Effects of sumac fruit powder (Rhus coriaria L.) supplementation on productive performance, egg quality traits and serum biochemical parameters in old laying hens

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ABSTRACT
This study aimed to investigate the effects of sumac fruit powder (SFP; Rhus coriaria L.) supplementation on productive performance, egg quality traits and serum biochemical parameters in old laying hens. One-hundred-twenty, 54 weeks old Hy-line W36 strain-laying hens were assigned to three treatments, five replicates and eight hens per replicate in a completely randomised design. Experimental diets included: (1) Control (C) without SFP supplementation, (2) 0.25% SFP and (3) 0.5% SFP supplemented diet. The experimental diets were fed for 8 weeks. The results showed that the egg production rate (EPR) and egg mass (EM) significantly reduced, and FCR increased in the SFP group compared to the control group (p < 0.05). During the first laying period (0–4 weeks), egg yolk percentage (YP), Yolk height (YH) and yolk index (YI) were significantly reduced by SFP supplementation; however, during both laying periods (0–4 and 4–8 weeks), yolk pH increased by 0.5% SFP supplementation as compared to the control group (p < 0.05). During the second laying period (4–8 weeks), Haugh unit (HU), YH and egg density (ED) significantly reduced in SFP supplemented groups (p < 0.05). However, albumen pH was significantly increased in both SFP supplemented groups; but, yolk pH and YI were significantly increased only in the group of birds fed diets supplemented with 0.5% SFP compared to the control group (p < 0.05). The serum biochemical analysis showed that SFP supplementation significantly increased total antioxidant capacity (TAC) and reduced malondialdehyde (MDA) (p < 0.05). SFP supplementation significantly reduced triglyceride, cholesterol and VLDL content of serum (p < 0.05). Also, yolk triglyceride showed a significant reduction through SFP supplementation (p < 0.05). In conclusion, SFP supplementation in the laying hens’ diet could significantly reduce triglycerides and cholesterol levels and increase the antioxidant status of laying hens. Nevertheless, it might have negative impacts on production performance.

HIGHLIGHTS
- Sumac fruit powder (SFP) can be used as a potential alternative to antibiotics and synthetic antioxidants.
- SFP can significantly reduce serum cholesterol and triglyceride by interrupting lipid absorbance.
- SFP can significantly reduce production performance due to reducing blood and, subsequently, yolk lipids levels, especially cholesterol and triglyceride.

Introduction
Due to the forbiddance of growth-promoting antibiotics inclusion in animal feeds, most countries, especially the European Union (EU), have banned using antibiotics over medical dosage and for growth-promoting purposes. Therefore, many interests have been attracted to investigate any naturally potential substituents of antibiotics, particularly bioactive products of medical plants, with similar features and no adverse effects on poultry spices (Saleh et al. 2014; Puvača, Ljubojević, Kostadinović, Lević et al. 2015; Puvača, Ljubojević, Kostadinović, Lukać et al. 2015; Qureshi et al. 2017). Sumac is considered one of the promising alternatives to antibiotics as its antioxidant, anti-inflammatory, antimicrobial, antifungal, antitumor (Janbaz et al. 2014) and other beneficial properties have been proven in many human and animal studies. It is acknowledged that humans have used sumac for...
medicinal purposes and as a food additive since ancient times (Fazeli et al. 2007).

Sumac (*Rhus coriaria*), is a member of the Nacardiaceae family, which includes more than 800 species and is found in tropical and subtropical countries, mainly in the Mediterranean, Africa, West Asia and south-eastern Anatolia (Wetherilt and Pala 1994). Phenols and phytochemical content of sumac have been analysed and found out that this medical herb contains almost 211 constituents, mainly including tannins, terpenoids and (iso)flavonoids as its most dominant compounds (Abu-Reidah et al. 2015). Other investigations indicated that tannic and gallic acid, myricetin, myricetin, ellagic, quercetin, isoquercetin, quercetin and avicularin are the other constituents of this medical plant (Duke 2002; Mehrdad et al. 2009; Shabbir 2012). Sumac usually tastes sour due to its citric and malic acid content, which lowers its pH to about 2.5. Earlier, epidemiologic studies have shown that medical herbs can reduce the chronic disorders hazards caused by oxidative stress and enhance the overall health situation (Halliwell et al. 1997). Sumac has been shown to reduce oxidative stress and thus protect DNA and the liver from oxidative stress damages. It seems that the antioxidant properties of sumac are due to its flavonoids, especially Gallic acid content (Giao et al. 2010).

It has been shown that 0.5% of sumac supplementation in laying hens diet did not significantly affect final body weight, egg production, egg weight (EW), body weight, feed conversion ratio (FCR) and feed consumption (Arp et al. 2014; Gumus et al. 2018). However, final body weight and egg mass (EM) significantly increased in the Japanese quail fed diet containing 0.25% sumac (Sabir and Aydin 2017). Besides, up to 1% sumac supplementation in laying hens diet did not affect Haugh unit (HU), albumen index, yolk colour and yolk index (YI) regarding the inner parameters of the eggs (Gumus et al. 2018). The same authors reported that sumac inclusion in the laying hens’ diet did not affect blood serum cholesterol, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels. Contrariwise, in another experiment, the blood cholesterol and low-density lipoprotein (LDL) reduced, and high-density lipoprotein (HDL) affected was by 2% sumac supplementation in laying hens’ diet (Gurbuz and Salih 2017). Yolk cholesterol level is shown to be not affected by sumac supplementation in laying hens’ diet (Sabir and Aydin 2017). According to the studies on broiler chickens, 0.5% sumac supplementation reduced negative impacts of heat stress and increased performance during the starter phase. However, sumac supplementation till 1% did not affect carcass traits, including the relative weight of thigh muscle, abdominal fat pad, liver and heart (Alishah et al. 2013).

Few studies have investigated the effects of SFP on broiler chicken performance, and there is a detailed review study in this context (Shariatmadari and Shariatmadari 2020). However, limited studies have investigated the effects of SFP supplementation in poultry nutrition, especially in laying hens. This study aimed to investigate the effect of sumac fruit powder (SFP) supplementation as a potential natural antioxidant on production performance, egg quality traits and blood parameters of aged laying hens.

### Material and methods

#### Birds, housing and sumac

This study was carried out following the procedures approved by the Animal Research Ethical Committee of the animal science department of Urmia University, Iran. One-hundred-twenty laying hens (Hy-line W36) of 54 weeks of age were provided from a commercial layer farm and distributed into three treatments, five replicates and eight birds per replication (with similar body weights ±5%) in a completely randomised design. Experimental diets included (1) control
(without SFP supplementation), (2) 0.25% SFP and (3) 0.5% SFP supplemented diets. Birds were housed in steel laying hen cages (45 × 45 × 110) with free access to water (nipple drinking system). Experimental diets were based on the corn-soybean meal and formulated according to the Hy-line W36 nutritional recommendations, and the hens were fed for eight weeks (Table 1). Two weeks were assigned for adaptation, during which the birds were fed with the control diet. Fresh sumac fruit was provided from a local market at Urmia city, which was dried and ground. Total phenol contents of SFP were measured using the standard extraction method (Slinkard and Singleton 1977) and Gallic acid as the standard. The reports of this analysis indicated that the total phenol content of desired SFP was 45.61 mg/g dry matter. A lighting program of 14 L:10D was used in this experiment, through which the light intensity of 30 lux and 3 lux were adjusted for the lightning and dark periods, respectively. The ambient temperature was kept at 20–25 °C and humidity in the range of 40–50%.

**Performance parameters measurement**

To evaluate the quantitative traits of egg and production performance, eggs were collected twice a day throughout the experiment to measure the egg number and mean EW. EM was evaluated weekly by multiplying the daily mean EW of each unit to its daily production percentage using the following equations:

\[
\text{Hendayeggproduction\%} = \frac{\text{Totaleggproductionofeachexperimentalunit}}{\text{relatedhenday}}
\]

\[
\text{Hen day} = (\text{live hens} \times \text{days of experiments})
\]

In this experiment, the feed conversion ratio (FCR) was also calculated weekly by dividing feed intake (gram) by the egg mass (gram) in each experimental unit. FI was measured weekly, and mortality rate was recorded throughout the experiment (97 ± 2.3% viable hens at the end of the experiment; data not reported in tables).

**Egg quality traits evaluation**

Qualitative traits of eggs were examined at the end of every laying period (4 weeks). Two eggs were collected from each replicate for these examinations. First, eggs were weighed using an electronic scale (0.01 g; model KEB 602, China) Egg-specific gravity was measured according to the procedure provided by the University of Florida (Butcher and Miles 1991). The eggshell strength or breaking resistance was evaluated using an analogue eggshell strength measuring machine (Ogawa Seiki Co. Ltd. Tokyo, Japan). Then, yolk and albumen were separated, and yolk weight was measured using an electronic scale (0.01 g) to calculate the yolk and albumen percentage. A certain amount of egg white and egg yolk were mixed separately with distilled water in a ratio of 1:9 and stirred well until the foam was formed on the surface of the resulting solution. Then, the pH of the solution was measured after the foam subsided. Albumen and yolk pH was measured using an electronic pH metre (model AZ-8688 Detachable Pen Type, Taiwan). Eggshells were washed and dried properly (12 h at room temperature then 72 h in 65 °C oven) for further analysis. First, the dried eggshells were weighed using an electronic scale (0.01 g) to calculate the albumen weight (albumen weight = egg weight - (yolk weight + shell weight)). Then, the eggshell thickness was measured using an outside micrometre (0.01 mm; model YP001, Japan) in three sections (top, middle, and bottom), and eventually, the average of those sections was calculated and considered as the eggshell thickness. Albumen was transferred on a clean and flat surface to measure its height for the HU calculation. HU numerical values (mm) have been reported wherever the tip of the Haugh metre contacts the albumen at a distance of 1 cm around the yolk. After determining albumen height, based on the related EW, we calculated the HU according to the equations mentioned below (Haugh 1937):

\[
\text{HU} = \log(\text{AH} - 1.7 \times \text{EW}^{0.37} + 7.57)
\]

\[
\text{AH} : \text{albumen height (mm)}
\]

\[
\text{EW} : \text{egg weight (g)}
\]

Yolk colour was measured using the Roche colour scale. Yolk height (YH) and width were, respectively, measured using a Haugh metre and a digital calliper (0.01 mm; BakingWin, China) immediately after yolk weighing to evaluate the YI. YI was evaluated according the following formula:

\[
\text{Yolkindex} = \left( \frac{\text{yolkheight}(\text{YH})}{\text{yolkdiameter}(\text{YD})} \right) \times 100.
\]

**Serum and yolk biochemical measurements**

At the end of the experiment, blood collection was conducted from two birds of each replicate. In addition, yolk samples were obtained from two eggs of each replicate. Blood samples were taken from the wing veins using 5 mL plastic syringes and then kept
for a while at room temperature to separate blood serum. The obtained serum was transferred to 1.5 mL microtubes and kept in the refrigerator (−18°C) until the laboratory experiments. To evaluate yolk triglyceride and cholesterol, obtained yolk samples were stored at −18°C until the laboratory experiments. One hundred milligrams of the yolk sample were weighed using a 0.001 g scale, mixed with 2.5 mL of NaOH solution (0.05N), and then neutralised with 2.5 mL of the hydrochloric acid solution (0.25N). Eventually, the obtained solution was analysed by enzymatic method and autoanalyzer system (model Technicon RA 1000) in 550 nm wavelength using Pars-Azmoun kits. Serum samples were used to analyse the biochemical parameters (triglyceride and cholesterol (Folch et al. 1957)), antioxidant factors (total antioxidant capacity [TAC] and malondialdehyde [MDA]), uric acid, total protein, liver enzymes (ALT, AST, alkaline phosphatase [ALP]) and albumin. The TAC was evaluated according to the procedure provided by Randox Total Antioxidant Control Cat. No. NX 2331, in a wavelength of 600 nm by a 1 cm light path at 37°C using a temperature-controlled spectrophotometer. Briefly, 80 mmol/L of the phosphate-buffered saline (pH 7.4) was provided to use as a diluant. In this regard, 10 mL of the buffer was used to reconstitute one vial of the chromogen (6.1 μmol/L metmyoglobin and 610 μmol/L ABTS) and 3 mL of the same buffer was used to dilute 1 mL of the substrate (250 μmol/L hydrogen peroxide in stabilised form). Additionally, 1 mL of double deionised water was used to reconstitute one vial of the standard solution (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid). In this examination, 20 μL of double deionised water was mixed with 1 mL of chromogen and 200 μL of the substrate to form a reagent blank solution. Also, the standard solution consisted of 20 μL the standard solution, 1 mL of chromogen and 200 μL of the substrate. Specifically, 20 μL of sample were mixed with 1 mL of chromogen and 200 μL of the substrate to analyse the total antioxidant status of samples. To evaluate the serum MDA level, 500 μL of serum sample was dissolved in three mL of phosphoric acid 1% in a test tube. After vortexing, 1 mL of thiobarbituric acid (TBA) 0.67% was added to the test tube and boiled in a bain-marie for 45 min. Then, the test tubes were chilled with cooled water, and three mL of butanol normal was added and vortexed for 1–2 min. The obtained solution was centrifuged at 3000 rpm for 10 min. After removing the supernatants, light absorption was measured at 532 nm using spectrophotometry versus normal butanol (as a blank solution). The MDA levels were determined after

| Table 2. Effects of different levels of sumac fruit powder (SFP) supplementation on production performance of laying hens. |
|---------------------------------------------------------------|
| Sumac, % | Egg production, % | Feed intake, g | FCR, g:g | Total period |
| 0.25 | 66.96 a | 67.41 | 67.19 | 67.46 | 67.19 | 66.96 | 67.41 | 67.19 | 67.46 | 67.19 | 66.96 | 67.41 | 67.19 |
| 0.5 | 62.83 b | 63.33 | 63.47 b | 64.46 | 63.61 b | 64.46 | 63.61 b | 64.46 | 63.61 b | 64.46 | 63.61 b | 64.46 | 63.61 b |
| 0.75 | 63.61 b | 64.38 | 63.47 b | 64.68 | 64.69 b | 64.68 | 64.69 b | 64.68 | 64.69 b | 64.68 | 64.69 b | 64.68 | 64.69 b |
| SEM | 0.492 | 1.104 | 0.696 | 0.226 | 0.259 | 0.224 | 0.352 | 0.718 | 0.449 | 0.471 | 0.363 | 0.297 | 0.024 |
| p Value | .008 | .067 | .007 | .371 | .011 | .074 | .001 | .018 | .002 | .697 | .083 | .493 | .002 |

Means within same column with different letters (a, b, c) differ significantly (p<.05).
comparing the obtained results with the standard curve. Liver enzymes, including ALT, AST and ALP, were measured according to the procedures provided in the catalogs of the Pars-Azmoon kits (Pars Azmoon Co., Tehran, Iran) using the spectrophotometry at 600, 340 and 340 nm wavelengths, respectively. Briefly, two reagents were used to evaluate the levels of ALT in serum. Reagent 1 consisted of 100 mmol/L TRIS (pH 7.5), 500 mmol/L L-alanine, and less than 1200 U/L LDH (lactate dehydrogenase); and reagent 2 consisted of 15 mmol/L 2-oxoglutarate and 0.18 mmol/L NADH. Almost similarly, two reagents were used to evaluate the levels of AST in the serum sample. Reagent 1 consisted of 80 mmol/L TRIS (pH 7.8), 240 mmol/L L-aspartate, less than 600 U/L MDH (malate dehydrogenase), and less than 600 U/L LDH (lactate dehydrogenase). Reagent 2 consisted of 12 mmol/L 2-oxoglutarate and 0.18 mmol/L NADH. In the case of ALP, a common method described by (Thomas1998) was used accompanied by the reagents provided from the Pars-Azmoon company.

**Statistical analysis**

The obtained data were statistically analysed using Procedure GLM in SAS version 9.2 software (SAS2009), and a Tukey test was performed to determine the differences between the means ($p < .05$). The statistical model used in this study was:

$$Y_{ij} = \mu + T_i + e_{ij}$$

$Y_{ij}$: observation;
$\mu$: mean of observations;
$T_i$: treatment effect;
$e_{ij}$: experimental error of each observation.

**Results**

**Productive performance**

The effects of SFP supplementation on egg production rate (EPR), EW, EM, FI and FCR of laying hens are shown in Table 2. The results showed that EPR of birds’ fed diets containing 0.25 or 0.5% SFP significantly reduced as compared to the control group, during weeks 0–4 and the whole experiment. EW was not affected by SFP supplementation except in weeks 4–8, during which, it was significantly reduced ($p < .05$). SFP supplementation completely affected EM thus significantly reduced EM during both experimental periods (weeks 0–4 and 4–8) and the whole period ($p < .05$). FI of birds was not affected by SFP supplementation in any period. FCR significantly reduced in all experimental periods as a result of SFP supplementation ($p < .05$).

**Egg quality traits**

The effects of SFP supplementation on egg quality traits of birds are shown in Table 3. As indicated, only parameters related to yolk were affected by SFP supplementation during the first four weeks. In this regard, yolk percentage (YP), YH and YI significantly reduced, whereas yolk pH (YpH) increased ($p < .05$). The results indicated that the HU, YH and egg density (ED) significantly reduced during both experimental periods (weeks 0–4 and 4–8) and the whole period ($p < .05$). FI of birds was not affected by SFP supplementation in any period. FCR significantly reduced in all experimental periods as a result of SFP supplementation ($p < .05$).

### Table 3. Effects of different levels of sumac fruit powder (SFP) supplementation on quality traits of egg.

|            | Turmeric, % | YP, % | AP, % | SHP, % | SHT, mm | HU | YH, mm | ApH | YpH | ED | SHS, kg/m² | YC | YI |
|------------|-------------|-------|-------|--------|---------|----|--------|-----|-----|----|-------------|----|----|
| Week 4     |             |       |       |        |         |    |        |     |     |    |             |    |    |
| Control    | 28.45       | 63.1  | 8.44  | 0.468  | 85.1    | 17.33 | 8.15  | 6.75 | 1.08 | 1.94 | 8.75       | 39.36 |
| 0.25       | 24.50       | 66.9  | 9.19  | 0.455  | 57.1    | 15.27 | 8.26  | 7.07 | 1.08 | 2.48 | 8.37       | 34.54 |
| 0.5        | 24.95       | 65.2  | 8.9   | 0.461  | 86.6    | 15.32 | 8.25  | 7.23 | 1.09 | 2.56 | 8.62       | 34.39 |
| SEM        | 0.999       | 1.19  | 0.329 | 0.014  | 2.03    | 0.298 | 0.082 | 0.133| 0.001| 0.417| 0.258      | 0.806 |
| p Value    | .023        | .095  | .300  | .799   | .763    | .004 | .612   | .053 | .464 | .165 | .598       | .001 |
| Week 8     |             |       |       |        |         |    |        |     |     |    |             |    |    |
| Control    | 27.94       | 63.26 | 8.79  | 0.438  | 85.52   | 16.11 | 7.53  | 6.77 | 1.09 | 2.67 | 8.12       | 36.01 |
| 0.25       | 29.71       | 62.42 | 8.85  | 0.406  | 78.46   | 14.77 | 8.26  | 6.89 | 1.08 | 2.71 | 8.12       | 33.96 |
| 0.5        | 27.99       | 62.32 | 8.71  | 0.406  | 74.22   | 14.11 | 8.17  | 7.15 | 1.08 | 3.56 | 8.62       | 43.46 |
| SEM        | 0.563       | 0.571 | 0.266 | 3.21   | 2.93    | 0.439 | 0.121 | 0.085| 0.002| 0.345| 0.263      | 1.568 |
| p Value    | .061        | .461  | .936  | .380   | .039    | .002 | .006   | .013 | .003 | .145 | .319       | .007 |

*CMeans within same column with different letters (a, b, c) differ significantly ($p < .05$).

YP: Yolk percentage; AP: Albumen percentage; SHP: Shell percentage; SHT: Shell thickness; HU: Haugh unit; YH: Yolk height; ApH: Albumin pH; YpH: Yolk pH; ED: Egg density; SHS: Shell breaking Strength; YC: Yolk colour index; YI: yolk index*
and Yoshida 2008; Kanani et al. 2020). Like green tea, due to feeding by high levels of green tea (Kojima reported a reduction in egg production performance which contains high polyphenolic compounds, have thus reduced egg production.

were affected by these compounds to some extent be expected that protein production and secretion, which may finally decrease egg production. As a limited number of studies examined SFP supplementation in laying hens, this study designated to investigate the effects of this herbal plant on production performance, egg quality traits and blood serum biochemicals to further knowledge and information in this area. Many studies have investigated different phytogenic plants or medicinal herbs as an alternative to synthetic antioxidants and antibiotics. The adverse effects of polyphenol compounds of sorghum and field beans (Vicia faba L.) on production performance have been reported in previous studies (Nyachoti et al. 1997). It has been recognised that polyphenols are components that could disturb protein digestion and absorption, and therefore reduce protein production and secretion, which may finally decrease egg production in laying hens’ reproductive system (Goñi et al. 2007). In this study, due to the high levels of polyphenolic compounds (45.61 mg/g dry matter) that were used for a relatively long time (8 weeks), it could be expected that protein production and secretion were affected by these compounds to some extent and thus reduced egg production.

Similarly, the previous experiments on green tea, which contains high polyphenolic compounds, have reported a reduction in egg production performance due to feeding by high levels of green tea (Kojima and Yoshida 2008; Kanani et al. 2020). Like green tea, SFP contains relatively high levels of polyphenolic compounds, including catechins and flavonoids. These compounds can disturb lipid absorption in the hens’ intestinal tract. Since egg yolk contains high levels of lipids, and low lipid absorption could reduce egg production, inhibiting lipid absorption may reduce egg yolk production and decrease egg production percentage (Ikeda et al. 1992). Consequently, SFP supplementation in laying hens’ diet, especially aged hens, would reduce protein production and lipid absorption for production performance purposes.

Reduced yolk production in the ovary could decrease yolk weight. EW highly depends on fatty acid and lipid absorption from the intestinal tract. Since polyphenolic compounds or catechin have an inhibiting effect on lipids absorption, it can be expected that EW would reduce in the laying hens fed with sumac supplemented diets (Ikeda et al. 1992). In this study, although EW was not affected by SFP supplementation during the first 4 weeks of the experiment, it significantly reduced during the second 4 weeks. The EM originates from the multiplication of the production percentage and the mean EW. Therefore, as expected, EM reduced by decreasing egg production and EW in SFP supplemented groups. Moreover, FCR results from the division of FI to EM. Therefore, this parameter is affected by FI, egg production, and EW parameters. Consequently, as FI did not significantly differ from reduced egg production and EW in this study, FCR significantly increased by SFP supplementation. The results obtained in this study disagree with previous studies in terms of SFP supplementation in laying hens’ diet (Arpášová et al. 2014; Gumus et al. 2018). Those studies, reported non-significant differences in production performance, whereas the results of this study showed a significant reduction in egg production, EM, and a significant increase in FCR by SFP inclusion in laying hens’ diet.

The evaluation of the eggs’ internal and external quality traits indicated that parameters related to yolk were mainly affected by SFP supplementation. As mentioned above, probably low lipid absorption has significantly decreased YH and weight in the groups.

### Table 4. Effects of different levels of sumac fruit powder (SFP) supplementation on serum biochemicals.

| Sumac, % | Uric acid, mg/dL | Total protein, g/mL | Albumin, g/mL | ALT, U/L | AST, U/L | ALP, U/L | TAC, mmol/L | MDA, μg/mL |
|---------|-----------------|-------------------|--------------|----------|----------|----------|-------------|------------|
| Control | 407             | 5.65              | 2.62         | 36.00    | 242.2    | 782.5    | 1.39<sub>p<.05</sub> | 3.42<sup>a</sup> |
| 0.25    | 489             | 6.03              | 2.52         | 39.25    | 233.2    | 815.0    | 1.66<sup>b</sup> | 2.22<sup>b</sup> |
| 0.5     | 539             | 6.10              | 2.65         | 39.18    | 240.0    | 816.0    | 1.73<sup>c</sup> | 1.33<sup>c</sup> |
| SEM     | 0.448           | 0.176             | 0.178        | 7.34     | 6.08     | 96.50    | 0.069       | 0.196      |

p Value: .469 .209 .873 .938 .520 .961 .003 .001

Means within same column with different letters (a, b, c) differ significantly (p<.05).

ALT: alanine transaminase; AST: aspartate transaminase; ALP: alkaline phosphatase; TAC: total antioxidant capacity; MDA: malondialdehyde

**Serum and yolk biochemical parameters**

Serum biochemicals evaluations (Table 4) showed that the use of 0.25% and 0.5% SFP in the diet could significantly increase the TAC of birds and reduce MDA. However, no significant differences were observed in other measured parameters (p<.05). The effects of SFP supplementation on serum triglyceride, total cholesterol, VLDL and egg yolk triglyceride and cholesterol are shown in Table 5. As indicated, SFP supplementation could significantly decrease the serum biochemicals level (p<.05). However, only triglyceride level was affected by SFP supplementation and reduced (p<.05).

**Discussion**

As a limited number of studies examined SFP supplementation in laying hens, this study designated to investigate the effects of this herbal plant on production performance, egg quality traits and blood serum biochemicals to further knowledge and information in this area. Many studies have investigated different phytogenic plants or medicinal herbs as an alternative to synthetic antioxidants and antibiotics. The adverse effects of polyphenol compounds of sorghum and field beans (Vicia faba L.) on production performance have been reported in previous studies (Nyachoti et al. 1997). It has been recognised that polyphenols are components that could disturb protein digestion and absorption, and therefore reduce protein production and secretion, which may finally decrease egg production in laying hens’ reproductive system (Goñi et al. 2007). In this study, due to the high levels of polyphenolic compounds (45.61 mg/g dry matter) that were used for a relatively long time (8 weeks), it could be expected that protein production and secretion were affected by these compounds to some extent and thus reduced egg production.

Similarly, the previous experiments on green tea, which contains high polyphenolic compounds, have reported a reduction in egg production performance due to feeding by high levels of green tea (Kojima and Yoshida 2008; Kanani et al. 2020). Like green tea,
fed with SFP supplemented diets. The reason for yolk pH changes due to the use of SFP in hens’ diet is not clear yet. The HU is directly related to egg white, and egg white depends on the whites’ thick protein/albumen. Thus, probably the reduction in thick protein production and secretion in the hens’ oviduct affected by SFP polyphenols in diet have negatively affected the HU. Also, in this study, the HU reduced due to SFP supplementation during the second 4 weeks of the experiment, and this could be the reason for decreasing the ED in SFP supplemented groups. It has been reported that as white pH increases, bonds between lysozyme and ovomucin weakens. Therefore, white height decreases and subsequently reduces the HU (Ahn et al. 1999). Hence, the increase in egg white pH is one of the probable reasons for the HU and egg white height reductions. Accordingly, since the YI is a parameter that comes from the division of YH to yolk diameter, it would be expected that reduce in YH might reduce the YI, and conversely. The findings of this study are in agreement with previous studies concerning SFP supplementation in laying hens’ diet (Arpášová et al. 2014).

It has been reported that flavonoids could increase animal antioxidant capacity (Ishikawa et al. 1997). Moreover, polyphenols in green tea could potentially reduce free radical production in the cell (Pannala et al. 1997). Another study has also reported the effects of green tea on reducing serum MDA (Sahin et al. 2008). Using green tea in laying hens’ diet, previous researchers reported improved serum TAC and reduced serum MDA in response to polyphenolic compounds of green tea (Abdo et al. 2010; Kanani et al. 2020). The findings of this study are in agreement with the previous studies. Catechins are polyphenolic compounds that destroy most free radicals, such as highly reactive hydroxide, which initiates lipid peroxidation (Nakagawa and Yokozawa 2002). Hence, due to the high levels of polyphenolic compounds in SFP, TAC enhancement and MDA reduction would be expected in the poultry diet. In this respect, the results obtained in this study agree with previous ones (Gumus et al. 2018).

Polyphenols like catechins can increase biliary acid excretion by preventing bile reabsorption. Cholesterol conversion to biliary acids in the liver would increase to compensate for the missing biliary acids. These mechanisms lower the cholesterol level in the liver, affecting the total cholesterol content of the blood and egg yolk (Myant and Mitropoulos 1977). It has been reported that some of the polyphenolic compounds found in medicinal herbs are potentially strong factors that reduce cholesterol and lipids such as triglyceride in the blood. These compounds can disturb the digestion and absorption of lipids, cholesterol and triglycerides by disturbing lipid emulsification and lipid entrance into the micelles (Shishikura et al. 2006). Due to the relatively high levels of polyphenols in SFP, serum cholesterol and triglyceride levels are expected to decrease in response to SFP supplementation in the diet. In the present experiment, serum cholesterol (from 573.5 mg/dL in control group to 446.2 in 0.25% SFP and 149.0 mg/dL in 0.5% SFP supplemented group) and triglycerides (from 268.0 mg/dL in the control group to 211.7 mg/dL in 0.25% SFP and 163.5 mg/dL in 0.5% SFP supplemented group) decreased significantly due to SFP increases in the diet. This finding is consistent with previous findings regarding the effects of polyphenols on lowering cholesterol and triglyceride levels of serum. Triglyceride contents are high in VLDL. Accordingly, VLDL would decrease by reducing triglyceride and lipids absorption. The same results were obtained in this study that supports the previous findings (Gálik et al. 2014; Gurbuz and Salih 2017).

**Table 5. Effects of different levels of sumac fruit powder (SFP) supplementation on serum and egg yolk cholesterol and triglyceride.**

| Sumac, % | Triglyceride, mg/g | Cholesterol, mg/g | Control | 0.25 | 0.5 |
|----------|--------------------|------------------|---------|------|-----|
|          | Yolk               | Serum            |         |      |     |
|          | Triglyceride, mg/dL| Cholesterol, mg/dL| VLDL, mg/dL |
| Control  | 317.70<sup>a</sup> | 28.35            | 2680.1<sup>a</sup> | 573.5<sup>a</sup> | 530.68<sup>a</sup> |
| 0.25     | 293.00<sup>b</sup> | 27.00            | 2117.3<sup>b</sup> | 446.2<sup>a</sup> | 425.23<sup>b</sup> |
| 0.5      | 291.00<sup>b</sup> | 29.35            | 1635.9<sup>c</sup> | 149.0<sup>b</sup> | 320.17<sup>c</sup> |
| SEM      | 3.79               | 0.612            | 88.73     | 44.7 | 163.7 |
| p Value  | .002               | .082             | .005      | .003 | .008 |

*Means within same column with different letters (a, b, c) differ significantly (p<.05).
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Data availability statement
The data that support the findings of this study are available from the corresponding author, Seyyed Ali Mirghelenj, upon reasonable request.

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