Assessment of effects of pomegranate seed oil on egg quality of Japanese (*Coturnix coturnix japonica*) quail

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The aim of this study was to investigate the effects of pomegranate seed oil on blood parameters and egg quality of Japanese quails (*Coturnix coturnix japonica*). For this reason, a total of 120 mixed quails at 5-7-day ages were divided into 4 groups (30 quails in each group) and placed in cages. For the feeding study, feed supplemented with 1, 3 and 5% pomegranate seed oil and control feed with no oil addition were prepared, the trial lasted 12 weeks. Quail blood parameters, egg quality characteristics, fatty acid composition, mineral compositions and combustion energy values were determined. The supplementation of pomegranate seed oil in quail feed did not affect the physical quality parameters of the eggs significantly. The total saturated fatty acids and polyunsaturated fatty acids increased, while the monounsaturated fatty acids and total unsaturated fatty acids decreased. These results clearly demonstrated that supplementation of the quail diet with pomegranate seed oil increased total amount of CLnA and n-6 fatty acids in egg.

Keywords: Pomegranate seed oil, Quail egg, Quality, Fatty acids, Punicic acid.

INTRODUCTION

Pomegranate (*Punica granatum L.)* seed is a “by-product" of pomegranate juice processing and its oil is usually produced by cold pressing. Although, pomegranate seed oil (PSO) is nutritive, healthier, and beneficial oil, PSO use as edible oil is limited. PSO consists of polyunsaturated fatty acids (PUFA), and major fatty acid is punicic acid (70-75%) [1 - 4]. Punicic acid (PA) is defined as conjugated linolenic acid (CLnA) isomers that inhibit prostaglandin biosynthesis and other lipoxygenase and cyclooxygenase pathways [5]. For this reason, PA has got some benefits against skin and colon cancer as well as inflammation, atheromatous, plaque formation, platelet aggregation, and asthma in children [5, 6]. Literature findings indicate that PSO reduced weight gain and type 2 diabetes risks in rats [7].

Quail (*Coturnix coturnix japonica*) is one of the important protein and vitamin sources that have higher meat yield and lower bone yield among poultry species. Additionally, quails have some advantages such as shortness of the generation intervals, conformity to genetic breeding trials, more animals in unit area, easy to grow, lower feed consumption and reach sexual maturity in a short time. Despite, quail meat consumption and production are not common. However, quail eggs are commonly consumed and produced according to quail meat. Quail eggs are regarded as nutritive, beneficial, and healthy foods for human diets, especially for children. Quail egg consist of approxi-

mately, 72.25% water, 4.01% carbohydrate, 12.7% protein, 9.89% fat and 1.06% ash. Moreover, quail egg is good source of calcium, phosphorus, vitamin B2 and vitamin A. Besides, quail egg fat consists of approximately 60-61% triglycerides, 33-34% phospholipids and 4-5% yolk cholesterol like chicken egg [8 - 11].

Quail, laying hen or the other poultry eggs are not preferred by consumer due to linear relationship between cardio-vascular diseases and cholesterol level. Particularly most studies reported low-density lipoprotein (LDL) and high-density lipoprotein (HDL) balance is important for preventing cardiovascular diseases. It is well known that an intake of saturated fatty acids (SFA) leads to an increase of cholesterol storage, while unsaturated fatty acid (UFA) intake can protect against cholesterol storage [12, 13]. In recent studies, the addition of polyunsaturated fatty acid (PUFA) or monounsaturated fatty acid (MUFA) group oils into poultry feed was made and the changes on the fatty acid composition due to egg cholesterol were investigated. In literature, there were different reports on effects of supplementation of oils on egg quality such as; fish oil (FO) and flax seed (FS) oil [14], conjugated linoleic acid (CLA) [15], CLA and fish oils [16], canola oil [17], flaxseed oil [18, 19], different oil sources [20] and sesame oil by [21] were reported.

The main aim of this study was to investigate the effects of supplementation of different levels of PSO on quail egg quality and blood parameters. The second aim was to increase the PUFA content of the quail eggs and enrich with punicic acid.

MATERIAL AND METHOD

MATERIALS

One hundred twenty 5-7-day age mixed quails (*Coturnix coturnix japonica*) were obtained from a local farm in Çanakkale Province of Turkey. Cold press pomegranate seed oil (KRK™, Smart Chem. Co., Turkey) (PO) was purchased from a market in Turkey. The fatty acid composition of the PO is presented in Table V. The quails were divided into four groups, the first group was fed on a control diet, the second group a 1% PO added diet, the third group a 3% PO added diet and the fourth group a 5% PO added diet. The quails were placed in 2 cages with 4 levels and 3 sections (50 cm × 46 cm × 46 cm). Thus, the study was duplicated for each group and planned in 3 replicates. The basal diet (Erişler Yem Co., Istanbul, Turkey) (control group) was purchased from a local farm market in Turkey in the province of Çanakkale and all diets are given in Table I.

The trial continued for 12 weeks (including the growing and ovulation period) and the cages were illuminated 16 hours per day. Eggs were collected daily and stored at +4°C and egg analysis were performed on the eggs on a weekly basis. All the chemicals used for physico-chemical analyses were of analytical grade and purchased from Merck (Darmstadt,

Table I - Chemical compositions of experimental diets given to quails

Nutrients	Ctrl	PSO1	PSO3	PSO5
Crude Protein (%)	16.50	16.50	16.50	16.50
Crude Fat (%)	4.20	4.20	4.20	4.20
Crude Fiber (%)	4.0	4.0	4.0	4.0
Crude Ash (%)	12.50	12.50	12.50	12.50
Pomegranate Seed Oil (%)	-	1.0	3.0	5.0
Lysine (%)	0.75	0.75	0.75	0.75
Methionine(%)	0.36	0.36	0.36	0.36
Calcium(%)	3.70	3.70	3.70	3.70
Phosphorus(%)	0.38	0.38	0.38	0.38
Sodium(%)	0.16	0.16	0.16	0.16
Vitamin A (IU)	10000	10000	10000	10000
Vitamin D3 (IU)	3000	3000	3000	3000
Vitamin E (mg)	15	15	15	15
Iodine (mg)	2.0	2.0	2.0	2.0
Cobalt (mg)	0.5	0.5	0.5	0.5
Cu (mg)	5.0	5.0	5.0	5.0
Mangane (mg)	90	90	90	90
Zinc (mg)	70	70	70	70
Selenium (mg)	0.16	0.16	0.16	0.16

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group

Germany) or Sigma-Aldrich (St. Louis, MO, USA).

EGG QUALITY PARAMETERS

As many as100 eggs was taken for each group and egg, yolk, albumen and shell weight were measured using Sartorius scale (Goettingen, Germany). Shell thickness, yolk and albumen width, height and length were measured with a digital calliper (Gates-78241, Germany). Albumen Index (1) Yolk Index (2) and Haugh Units (3) were calculated using the following equations [22].

$$\text{Albumen index (\%)} = \frac{\text{Albumen height (mm)}}{\left[\frac{\text{Albumen length (mm)} + \text{Albumen width (mm)}}{2}\right]} \times 100 \quad (1)$$

$$\text{Yolk index (\%)} = \left(\frac{\text{Yolk height}}{\text{Yolk diameter}}\right) \times 100 \quad (2)$$

$$\text{Haugh Unit} = 100 \log [\text{Albumen height (mm)} + 7.57 - 1.7\ \text{Egg weight (g)}^{0.37}] \quad (3)$$

The shell strength of the quail eggshell was evaluated using Texture Analyser TA-XT2i (Stable Microsystems, Surrey, UK), according to its manual. The puncture test was used, and test parameters were weight head 50 kg, 2 mm cylinder probe, probe inlet velocity 2 mm/s, outlet velocity 2 mm/s. The test results were evaluated by using TA-XT2i Software and the shell strength of the quail eggs were expressed in (N).

The colour values of the egg samples were determined with Minolta Colorimeter (Cr 400, Konica, Minolta, Japan) and the results were expressed as L (Lightness), a* (+green/-red) and b*(+yellow/-blue). The pH values of the egg samples were measured using Sartorius pH meter (Goettingen, Germany) according to ISO [23]. The moisture, protein, fat and ash values of the egg samples were determined according to AOAC methods (950.46B), (928.08), (960.39B) and (920.153), respectively [24]. The combustion energy values of the egg samples were determined with a Leco AC-350 bomb calorimeter (St. Joseph, USA) according to its manual and results were presented as cal/g.

FATTY ACID COMPOSITION

The lipid phase extraction of the egg samples (5 samples of each groups) and preparation of the fatty acid methyl esters (FAME) was done according to the Bligh and Dyer [25] and ISO method 5509 [26], respectively. Determination of the fatty acid methyl esters was performed with GC-MS (Shimadzu QP2010, Kyoto, Japan) equipped with Mass Spectroscopy (MS) and column (100m × 0.25mm × 0.20um, Restek, USA). The GC parameters were injector port and detector temperature 240°C, injected volume 1.0 µL, carrier gas helium. The column temperature increased from 60 to 220°C at 3°C /min and held at 220°C for 12 min. The fatty acids of the samples were defined using FAME mix 37 (Supelco, USA) standards according to its retention time. The amounts of the fatty acids were presented as percentage of total methyl esters of fatty acids.

MINERAL COMPOSITION

For the mineral composition, egg samples (5 samples of each groups) were dried at 105°C for 4 h in vacuum dryer and then the 0.5 g dried egg samples were weighed into Teflon tubes and 20 mL HNO_3 was added and mixture was ashed at 450°C for 6 h in microwave oven [27]. At the end of the wet ashing process, the mixture was completed to 50 mL with deionised water and filtered with filter paper. The element standards were uploaded to the device and calibration curve was

Table II - Physical properties of the control and PSO supplemented quail eggs

Features	Ctrl	PSO1	PSO3	PSO5
Weight (g)	10.25±1.18	10.35±1.40	10.17±1.33	9.80±1.45
Shell Weight (g)	1.48±0.03a	1.28±0.01ab	1.10±0.02b	1.12±0.13b
Shell Thickness (mm)	0.24±0.01	0.22±0.01	0.23±0.01	0.24±0.01
Shell Strenght (N)	11.22±0.99	11.14±2.04	9.14±1.07	9.54±1.94
Albumen Weight (g)	5.73±0.79	5.78±0.39	5.61±0.62	5.40±0.44
Albumen Index (%)	4.03±0.27	3.86±0.07	4.15±0.21	4.07±0.27
Yolk Weight (g)	3.35±0.18	2.95±0.29	3.06±0.14	2.83±0.05
Yolk Index (%)	46.10±0.18	47.42±0.45	47.90±0.34	46.07±1.47
Haugh Unit	82.25±0.21	82.33±0.44	82.36±0.41	82.91±0.28

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group

*Small letters shows differences among the samples in the same line ($p<0.05$)

determined. The elemental composition of the egg samples was analysed by using Spectro-spectroblue ICP-OES (Kleve, Germany) and the mineral contents were expressed in ppm sample.

BLOOD COLLECTION AND ANALYSES

For the blood collection, five quails randomly selected from each group were decapitated. The analyses were made on their blood, according to [10]. Prior to blood collection, the quails were fasted for 12 h. After the 12 h, the blood samples were collected from the jugular vein on the last day of the trial, for use in biochemical analyses. The blood was then centrifuged at 4000 rpm for 10 min to separate the serum for biochemical analyses. Biochemical indices, including albumin, total protein, cholesterol, triglyceride, glucose, alkaline phosphatase, glutamic oxaloacetic transaminase and glutamic pyruvic transaminase in serum were analysed using bioanalytical test kits (Bioanalytic Diagnostic Industry, Co) and measured by a Shimadzu spectrophotometer (PG Instruments, UK).

STATISTICAL ANALYSES

The results obtained from the quail egg samples were evaluated by Minitab v.17.1.0. [28] statistical programme using ANOVA. Tukey's test was used for

Table III - Colour values of the control and PSO supplemented quail eggs

Sample	Yolk			Albumen		
	L	a*	b*	L	b*	b*
Ctrl	55.71±2.20	3.06±0.98	53.94±3.59	91.58±1.73	2.27±0.61	5.91±2.14
PSO1	54.69±3.87	3.98±0.67	51.51±6.28	91.18±1.70	2.29±0.49	7.26±2.04
PSO3	53.81±2.09	3.52±1.28	50.03±1.95	91.82±1.30	2.41±0.41	6.61±1.54
PSO5	53.57±1.03	4.15±1.37	50.35±1.97	92.11±1.26	2.09±0.44	5.90±1.20

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group

Table IV - Chemical properties of the control and PSO supplemented quail eggs

Sample	pH	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Crude Ash (%)	C. Energy (cal/g)
Ctrl	7.69±0,01	72.65±0.24	11.32±1.12	12.13±0.15b*	1.09±0.18	3925±254
PSO1	7.67±0,02	73.88±0.02	10.88±0.71	12.31±0.20b	0.91±0.15	3644.70±47.60
PSO3	7.56±0,02	73.41±1.08	12.72±0.47	10.86±0.03c	1.22±0.47	3698±63.70
PSO5	7.51±0,02	72.23±0.54	12.31±2.00	13.44±0.13a	1.06±0.31	4188±145

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group
*Small letters shows differences among the samples in the same column ($p<0.05$)

Table V - Fatty acid composition (%) of the control and PSO supplemented quail eggs

Fatty Acids	CTRL	PSO1	PSO3	PSO5	PSO
C16:0	23.96±0.13	25.63±1.72	27.49±0.59	27.15±0.34	2.90
C16:1n-7	6.09±0.53	5.24±0.94	5.10±0.63	2.45±0.37	Nd
C18:0	9.82±0.39	10.72±0.43	10.40±0.43	12.93±0.92	2.19
C18:1n-9	46.57±0.08a	41.81±0.12b	35.34±0.05c	31.61±0.46d	4.68
C18:2n-6	11.67±0.13c	14.11±2.15bc	18.48±0.46ab	21.25±0.56a	4.83
C18:3n-5	Nd	0.76±0.01c	2.11±0.14b	3.13±0.16a	85.42
C20:4n-6	1.91±0.06ab	1.96±0.02a	1.11±0.14c	1.50±0.04bc	Nd
∑*Unsaturated*	66.23±0.26	63.50±1.45	62.12±0.15	59.93±0.59	94.93
∑*MUFA*	52.66±0.45	47.05±1.06	40.43±0.58	34.06±0.09	4.68
∑*PUFA*	13.57±0.19	16.45±2.51	21.69±0.73	25.87±0.68	90.25
∑*Saturated*	33.78±0.26	36.51±1.46	37.89±0.16	40.07±0.58	5.09

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group, PSO; Pomegranate seed oil, Nd; not detected.
*Small letters shows differences among the samples in the same line ($p<0.05$)

the determination of the differences among the means. The evaluated data were given as mean values with standard deviation.

RESULTS AND DISCUSSION

The physical quality parameters of the quail eggs are given in Table II. As seen in Table II, the egg weight and eggshell weight ranged between 9.80-10.17 g and 1.10-1.48 g, respectively. These results showed that the egg weight was not affected by PSO addition ($p>0.05$) but shell weight was significantly affected ($p<0.05$). Like the egg weight results shell thickness, shell strength, albumen weight, albumen index, yolk weight, yolk index and Haugh unit was not significantly affected by PSO addition ($p>0.05$). Differences between shell thickness and shell weight may be explained by differences among the surface area of eggs. Nordstrom and Ousterhout [29] reported that shell thickness increased with increasing shell weight, decreasing egg surface area or a combination of these two changes. Anderson et al. [30] reported that shell weights and surface area were different in hen eggs though shell thickness was similar. Rowghani et al. [17] reported that egg weight and albumen weight of control and canola oil supplemented eggs of laying hens had no significant differences but addition of 5% canola oil significantly affected yolk weight. Alvarez et al. [16] reported that addition of conjugated linoleic acid (CLA) increased the yolk weight of laying hen eggs. Al-Daraji et al. [20] reported the supplementation of sunflower, linseed, maize, and fish oils effects on 7 weeks old 120 (*Coturnix coturnix japonica*) quails. In the same study, it was indicated that the supplementation of maize and fish oils significantly increased egg weight, yolk weight, albumen weight, yolk diameter, yolk height, albumen diameter, albumen height, shell thickness and Haugh unit [20]. Literature findings are different from our results. These differences between our results and literature findings may be explained with age, species of birds and the fact that supplemented oils are different.

The colour values of the quail egg yolk and albumen are given in Table III. There were no statistically significant differences among the control and treated egg

Table VI - Elemental composition of the control and PSO supplemented quail egg

Elements (ppm)	Ctrl	PSO1	PSO3	PSO5
Na	3031.10±117.70b	3684±220a	2789.30±77.30b	2507.70±33.90c
Mg	35.47±4.73b	59.50±4.40a	43.40±3.20b	Nd
K	2583.40±111.90b	3301±224a	3196.20±139.40a	2852.30±49.30b
Ca	1131.30±101.20ab	1275.30±166a	805±182.70c	981.70±56.30bc
P	6205.20±76.30	6171±681	5926.20±182.50	6348±181.50
Fe	69.27±6.38	50.80±5.85	37±0.10	49.92±7.17
Cu	3.51±0.22	3.58±0.42	3.33±0.10	3.18±0.26
Mn	0.91±0.04b	0.55±0.03d	1.06±0.09a	0.75±0.02c
Zn	76.85±6.82a	71.83±6.33a	74.38±0.22a	59.98±1.11b
S	2996.90±14.50b	3508±267a	2775±366b	2794.50±21.20b

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group, Nd; not detected.
*Small letters shows differences among the samples in the same line ($p<0.05$).

Table VII - Some blood parameters of the control and PSO supplemented quails.

	Ctrl	PSO1	PSO3	PSO5
ALB (g/dL)	4.52±0.42ab	5.46±0.41a	5.15±0.80a	3.74±0.66b
TPROT (g/dL)	4.69±0.58	4.63±0.85	4.60±0.32	3.62±0.72
CHOL (mg/dL)	301.80±22.70a	237.28±19.32b	238.42±21.08b	219.61±19.08b
TRIG (mg/dL)	188.90±53.4	171.30±42	167.30±36.6	151.17±18.62
GLU (mg/dL)	286.80±29a	215.21±11.17c	239.40±22.90bc	273.60±12.25ab
ALP U/L)	157.26±9.48a	132±7.95b	148.49±9.32ab	161.35±16.25a
GOT (U/L)	23.61±2.66ab	21.56±3.06b	25.66±1.15ab	27.34±2.07a
GPT (U/L)	34.08±3.90a	28.61±3.06b	23.99±1.62b	26.46±1.88b

Ctrl; control, PSO1; 1% pomegranate seed oil supplemented group, PSO3; 3% pomegranate seed oil supplemented group PSO5; 5% pomegranate seed oil supplemented group.
ALB; Albumin, TPROT; total protein, CHOL; cholesterol, TRIG; triglycerides, GLU; Total glucose, ALP; alkaline phosphatase, GOT; glutamic oxaloacetic transaminase, GPT; glutamic pyruvic transaminase.
*Small letters shows differences among the samples in the same line ($p<0.05$).

samples (p>0.05). The L, a* and b* values of the yolk and albumen samples ranged between 53.57-55.71, 3.06-4.15, 50.03-53.94 and 91.18-92.11, 2.09-2.41, 5.90-7.26, respectively. These results proved that the yolk and albumen colour values of the quail egg samples were not influenced by PSO addition. Table IV show the chemical properties of the quail eggs. According to Table IV, there were no significant differences among the pH, moisture, crude protein, crude ash, and combustion energy values of the egg samples (p>0.05). Additionally, there were statistically significant differences among the samples in terms of crude fat (p<0.05). As expected, the fat content of the egg samples was affected by PSO addition in quail feed. Alvarez et. al. [16] reported that CLA supplementation increased linearly yolk moisture and firmness and altered albumen and yolk pH.

The fatty acid composition of the quail egg samples and pomegranate seed oil (PSO) are given in Table V. The fatty acid composition of the PSO was 2.90% palmitic, 2.19% stearic, 4.68% oleic, 4.83% linoleic and 85.42% punicic acid (conjugated linolenic acid isomers). PSO consists of 5.09% total saturated fatty acids, 94.93% total unsaturated fatty acid and 4.68% monounsaturated fatty acids and 90.25% polyunsaturated fatty acids. The major fatty acids of the quail eggs were palmitic acid, oleic acid, and linoleic acid. The statistical evaluation indicated that there were significant differences among the quail egg samples in terms of C18:1, C18:2 and C20:4 fatty acids (p<0.05). The total unsaturated fatty acids of the control, PSO1, PSO3 and PSO5 samples were 66.23%, 63.50%, 62.12% and 59.93%, respectively. These results revealed that PSO addition led to a decrease in unsaturated fatty acid content of the egg samples. Similar results were observed for the monounsaturated fatty acid contents of the control, PSO1, PSO3 and PSO5 samples.

On the other hand, the polyunsaturated fatty acid contents of the control, PSO1, PSO3 and PSO5 samples were 13.57%, 16.45%, 21.69% and 25.87%, respectively. According to these results, the PSO addition increased the PUFA amount of the egg samples. Additionally, similar results were observed for the total saturated fatty acid contents of the control, PSO1, PSO3 and PSO5 samples. Furthermore, dietary PSO supplementation increased both total amount of CLnA and n-6 fatty acids. The remarkable result was that the control sample had no C18:3 fatty acids (CLnA, punicic acid), while the PSO treated quail egg samples had C18:3 fatty acids. Moreover, depending on the PSO addition concentration, the C18:3 fatty acid ratio increased. These results demonstrated that PSO supplementation changed the quail egg fatty acid composition. Alvarez et al. [16] reported that CLA addition increased saturated and total n-3 fatty acids while decreased those of monounsaturated and total n-6 fatty acids. On the other hand, in the same study, the researchers reported that FO addition increased n-3 fatty acids while decreased those of CLA, saturated and n-6 fatty acids [13]. Çitil et al. [19] reported that flaxseed oil supplemented at 3% level increased the concentration of C18:3 in egg yolk. Silva et al. [18] reported similar results on 58-week old laying quails (*Coturnix coturnix japonica*). Literature findings are similar to our findings.

The mineral composition of the quail egg samples is shown in Table VI. The major elements were Na, K, Ca, P and S. Furthermore, supplementation of pomegranate seed oil were not affecting in terms of P, Fe and Cu values (p>0.05), while there were statistically significant differences among the Na, Mg, K, Ca, Mn, Zn and S values (p<0.05).

The blood parameters of the control group and PSO supplemented groups of quails are presented in Table VII. There were statistically significant differences among the samples in terms of ALB, GOT and GPT levels (p<0.05). On the other hand, PSO1 and PSO3 groups had higher ALB levels than the control and PSO5 groups. The GOT levels ranged from 21.56 to 27.34 U/L while, GPT levels ranged from 23.99-34.08 U/L. PSO5 group had higher GOT level, while control group had higher GPT level. The PSO1 and PSO3 groups had lower GOT and GPT levels. In literature, it was reported that ALB, GOT and GPT were related with the liver damage in birds [31].

There were no statistically significant differences among the samples in terms of TPROT, CHOL and TRIG levels. However, the TRIG level decreased when the PSO concentration increased. One of the remarkable results was the change in the CHOL levels of the PSO supplemented groups. PSO supplementation reduced the CHOL level depending on the adding concentration of PSO. Similar result was observed for ALP level of the groups. In terms of GLU level, the control group had higher values than that of the PSO supplemented groups, while PSO1 and PSO3 group had lower GLU level. Hoan and Khoa [21] reported that sesame oil supplemented at different levels decreased the blood serum lipid profile of laying hens.

CONCLUSION

The supplementation of pomegranate seed oil in quail feed did not significantly affect the physical quality parameters of the eggs such as egg weight, shell strength, albumen index, yolk index, Haugh unit. In addition to these findings, supplementing the quail diet with pomegranate seed oil was effective on the egg fatty acid composition. The total saturated fatty acids and polyunsaturated fatty acids increased, while the monounsaturated fatty acids and total unsaturated fatty acids decreased. These results clearly demon-

strated that supplementation of the quail diet with pomegranate seed oil has improved the fatty acid composition and some egg quality parameters.

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