0.000	0.009	0.005	0.688	0.000	0.489	0.002
	Sex	0.000	0.001	0.000	0.000	0.004	0.033	0.623	0.026	0.042
	FS × sex	0.831	0.252	0.000	0.000	0.001	0.033	0.000	0.001	0.242

FS: fig seeds; TAS: total antioxidant status; TOS: total oxidant status; AST: aspartate aminotransferase; ALP: alkaline phosphatase; TP: total protein; Alb: albumin; GLU: glucose; CHOL: cholesterol; UA: uric acid; FS$^{0.25}$: 0.25% fig seeds; FS$^{0.50}$: 0.50% fig seeds; FS$^{0.75}$: 0.75% fig seeds; FS$^{1.00}$: 1.00% fig seeds

^{a,b,c,d}: according to Duncan's test, the values within different letters in the same row are statistically different (P <0.05)

Discussion

At end of the experiment (42 d), the BW and ADG were substantially higher in the $FS^{0.25}$, $FS^{0.75}$, and $FS^{1.00}$ groups than in the control group, whereas the $FS^{0.50}$ group had similar values to the control (Table 3). Throughout the experiment, it was found that feed consumption was substantially higher in the $FS^{0.25}$ group than in all other groups. FCR was substantially higher in the $FS^{0.75}$ and $FS^{1.00}$ groups than in the other groups. When the fattening performance parameters were evaluated in general, better results were obtained in the experimental groups than the control group. The performance results obtained in the $FS^{0.75}$ and $FS^{1.00}$ groups were substantially higher than the control group. It was determined in the present study that the addition of FS to the ration improved BW and ADG (except for the period of 1–21 d) and FCR; the increase depended on the elevated dose (except for $FS^{0.50}$) (Table 3). The positive effect of the addition of FS on growth performance can be associated with i) the strong inhibitory effect of the active compounds against intestinal pathogenic microorganisms, ii) the high antioxidant content, iii) its positive effect on digestion, and iv) the nutritional content of fig seeds (Jeong & Lachance 2001; Tufan *et al*., 2015; Mopuri *et al*., 2018). Since there is no study in the literature that has investigated the effects of FS as a feed additive in poultry, the present study's results were compared with studies on the addition of different fruit seeds or aromatic plants to the ration. The results of BW, ADG, and FCR obtained in the present study were compatible with the results obtained with the addition of grape seed (Shata *et al*., 2017); sumac (Söğüt & Mohammad, 2018; Tag El-Din *et al*., 2019), and date palm extract (Bolacali *et al*., 2021) to the ration. In contrast, fruit seeds have also had no significant effect on growth performance (Mohammadi *et al*., 2011). The current study indicated that the addition of FS to the ration had no marked effect on FI (except for the $FS^{0.25}$ group) and this result is compatible with the results of the studies conducted with the addition of fig (Farahat *et al*., 2017) and sumac (Kırar *et al*., 2020).

Antioxidants are among the most important compounds that protect cells from the detrimental effects of free radicals (Knox *et al*., 2001). Phytobiotics as a good source of antioxidants and contain substantial amounts of A, C, and E vitamins, carotenoids, and polyphenols (Pieszka *et al*., 2015; Abdel-Moneim *et al*., 2020). Thanks to these features, phytobiotics also improve many parameters related to meat and carcass quality; these may influence the health of consumers positively, in addition to their positive effects on growth performance (Pieszka *et al*., 2017; Bolacali *et al*., 2021).

The effect of sex on carcass weights and percentages in the present study can be associated with the higher live weights of female quail than male quail in the growth period until puberty (Leeson & Summers, 2005; Taskin *et al*., 2017; Bolacali *et al*., 2021). The effects of sex on carcass parameters also are supported by Bolacali *et al*. (2021). When the other carcass parameters (except for hot carcass and leg weight and percentage) were evaluated, the absence of the sex × feed additive interaction was also found to be partially compatible with the results of the study by Bolacali *et al*. (2021).

It was observed in the present study that the addition of FS to quail rations led to improvement in carcass parameters (except for the percentages of leg, wing, neck, and other, as well as neck weight and other-weight) depending on the dose. The positive effect of the addition of FS on carcass parameters is compatible with the results of Bolacali *et al*. (2021) on palm extract. The studies associated the improvement in growth performance and carcass parameters achieved by some fruit seeds with active biological components such as polyphenols in the fruit seeds (Pieszka *et al*., 2015; Pieszka *et al*., 2017; Duman & Yazıcı 2018; Abdel-Moneim *et al*., 2020).

The addition of FS in the current study had no marked effect on the weights and percentages of internal organs. This agrees with the results of studies on different fruits and products (Abu Hafsa & Ibrahim, 2018; Bolacali *et al*., 2021; Gümüş *et al*., 2021; Gungor *et al*., 2021; Turcu *et al*., 2021). The effect of sex on the weights and percentages of internal organs (except for gizzard % and abdominal fat weight/%) can be associated with the higher live weights of female quail and laying activities of female quail.

In this study, it was shown that the addition of fig seeds to the ration had a positive effect on carcass parameters in general. The improvement in carcass parameters can be associated with the antioxidant and antimicrobial activity of the phenolic compounds in the fig seed, which protect the intestinal mucosa from oxidative damage and pathogens, limit the peristaltic activity in digestive disorders, and reduce intestinal motility leading to better nutrient absorption (Ismail *et al*., 2003; Soni *et al*., 2014; Opyd *et al*., 2017).

The investigation of various biochemical parameters in the blood provides crucial information about the changes in metabolic profile (Otto *et al*., 1992; Phogat *et al*., 1992). Since no study investigating the effect of fig and its products on serum biochemical parameters and antioxidant status

in quail has been encountered in the literature, the results of the present study were interpreted in the light of similar studies.

The biochemistry evaluation of liver enzymes (such as AST, ALT) gives evidence about metabolic disorders caused by diseases or nutritional deficiencies that influence hepatic activity (Sallie *et al*., 1991). The results of the present study revealed that the addition of FS at all doses to the ration had no marked effect on serum AST and ALP concentrations. However, it resulted in a quantitative decrease in all the groups except for the $FS^{0.25}$ group, compared to the control (Table 6). This finding was considered to be due to a positive effect of FS on the liver. Mohan *et al*. (2007) reported that the methanolic extract of *F. carica* leaves was protective against carbon tetrachloride-induced hepatic damage by inhibiting the elevation of transaminase levels. It was suggested in another study that dry fig had a positive effect on the liver enzymes of rats and regular intake of this functional nutrient may be beneficial in the prevention of chronic degenerative liver diseases (Turan & Celik, 2016).

In the present study, the addition of FS at all doses to the basic diet increased serum TP and Alb concentrations. The higher TP and Alb levels of female quail may have resulted from the increased protein synthesis due to accelerated liver metabolism in females at the onset of egg production (Vignale & Lake, 2014). In contrast, the addition of grape seed (Abu Hafsa & Ibrahim, 2018) and sumac (Cakmak *et al*., 2017) did not affect TP and Alb concentrations.

Researchers have reported that adding figs and their products to the diet can help regulate hypercholesterolaemia (El-Shobaki *et al*., 2010) and hyperlipidaemia (El-Shobaki *et al*., 2010; Irudayaraj *et al*., 2017). Extract of *F. carica* leaf may be useful in modulating the release of triglycerides and cholesterol from the poultry liver (Asadi *et al*., 2006). The lower CHOL level in females than in male quail can be associated with the excretion of cholesterol together with eggs due to the physiology of laying at the age of slaughter. The result of the present study indicated that the addition of FS to the ration did not affect CHOL levels of the quail and this result is different from the results of Asadi *et al*. (2006) due to the use of different material (*Ficus carica* leaf) in the study.

Studies have shown that figs and their products can help in the treatment of hyperglycaemia (Perez *et al*., 2000; Perez *et al*., 2003; El-Shobaki *et al*., 2010; Irudayaraj *et al*., 2017). The addition of FS in the current study generally lowered the glucose level in the blood of quails. This finding can be explained by the fact that flavonoids modulate glucose transport by their respective intestinal transporters (Song *et al*., 2002).

It has been reported that fig fruit and leaves reduce uric acid levels in diabetic rats (El-Shobaki *et al*., 2010). The lower uric acid levels in the $FS^{0.75}$ and $FS^{1.00}$ groups can be associated with antioxidant characteristics of phenolic compounds in fig leaves, which concurs then with the result of El-Shobaki *et al*. (2010).

Different commercial fig varieties contain high contents of polyphenols, flavonoids, and anthocyanins, and exhibit high antioxidant capacity (Solomon *et al*., 2006). In a study on rats, plasma total antioxidant capacity increased up to 35% within 4 h of consuming *F. carica* fruit; this increase was related to the intense phenolic compounds in the fig fruit. It was stated in the same study that fresh and dry fig fruits contained 486 mg/100 g and 326 mg/100 g total phenols, respectively (Vinson *et al*., 2005). In the present study, the addition of FS to the ration increased the TAS values of the quail whereas it statistically decreased TOS content. The FS × sex interaction was effective on TAS (P <0.001), and males had a higher average TAS than females. Isler *et al*. (2022) found an increase in antioxidant capacity in a study in which they examined the effect of *F. carica* seed oil application at different doses (3 ml/kg and 6 ml/kg) on serum GSH levels in male rats. The FS × sex interaction can be associated with high levels of polyphenols, flavonoids, and anthocyanin in figs, as well as a high antioxidant capacity. The high phenolic concentration of fig seed added to the ration (617.87 mg/100 g gallic acid) in the present study supports this hypothesis.

Conclusions

The addition of FS at 0.25, 0.50, 0.75, and 1.00% to quail rations generally improved growth performance and carcass parameters. These improvements were substantially higher with the addition of FS at 0.75 and 1.00%, and increased serum antioxidant capacity. Consequently, it was concluded that the addition of fig seeds as a feed additive at 0.75–1.00% to quail rations can be beneficial based on growth performance, carcass, and blood parameters.

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Conflicts of interest

The authors declare no conflict of interest.

Author contributions

TT carried out all the processes of this research. TT, MB, KI, CA, CÖ, MI, and OK took responsibility for the logical interpretation and presentation of the results. TT, MB, and KI wrote the manuscript. All the authors mentioned have contributed to the study.

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