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Original article

Effect of dietary supplementation of jujube fruit (Ziziphus jujuba) powder on performance, some biochemical parameters, and egg quality in quails (Coturnix coturnix japonica)

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Abstract

This study aimed to evaluate the effects of different dietary supplementation levels with jujube fruit powder on the performance, biochemical parameters, and egg quality characteristics of laying quails. A total of 60 quails (45 days old) were randomly assigned to treatments with different levels of jujube fruit powder: a basal diet (control) and diets supplemented with 5 g/kg (T1), 10 g/kg (T2), with five replicates per treatment (20 quails/treatment and four quails/replicate). The differences between 1-15 and 16-30 days for feed intake ($p<0.05$), 1-60 days for egg production ($p<0.05$), 16-30 days for egg weight ($p<0.05$), and 1-15 and 1-60 days for feed conversion ratio were statistically significant. The highest values for egg width ($p<0.01$) and egg length ($p<0.05$) were found in the control group (25.87 and 33.55 mm), while lower values were observed in the T1 and T2 groups. There was no statistical difference between the groups in egg shape index, shell weight, shell ratio, and shell thickness ($p>0.05$). The yolk height ($p<0.05$) and yolk diameter ($p<0.01$) were statistically significant. The differences between the groups for all serum biochemical parameters were insignificant ($p>0.05$). According to the results of this study, jujube fruit, a rich energy source, can be used as an alternative supplement in poultry diets with positive effects on egg production and feed conversion ratio.

Keywords: egg, jujube, performance, supplement, quail

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Introduction

Poultry farming is an important animal husbandry activity for quickly obtaining high-quality and economical animal products. Eggs have been the highest quality and cheapest source of animal protein used as food since ancient times. The body can almost entirely utilize egg albumin due to its proportional and balanced content of essential amino acids. This is why it is known as the protein with the highest biological value among proteins.

Antibiotics have been used as growth promoters to meet the growing demand for these essential foods for the world's expanding population. However, because of growing public anxiety about the adverse effects of antibiotics and the rise in drug-resistant microorganisms in recent years, restrictions and bans on the use of antibiotics have been introduced (Yesilbag 2018, Gumus et al. 2023). As a result, alternatives to antibiotics are being considered by both producers and consumers. Antibodies, bacteriophages, vaccinations, organic acids, enzymes, plant derivatives, essential oils, prebiotics, and probiotics are just a few currently produced substitutes (Gul et al. 2022). Herbs have a great deal of potential to replace antibiotic growth promoters in this regard due to their antibacterial, coccidiostat, and anthelmintic-like pharmacological features, which may enhance growth performance by maximizing feed intake and intestinal health (Faroog et al. 2022). Aloe-vera, giloy, tabasheer, vaghayani, anwara, gadamri, garlic, cumin, black cumin, wild mint, pumpkin, thyme, cinnamon, chestnut, clove, alfalfa, turmeric, sumac, mushroom, grape seed, goldthread, mulberry leaf, and honeysuckle are the most often used herbs and plant extracts used as an alternative source of antimicrobials in poultry (Aroche et al. 2018).

Jujube is another natural plant that would be a suitable alternative for poultry diets due to its high level of phenolic compounds, alkaloids, vitamins, minerals, fatty acids, carbohydrates, and proteins. Jujube (Ziziphus jujuba) is a member of the Rhamnaceae family and can grow naturally in different climates, such as some parts of the Middle East, southern China, Italy, and western and southern parts of Turkey (Gunduz and Saracoglu 2014, Xu et al. 2022). The high level of phenolic compounds (275.6-541.8 mg/100 g) in the structure of jujube fruit shows that it has a substantial antioxidant property (Koley et al. 2011). In addition, the presence of bioactive secondary metabolites in jujube may help to explain the antiproliferative, anti-inflammatory antioxidant, antiobesity, antitumor, proapoptotic activity and the protective effect against cardiovascular diseases and type II diabetes (Yu et al. 2012).

The wide availability, relatively low price, and health benefits of jujube make it an attractive choice for inclusion in animal diets (Xu et al. 2022). Different studies show the positive effects of jujube on feed conversion ratio, average daily gain, milk production and meat quality in various species (Wang et al. 2010, Zhao et al. 2015, Liu et al. 2020). Liu et al. (2020) reported that the addition of 0.5% jujube extract promoted renal function, protected the liver, and improved non-specific immune function. Cellat et al. (2022) observed that the jujube fruit powder added to the feed positively affected the live weight, daily live weight increase, feed consumption, and villus height in quails. In one study, Ma et al. (2017) investigated the effects of using different levels of powdered jujube (0, 2, 4, 6, 8, 10 %) in the ration instead of corn at the same levels on performance and egg quality in laying hens for 74 days. They also reported that there was no significant difference between the groups in terms of feed conversion ratio, damaged egg ratio, and mortality rate, and that jujube supplementation at 6, 8, and 10% levels increased feed intake had no significant effect on egg quality parameters but did reduce egg cholesterol levels. The 10% level was more effective than other levels in the ration. In a study, Zhonghua et al. (2011) reported that jujube oligosaccharides improved performance and immunity and can be optimally used at 1000 mg/kg in the diet. In another study, Asheg et al. (2014) reported that adding 1 g/kg Zizyphus vulgaris to the diet of male broiler chicks reduced the number of fecal coliform bacteria compared to the control group.

This study was conducted to determine the effects of jujube fruit powder supplementation at different levels in diets on the performance, biochemical parameters and egg quality characteristics of laying quails.

Materials and Methods

Fırat University Animals Experiment Local Ethics Committee (protocol no: 15367) granted the approval to conduct the study.

Animal and feed materials

The study used 60 quails (Coturnix coturnix Japonica), 45-day-old, obtained from a commercial farm. The 60 Japanese quails with similar body weights were randomly divided into three groups with five replicates of 4 quails each. The diets used in the study contained 20% crude protein and 2900 kcal/kg metabolizable energy (ME) according to NRC standards. Jujube fruit (Ziziphus jujuba), collected in season and powdered after grinding, was used in the study. The experimental diets composition is summarized in Table 1.

Table 1. Ingredients and nutrient composition of the experimental diets (%) for quails.

Feed ingredients (%)	Control	T1	T2
Corn	50.50	50.00	49.50
Soybean meal (43% CP)	34.00	34.00	34.00
Wheat Bran, Razmol	4.10	4.10	4.10
Vegetable Oil	3.88	3.88	3.88
Dicalcium Phosphate (DCP)	1.20	1.20	1.20
Limestone	5.52	5.52	5.52
Salt	0.35	0.35	0.35
DL-Methionin	0.10	0.10	0.10
L-Lizin Hidroklorit	0.10	0.10	0.10
Vitamin- Mineral Mix	0.25	0.25	0.25
Jujube Fruit Powder	0	0.50	1.00
Nutritional composition (%)			
Dry Matter	89.70	89.85	90.25
Crude protein	20.00	20.00	20.00
ME, kcal/kg**	2900	2900	2900

* Vitamin-Mineral mix supplied per kg: Vitamin A 6.000.000 IU, Vitamin D3 1.500.000 IU: Vitamin E 25.000 mg, Vitamin K3 2.500 mg, Vitamin B1 1.500 mg,Vitamin B2 3.000 mg, Niacin 22.500 mg, Calcium D-pantothenate 5.000 mg, Vitamin B6 3. 750 mg, Vitamin B12 15 mg, Folic Acid 500 mg, D-Biotin 75 mg, Folic acid 500 mg, manganese 100.000 mg, iron 60.000 mg, zinc 60.000 mg, copper 5.000 mg, cobalt 300 mg, iodine 1.000 mg, selenium 350 mg.
** Calculated

Table 2. Nutrient composition of jujube powder for quails used in the study (%).

Nutritional composition (%)	
Dry Matter	94.54
Moisture	5.46
Crude protein	3.20
Crude Cellulose	32.80
Crude Fat	2.30
Crude Ash 1.84	1.84
Nitrogen-Free Soluble Matter	54.40
ME, kcal/100g	304.70

Experimental design

The quails were placed in laying quail cages with automatic nipple drinkers. Water and feed were provided *ad libitum* throughout the experiment. The experimental groups were randomly assigned to treatments that varied in jujube fruit powder (JFP) levels: a basal diet without JFP (control) and diets supplemented with 5 g/kg JFP (T1) and 10 g/kg JFP (T2). Previous similar studies on jujube fruit powder in poultry were considered in determining the trial dose for this study (Kilinc et al. 2020, Cellat et al. 2022, Yang et al. 2023). All laying hens were exposed to 16 hours of continuous light during the experimental period. The experiment lasted for 56 days, and at the end of the study, blood samples were taken from 6 quails from each experimental group to determine serum biochemical parameters.

Feed analyses

The crude nutrient contents of the diets used in the study were determined in the Feed Analysis Laboratory of the Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Firat University. The crude nutrient compositions (dry matter, crude ash, crude protein, crude fat and nitrogen-free solids) of the diets were determined according to the analytical methods of AOAC (1980), and the crude cellulose content was determined according to Crampton and Maynard (1983). The nutritional composition of jujube powder used in the study is shown in Table 2. The chemical composition of the jujube (Ziziphus jujuba) fruit used in the diets was determined by HPLC and GC/GC-MS at the central laboratory of Hatay Mustafa Kemal University and is shown in Table 3.

Table 3. Chemical composition of jujube powder for quails used in the study (%).

RT	Compound name	SI	RSI	Area %
13.40	Methyl formate	979	999	1.92
16.53	Propanoic acid	895	995	0.7
17.08	Propanoic acid, 2-methyl	882	949	0.45
17.80	2-Propenoic acid, methyl ester	829	959	0.87
19.51	Butanoic acid	984	989	2.53
20.53	Butanoic acid, 2-methyl	948	979	2.17
20.79	Iso-Valeric acid	822	969	1.15
24.23	2-Furanmethanol	979	989	1.55
25.61	Decanoic acid, ethyl ester	909	958	0.43
26.86	Hexanoic acid	868	976	0.26
29.24	Mebutamate	752	763	0.67
30.29	9,12-Octadecadienoyl chloride	807	835	0.26
30.42	Hexadecadienoic acid, methyl ester	859	860	0.48
31.88	Benzene, 1-methoxy-4-(1-propenyl)	976	985	11.22
34.95	Phenol	634	787	0.58
35.43	2,5-Dimethyl-4-hydroxy-3(2H)-furanone	885	986	0.64
36.06	2H-Pyran-2,6(3H)-dione	803	978	0.27
37.31	Aspartame	781	796	0.56
37.90	2,4-Pyrimidinedione, 5-methyl	837	905	1.18
38.45	2-Hexenoic acid, 4-amino-5-methyl-, methyl ester	610	682	0.29
39.22	Decanoic acid	765	849	0.3
40.49	2-Amino-3-methyl-1-butanol	573	604	5.32
40.73	Benzaldehyde, 4-methoxy	706	980	0.34
41.88	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl	825	961	4.99
42.40	Hexadecanoic acid, ethyl ester	921	929	4.12
43.68	Desulphosinigrin	594	642	0.26
44.34	2,5-Octadecadiynoic acid, methyl ester	832	872	1.21
45.54	4-Oxopental	858	978	0.8
46.36	1-Bromo-3-butene-2-ol	758	918	1.01
47.19	Butanal, 2-methyl	914	974	4.69
47.73	9-Octadecenoic acid-ethyl ester	875	882	1.23
48.93	8-Azabicyclo[3.2.1]octane-3-carbonitrile, 8-methyl	811	845	12.67
49.33	10-Heptadecen-8-ynoic acid, methyl ester	791	803	0.71
49.69	Methyl arachidonate	797	808	2.19
50.74	1,2-Cyclohexanedicarboxaldehyde	743	813	0.61
51.08	2-Butyl-1-iodo-bicyclo[2.2.1]heptane	712	781	1.27
52.04	1’-Hydroxy-4,3’-dimethyl-bicyclohexyl-3,3’-dien-2-one	740	809	1.71
52.69	Propane, 1-methoxy-2,2-dimethyl	706	882	2.5
53.28	5-Hydroxymethylfurfural	889	966	21.14
54.03	Thiophene, 2,5-dihydro	724	866	0.57
54.16	Phenol, (1,1-dimethylethyl)-4-methoxy	604	663	0.78
55.01	Dihydro-5-(1-hydroxyethyl)-2(3H)-furanone	671	990	0.46
56.04	Procainamide	594	611	0.78
56.44	Androstan-17-one, 3-ethyl-3-hydroxy	608	636	1.21

RT – Retention Time, SI – Similarity Index, RSI – Reversed Search Index

Egg production

Eggs were counted and collected at the same time each day, and egg yield (%) was determined daily by dividing the number of eggs obtained by the number of quails on that day.

Feed consumption

Feeding was performed daily, the remaining feed was weighed weekly, and the daily feed consumption was determined.

Feed conversion ratio

Feed conversion ratios (FCR) were determined weekly. The average daily egg weight was determined each week during the production period and the FCR was calculated as g feed/g egg (Mutlu et al. 2021).

Egg quality characteristics

In the study's second, fourth, and sixth weeks, 90 eggs (3 groups X 5 subgroups X 6 eggs) were used to determine external and internal quality characteristics. The eggs were weighed using a 0.01 mg precision balance (Densi, Turkey). The lengths and widths of the eggs were measured with a digital caliper (Tronic, Turkey) and then broken on a flat plastic platform (pre-calibrated) to measure the length, height and width of the albumen and the diameter and height of the yolk. The yolk color was assessed using the Roche Yolk Color Fan. The shells were dried at room temperature for 48 hours, and weighed. Eggshell thicknesses with membranes were determined from the center of the eggs using a digital micrometer (Tronic, Turkey). Other characteristics were calculated using the following formulae (Nazlıgul et al. 2001);

Shape index (%) = [Egg width (mm) / Egg length (mm)] x 100

Shell ratio (%) = (Shell weight (g) / Egg weight (g)) x 100

Albumen ratio (%) = (Albumen weight (g) / Egg weight (g)) x 100

Albumen index (%) = [Albumen height (mm)/{(Albumen length (mm) + Albumen width (mm)) /2}] x 100

Yolk ratio (%) = (Yolk weight (g) / Egg weight (g)) x 100

Yolk index (%) = [Yolk height (mm) / Yolk diameter (mm)] x 100

Haugh unit (HU) = 100 log [Albumen height (mm) + 7.57 – 1.7 x Egg weight (g) $^{0.37}$]

Blood analyses

At the end of the experiment, blood samples were taken from the cervical vein of six quails in each group, and all blood samples were collected in serum tubes. The glucose (catalog number EIAGLUC; Thermo Fisher Scientific), total cholesterol (catalog number TR13421; Thermo Fisher Scientific), uric acid (catalog number A13346.14; Thermo Fisher Scientific) levels were analyzed using an Olympus AU-600 (Optical Co Ltd., Japan) device.

Statistical analysis

The data are expressed as mean ± standard error. After checking for homogeneity of variances (Levene test) and normality of distributions (Shapiro-Wilk test), the data were analyzed by one-way ANOVA using SPSS 21.0 (Chicago, IL). Tukey's test was used to determine significant differences among the treatment means. Differences were considered statistically significant at $p<0.05$.

Results

Laying performance

The effects of jujube fruit powder supplementation on the performance characteristics of quails are shown in Table 4. The differences between 1-15 and 16-30 days for feed intake ($p<0.05$), 1-60 days for egg production ($p<0.05$), 16-30 days for egg weight ($p<0.05$), and 1-15 and 1-60 days for feed conversion ratio were statistically significant. It was observed that the T1 group showed higher performance than the other groups in terms of egg production; also, the feed conversion ratio was lower.

Egg quality characteristics

The effects of jujube fruit powder supplementation on egg internal and external quality characteristics of quails are shown in Table 5. The differences between the groups were statistically significant in egg length ($p<0.01$) and width ($p<0.05$) for external quality traits. There was no statistical difference between the groups in egg shape index, shell weight, shell ratio, and shell thickness ($p>0.05$).

The yolk height ($p<0.05$) and yolk diameter ($p<0.01$) were higher in the T2 group than the C and T1 groups. In terms of albumen width, albumen length, albumen height, albumen index, albumen weight and yolk ratio, yolk color, yolk diameter, yolk height, and yolk index were not statistically different between groups ($p>0.05$).

Serum biochemical parameters

The effects of Jujube fruit powder supplementation on serum biochemical parameters are presented in Fig. 1.

Table 4. Effect of jujube fruit powder on performance in quails.

	Control	T1	T2	p
Feed İntake (g/quail/day)				
1-15 days	31.86±1.27[a]	28.43±0.49[b]	30.52±0.53[ab]	0.026
16-30 days	32.34±0.60[ab]	30.50±0.60[b.]	33.03±0.65[a]	0.022
31-45 days	24.16±1.88	20.44±1.18	23.22±1.28	0.202
46-60 days	28.26±1.52	30.46±0.63	30.73±0.67	0.195
1-60 days	29.16±1.00	27.46±0.61	29.37±0.68	0.188
Egg production %				
1-15 days	79.77±2.44	85.76±2.14	81.75±2.34	0.196
16-30 days	90.35±2.38	93.56±1.48	88.56±2.36	0.258
31-45 days	87.13±4.08	91.42±1.21	93.56±2.48	0.284
46-60 days	77.85±4.91	90.35±1.96	83.21±4.68	0.114
1-60 days	83.78±1.07[b]	90.27±1.02[a]	86.77±2.48[ab]	0.035
Egg weight (g)				
1-15 days	11.27±0.20	11.42±0.27	11.49±0.18	0.770
16-30 days	11.76±0.15[b]	12.01±0.19[ab]	12.38±0.11[a]	0.032
31-45 days	12.19±0.30	11.80±0.26	12.17±0.12	0.455
46-60 days	12.34±0.28	11.73±0.25	11.94±0.14	0.196
1-60 days	11.98±0.17	11.74±0.21	11.99±0.09	0.564
Feed conversion ratio				
1-15 days	3.45±0.15[a]	2.98±0.08[b]	3.36±0.08[ab]	0.025
16-30 days	3.12±0.15	2.81±0.12	3.05±0.11	0.270
31-45 days	2.07±0.22	1.73±0.08	1.98±0.13	0.337
46-60 days	2.89±0.14	2.86±0.11	3.01±0.23	0.816
1-60 days	2.94±0.11[a]	2.59±0.07[b]	2.83±0.07[ab]	0.031

[ab…]Means within a row not sharing a common superscript are significantly different at $p<0.05$

The differences between the groups for serum biochemical parameters were insignificant ($p>0.05$). Cholesterol levels (384.40 mg/dl) were highest in T2, glucose levels (389.00 mg/dl) were highest in T1, and uric acid levels (4.95 mg/dl) were similar in the C and T2 groups.

Discussion

Laying performance

Jujube is characterized by high energy yield, mineral concentration and low crude fiber content and has multiple physiological functions it can therefore be widely used in animal feed. Appropriate levels of jujube as a supplement or substitute can improve feed palatability, feed intake, nutrient digestibility, reduce the rate of feed conversion to gain, and improve the gut microbiome and the quality of animal products (Xu et al. 2022). It has been reported that the daily feed intake of quails is between 25-30 g (Simsek et al. 2020), and similar results were obtained in this study. This study found that the highest feed intake was 29.37 g in the T2 group. Similarly, a study conducted by Yang et al. (2023) found higher feed intake in the group supplemented with 1% jujube fruit powder. Hoseinifar et al. (2019) found dietary supplementation of 0.5% jujube fruit extracts was also found to increase the performance parameters of common carp during an eight-week feeding trial. Similarly, in this study the highest egg production (90.27%) was recorded in the T1 group with relatively low feed intake. This may be because quails adjust their feed consumption according to their energy need, adding 0.5% jujube powder to the diet increases the activity of intestinal protease, α-amylase, and lactase, which support digestive ability and decrease the feed conversion rate (Muniz et al. 2018, Liu et al. 2020). These result are also consistent with Zhao et al. (2012), and Ma et al. (2017), who reported that jujube fruit powder increased egg production and quality in poultry. It was observed that the groups whose diets were supplemented with jujube fruit powder showed better performance in terms of feed conversion ratio compared to the control group. These results could be attributed to the various bioactive components found

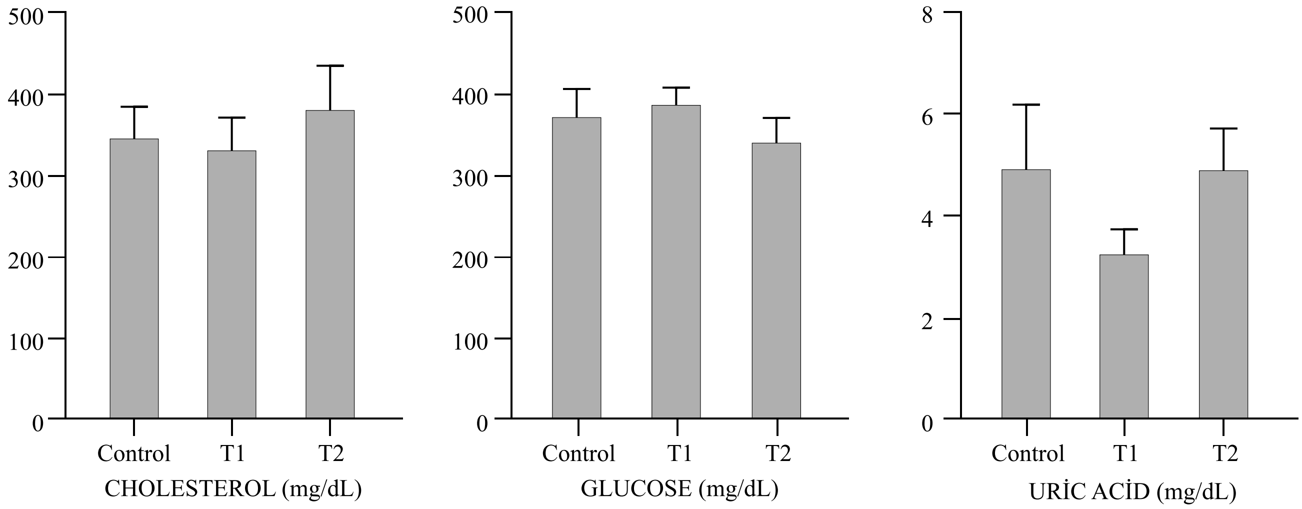

Fig. 1. Effect of jujube fruit powder on serum biochemical parameters in quails.

Table 5. Effect of jujube fruit powder on egg quality chracteristics in quails.

	Control	T1	T2	p
Egg width, mm	25.87±0.09[a]	25.50±0.10[b]	25.58±0.12[ab]	0.030
Egg length, mm	33.55±0.23[a]	32.66±0.19[b]	33.38±0.19[a]	0.005
Egg shape index (SI), %	77.26±0.42	77.17±1.16	76.71±0.39	0.539
Egg shell weight	1.01±0.01	1.15±0.15	1.03±0.01	0.539
Egg shell ratio, %	8.34±0.12	8.67±0.12	8.64±0.12	0.122
Egg shell thickness, mm	2.02±0.02	2.00±0.01	2.03±0.02	0.478
Albumen weight, g	6.31±0.09	6.07±0.08	6.24±.0.08	0.139
Albumen ratio, %	51.90±0.40	52.69±0.88	51.88±0.39	0.584
Albumen width, mm	34.33±0.36	33.89±0.53	35.32±0.41	0.068
Albumen length, mm	46.20±0.53	45.15±0.64	45.77±0.51	0.414
Albumen height, mm	4.89±0.09	5.07±0.11	5.00±0.09	0.429
Albumen index, %	3.05±0.06	3.25±0.08	3.09±0.06	0.156
Yolk weight, g	3.70±0.05	3.59±0.05	3.70±0.05	0.221
Yolk ratio, %	30.46±0.25	31.19±0.55	30.79±0.22	0.410
Yolk color	12.98±0.06	14.85±1.87	13.05±0.09	0.433
Yolk diameter, mm	24.27±0.24[b]	23.78±0.28[b]	25.16±0.21[a]	0.001
Yolk height, mm	10.33±0.09[b]	10.35±0.09[b]	10.70±0.10[a]	0.017
Yolk index, %	42.71±0.44	44.01±0.85	42.67±0.53	0.238
Haugh Unit	80.59±0.47[ab]	81.57±0.43[a]	79.95±0.40[b]	0.039

[ab…]Means within a row not sharing a common superscript are significantly different at $p<0.05$

in the jujube fruit, such as triterpenic acids, nucleosides, flavonoids (flavones and flavone- 3- ols), polysaccharide, fibre and the water-soluble carbohydrates, which may positively affect maintaining or improving the gastrointestinal environment and this is achieved by reducing the exposure of the intestinal mucosa to harmful substances such as toxic ammonia and other harmful compounds (Xie et al. 2018, Hoseinifar et al. 2019).

Egg quality characteristics

In poultry farming, eggs' external and internal quality characteristics are essential for sustainable production, embryo development, and food safety (Duru et al. 2017). This study found no difference between the groups regarding shell thickness, weight, and ratio ($p>0.05$). Egg shell quality is affected by the animal's age, minerals, calcium and phosphorus, and additives (Gül et al. 2023). Rashwan et al. (2020) reported that the jujube fruit is rich in calcium, while Xu et al. (2022) reported that calcium and phosphorus content varied with the jujube variety. It is believed that there was no difference in shell quality characteristics between the groups in the study due to the variety of jujube fruit used. In this study, the highest values for egg width and length were found in the control group (25.87 and 33.55 mm), while lower values were observed in the T1 and T2 groups, supplemented with Jubube powder. Although the eggs were shrunken in width and length, these results did not cause a difference in the shape index and egg weight between the groups ($p>0.05$).

The Haugh unit (HU) score is an important indicator of egg quality, and determining the HU score is a common way of assessing the internal quality of the egg. The highest HU value was 81.57 in the T1 group, and the lowest value was 79.95 in the T2 group, and the differences between the groups were statistically significant ($p<0.05$). Also, the HU value is often used to measure albumen quality; a high HU unit value depicts thick albumen content and jelly nature with strong viscosity, which reflects better albumen quality, while a low HU unit value is vice versa (Zhang et al. 2020). In this study, albumen height and albumen index were highest in the T1 group and lowest in the control group; weight and length of albumen were highest in the control group and lowest in the T1 group; width was highest in albumen in the T2 group and lowest in the T1 group. When the correlation between albumen characteristics (Alkan et al. 2010; Sarı et al. 2016) and this study's results are considered together, it is thought that jujube fruit powder may not have a positive or negative effect on albumin characteristics. The highest yolk diameter and yolk height were observed in the T2 group, while similar values were found in the C and T1 groups. Because egg weight has a positive influence on yolk height and diameter (Ukwu et al.2017), increasing yolk weight positively affects the yolk ratio due to the correlation (0.67) between the yolk ratio and yolk weight (Sarı et al. 2016). In this study, the yolk weights were 3.70, 3.59, and 3.70 g in the C, T1, and T2 groups, respectively, and the yolk ratios were 30.46%, 31.19%, and 30.79%, respectively. However, this study did not observe a similar correlation between yolk ratio and weight.

Serum biochemical parameters

Cholesterol is a fat found in all animal cells and makes up 30% of animal cell membranes. It is produced by the liver and made by most cells such those in the kidneys, intestines, and adrenal glands. (Chapman et al. 2010, Sadava et al. 2011). It is essential for building and maintaining the body's metabolic processes (Khalifa et al. 2019). In this study, there was no difference in cholesterol levels between the groups. This contradicts the findings of Zhao et al. (2012) and Ma et al. (2017) that jujube fruit lowered cholesterol levels. It is thought that this may be due to the different ratios used in the studies. This study measured 373.80, 389.00, and 342.60 mg/dl serum glucose levels in the C, T1, and T2 groups, respectively. In a study conducted by Kilinc et al. (2020), adding jujube leaves to the diet of laying hens did not affect serum glucose levels. Similar results were obtained in the present study.

Jujube fruit contains polyphenols, polysaccharides, and trienoic acid (Shi et al. 2022), which have been reported to have immune-enhancing, antioxidant properties (Rashwan et al. 2020). Another powerful antioxidant is uric acid, the end product of purine metabolism and which plays an important role in many biological processes (Bove et al. 2017, Jiang 2020). However, this study found no difference between the groups in uric acid, an effective antioxidant.

Conclusion

According to the results of this study, jujube fruit, a rich energy source, can be used as an alternative supplement in poultry diets with positive effects on egg production and feed conversion ratio. In addition, it is thought that it will be useful for producers and researchers to investigate the effects of it's use in different ratios in other research.

References

Alkan S, Karabağ K, Galic A, Karsli T, Balcioglu MS (**2010**) Effects of selection for body weight and egg production on egg quality traits in Japanese quails (Coturnix coturnix japonica) of different lines and relationships between these traits. Kafkas Univ Vet Fak Derg 16: 239-244.

AOAC (**1980**) Official Methods of Analysis (13th edition) Assosciation of Official Agricultural Chemist, Washington D.C. https://archive.org/details/gov.law.aoac.methods.1980/page/n21/mode/2up (Accessed on 3 March 2023)

Aroche R, Martinez Y, Ruan Z, Guan G, Waititu S, Nyachoti CM, Más D, Lan S **(2018)** Dietary inclusion of a mixed powder of medicinal plant leaves enhances the feed efficiency and immune function in broiler chickens. J Chem 2018:1-6.

Asheg AA, El-Nyhom SM, Ben Naser KM, Kanoun AH, Abouzeed YM **(2014)** Effect of Arbutus pavarii, Salvia officinalis and Zizyphus vulgaris on growth performance and intestinal bacterial count of broiler chickens. Int J Vet Sci Med: 151-155.

Bove M, Cicero AF, Veronesi M, Borghi C (**2017**) An evidence-based review on urate-lowering treatments: implications for optimal treatment of chronic hyperuricemia. Vasc Health Risk Manag 13: 23-28.

Cellat M, Alasahan S, Etyemez M, Gokcek, I, Kutlu T, Turkmen M, Guvenc M, Ciftci M (**2022**) The effects of jujube fruit (*Ziziphus Jujuba* Mill.) added in the mixed feed on growth performance and oxidative stress parameters in quails raised in different stocking densities. IJVAR 5: 19-6.

Chapman MJ, Le Goff W, Guerin M, Kontush A **(2010)** Cholesteryl ester transfer protein: at the heart of the action of lipid-modulating therapy with statins, fibrates, niacin, and cholesteryl ester transfer protein inhibitors. Eur Heart J 31: 149-164.

Crampton EW, Maynard LA (**1983**) The relation of cellulose and lignin content to nutritive value of animal feeds. J Nutr 15: 383-395.

Duru M, Duru AA, Karadas K, Eyduran E, Cinli H, Tariq MM **(2017)** Effect of carrot (Daucus carota) leaf powder on external and internal egg characteristics of Hy-Line White laying hens. Pak J Zool 49: 125-132.

Farooq U, Mustafa R, Khalid MF, Auon M, Mahmood U, Wahaab A, Rehman ZU, Huda NU, Bashir MK, Mahmood S and Hussain J **(2022)** Supplementation of herbal seeds to improve the growth performance and digestion in Japanese quail (Coturnix coturnix Japonica). Agrobiol Rec 10: 19-25.

Gül ET, Olgun O, Yıldız A, Çolak A (**2023**) Effect of increasing valine level in the diet on performance, egg quality, and serum components in laying quails. Trop Anim Health Prod 55: 54.

Gul ST, Alsayeqh AF **(2022)** Probiotics as an alternative approach to antibiotics for safe poultry meat production. Pak Vet J 42: 285 291.

Gumus E, Sevim B, Olgun O, Kucukersan S **(2023)** Effects of dietary betaine and protected calcium butyrate supplementation on growth performance, blood biochemical status, and meat quality in growing Japanese quail (Coturnix coturnix Japonica). Pol J Vet Sci 26: 377-383.

Gunduz K, Saracoglu O (**2014**) Changes in chemical composition, total phenolic content and antioxidant activities of jujube (Ziziphus jujuba Mill.) fruits at different maturation stages. Acta Sci Pol 13: 187-195.

Hoseinifar SH, Zou HK, Van Doan H, Harikrishnan R, Yousefi M, Paknejad H, Ahmadifar E **(2019)** Can dietary jujube (Ziziphus jujuba Mill.) fruit extract alter cutaneous mucosal immunity, immune related genes expression in skin and growth performance of common carp (Cyprinus carpio)? Fish Shellfish Immunol 94: 705-710.

Jiang LL, Gong X, Ji MY, Wang CC, Wang JH, Li MH (**2020**) Bioactive compounds from plant-based functional foods: A promising choice for the prevention and management of hyperuricemia. Foods 9: 973.

Khalifa MI, Noseer EA (**2019**) Cholesterol quality of edible eggs produced by quail fed diets containing probiotic and/or ginger (Zingiber officinale). Livest Res Rural Dev 31: 165.

Kilinc G, Sezener MG, Gülhan T (**2020**) The Effects of jujube (zizyphus jujuba mill.) leaf extract on small intestinal microflora and some blood parameters in laying hens. IJAWS 6: 91-99.

Koley TK, Walia S, Nath P, Awasthi OP, Kaur C (**2011**) Nutraceutical composition of Zizyphus mauritiana lamk (Indian ber): effect of enzyme-assisted processing. Int J Food Sci Nutr 62: 276-279.

Liu F, Liu X, Wang F, Cui C, Su M, Gao B **(2020)** Effects of jujube extracts on growth and antioxidant capacity of rainbow trout (Oncorhynchus mykiss). China Feed 9: 98-103.

Ma K, Zhao Y, Liu Y, Zhang Z, Hao Y, Zhao G (**2017**) Effect of jujube powder on lipid metabolism, antioxidant performance and immune function of layers. China Feed 19: 5-8.

Muniz JC, Barreto SL, Viana GS, Mencalha R, Reis RS, Hannas MI, Barbosa LM, Maia RC **(2018)** Metabolizable energy levels for meat-type quails at starter phase. Braz J Poult Sci 20: 197-202.

Mutlu Sİ, Baykalır Y, Azman MA, Şimşek ÜG, Özçelik M, Bayraktar O, Çiftçi M, Erişir Z **(2021)** The effects of dietary supplementation of olive leaf extract and eggshell with membrane on performance, egg quality, blood biochemical, and bone parameters in laying Japanese quail. Ankara Univ Vet Fak Derg 68: 251-258.

Nazligül A, Türkyilmaz K, Bardakçioğlu HE **(2001)** A study on some production traits and egg quality characteristics of Japanese quail. Turk J Vet Anim Sci 25: 1007-1013.

NRC (**1999**) Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC. https://www.agropustaka.id/wp-content/uploads/2020/04/agropustaka.id_buku_Nutrient-Requirements-of-Poultry_Ninth-Revised-Edition-1994-NRC.pdf (Accessed on 3 March 2023)

Rashwan AK, Karim N, Shishir MR, Bao T, Lu Y, Chen W (**2020**) Jujube fruit: A potential nutritious fruit for the development of functional food products. J Funct Foods 75: 104205.

Sadava D, Hillis DM, Heller HC, Berenbaum MR (**2011**) Life: The Science of Biology 9th ed., San Francisco: Freeman, pp 105-114.

Sari M, Tilki M, Saatci M (**2016**) Genetic parameters of egg quality traits in long-term pedigree recorded Japanese quail. Poult Sci 95(8): 1743-1749.

Shi Q, Han G, Liu Y, Jiang J, Jia Y, Li X (**2022**) Nutrient composition and quality traits of dried jujube fruits in seven producing areas based on metabolomics analysis. Food Chem 385: 132627.

Simsek UG, Aslan S, Birben N, Altundal B (**2020**) Examining the effects of adding boric acid at different doses into mixed feed on fattening performance, carcass characteristics, and bone quality of Japanese quails. GSC Biol Pharm Sci 13: 1-9.

Ukwu HO, Ezihe CO, Asaa SK, Anyogo ME **(2017)** Effect of egg weight on external and internal egg quality traits of Isa Brown egg layer chickens in Nigeria. JASVM 2: 126-132.

Wang X, Zhao H, You W, Cheng H, Wu L **(2010)** The effect of adding feed date, soybean hulls or fresh beer residue on milk performance of dairy cows. Feed Ind 31: 27-29.

Xie B, Wang PJ, Yan ZW, Ren YS, Dong KH, Song ZP, Zhang JX, Zhang CX (**2018**) Growth performance, nutrient digestibility, carcass traits, body composition, and meat quality of goat fed Chinese jujube (Ziziphus Jujuba Mill) fruit as a replacement for maize in diet. Anim Feed Sci Technol 246: 127-136.

Xu T, Zhou X, Degen A, Yin J, Zhang S, Chen N (**2022**) The inclusion of jujube by-products in animal feed: A Review. Sustainability 14: 7882.

Yang C, Zhu X, Liu W, Huang J, Xie Z, Yang F, Zhang L, Wei Y (**2023**) Dietary dried jujube fruit powder (djfp) supplementation improves growth performance, antioxidant stability, and meat composition in broilers. Foods 12: 1463.

Yesilbag D (**2018**) The effect of rosemary and fennel volatile oil on performance and egg quality parameters in layerquail diets. Ankara Üniv Vet Fak Derg 65: 413-418.

Yu L, Jiang BP, Luo D, Shen XC, Guo S, Duan JA, Tang YP (**2012**) Bioactive components in the fruits of Ziziphus jujuba Mill. against the iınflammatory irritant action of euphorbia plants. Phytomedicine 19: 239-244.

Zhang J, Zhang M, Liang W, Geng Z, Chen X (**2020**) Green tea powder supplementation increased viscosity and decreased lysozyme activity of egg white during storage of eggs from Huainan partridge chicken. Ital J Anim Sci 19: 586-592.

Zhao J, Jiao J, Zhao Y, Liu P, Tao W, Tao D **(2015)** Feasibility analysis of incorporating disabled dates into fattening cattle feed. Contemp. Anim Husb 18: 48–50.

Zhonghua W, Huang X, Quanhai G **(2011)** Effects of jujube oligosaccarides on production performance and immune function of laying chicken. China Feed 19.