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The Effects of Safflower Oil on Growth Performance, Meat Quality, Carcass Composition and Oxidative Stress in Japanese Quails

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Abstract

This study was conducted to investigate the effects of the addition of SFO (*Chartamus tinctorius* L.) to dietary of Japanese quail on growth performance, meat quality, carcass composition, and oxidative stress. A total of 40 Japanese quails at ten days of age were used as material and divided into four groups comprising ten birds. The experiment was continued for 35 days. The control group was fed with a diet including no additives, while 0.1%, 0.2%, and 0.3% SFO were added to the feed of the other groups. For this purpose, the effects of SFO on body weight and average daily weight gain of quails, feed consumption (FC) and feed conversion ratio (FCR) of quails, slaughter and carcass piece weights of quails, breast meat quality characteristics, breast meat color characteristics and stress parameters were investigated. There was no significant (P>0.05) difference between the groups in terms of body weight (BW), daily body weight gain (DBWG), daily feed consumption (DFC), FCR, carcass, and slaughter characteristics, color, and pH values. It was found that the addition of SFO significantly reduced total oxidative status (TOS) (P<0.05) and increased total antioxidant status (TAS) (P<0.01) in blood. The results indicated that the addition of SFO to quail diets would be useful as an additive improving TAS (P<0.01) and reducing TOS values (P<0.05), although SFO addition did not change the feeding performance and carcass characteristics of quails.

Key Words: Carcas quality, meat quality, oxidative stress, performance traits, safflower oil.

Aspir Yağının Japon Bıldırcınlarında Büyüme Performansı, Et Kalitesi, Karkas Kompozisyonu ve Oksidatif Stres Üzerine Etkileri

Öz

Bu çalışma, Japon bıldırcının diyetine Aspir yağı (AY) (*Chartamus tinctorius L.*) ilavesinin büyüme performansı, et kalitesi, karkas kompozisyonu ve oksidatif stres üzerine etkilerini araştırmak amacıyla yapıldı. Materyal olarak 10 günlük yaştaki 40 adet Japon bıldırcını kullanıldı. Bıldırcınlar her biri 10'ar adetten oluşan 4 gruba ayrıldı. Deneme 35 gün boyunca sürdürüldü. Kontrol grubu hiçbir katkı maddesi içermeyen diyetle beslenirken, diğer grupların yemlerine %0.1, %0.2 ve %0.3 oranında AY ilave edildi. AY'nın bıldırcınların canlı ağırlığı (CA) ve ortalama günlük ağırlık artışı (GCAA), yem tüketimi (YT) ve yemden yararlanma oranı (YYO), kesim ve karkas parça ağırlıkları, göğüs eti kalite özellikleri, göğüs eti rengi ve stress parametreleri üzerine etkileri araştırıldı. Gruplar arasında CA, GCAA, günlük YT, YYO, karkas ve kesim özellikleri, renk ve pH değerleri açısından anlamlı (P>0,05) bir fark bulunmadı. AY ilavesinin kandaki toplam oksidatif durumu (TOS) önemli ölçüde (P<0.05) azalttığı ve toplam antioksidan durumu (TAS) arttırdığı (P<0.01) bulundu. Sonuçlar, bıldırcın rasyonlarına AY eklenmesinin, TAS'ı iyileştiren ve TOS değerlerini azaltan bir katkı maddesi olarak faydalı olabileceğini, ancak AY eklenmesinin bıldırcınların beslenme performansını ve karkas özelliklerini değiştirmediğini gösterdi.

Anahtar Kelimeler: Karkas kalitesi, et kalitesi, oksidatif stress, performans özellikleri, aspir yağı.

INTRODUCTION

As a result of the rise in public awareness about human and environmental health, the use of natural products and consumption of safe foods gain attention, especially in developed and developing countries (1). Due to the prohibition of the use of antibiotics in animal feed, the demand for natural additives without residual risk to enhance the performance of animals has increased. Aromatic plants are recognized as safe additives because of the active components originating from their chemical structure. Therefore, active substances from herbal products have gained popularity as natural and reliable food and feed additives due to their antimicrobial, antioxidant, anticarcinogenic, antiviral, anti-inflammatory, and digestive system stimulant effects (2).

Safflower (*Chartamus tinctorius* L.) is a member of the Compositae/Asteraceae family and is an oilseed plant with an oil content of 20-40% (3). Safflower is an annual plant that can be used in various fields such as food, paint, varnish, feed, and the pharmaceutical industry (4). Safflower oil (SFO) contains composed of linoleic acid (63-75%), oleic acid (16-25%), palmitic acid (6-8%), and stearic acid (2-4%) (5). SFO shows a high antimicrobial activity. Khémiri et al. (6) have observed an inhibitory zone of 13.0-15.0 mm diameter against bacteria including *Escherichia coli*, *Streptococcus agalactiae*, *Enterobacter cloacae*. An ophthalmic emulsion prepared by using SFO has shown an inhibitory zone of 9.0 and 6.0 mm diameter against *Staphylococcus aureus* and *Candica albicans*, respectively (7). The high linoleic acid content in the composition of SFO reduces the cholesterol level in the blood, while the oleic acid content provides oxidative stability to the oil during the frying process (8). SFO shows a high vitamin E activity because of its high α-tocopherol content which is a strong antioxidant agent (9). In addition, SFO has a high content of polyphenolic components (10,11) ranging between 2616.10 and 4079.30 mg/100 g gallic acid equivalent (12). Addition of SFO to various cancer cell cultures has been shown to activate different pathways of apoptosis suggesting an anticancer activity of SFO (13). There is evidence that SFO prevents gastric ulcerogenesis, increases gastric mucus secretion and gastric pH by decreasing acid secretion (14).

On the other hand, addition of SFO as low as 0.5% to the chicken diets increases body weight gain which can be associated with the increased length and depth of intestinal villi (15).

Quail production has become a growing sector due to the low cholesterol content of quail meat, high egg production, high growth rate, early sexual maturity, and low breeding costs (16). Addition of the SFO into Japanese quail diets has been reported to decrease serum malondialdehyde levels and increase the level of serum antioxidant activity. In addition, it affects preventing serum lipid oxidation in quails (17).

In a study by Bulbul et al. (18) the addition of safflower into diets along with sunflower cakes at equal ratio up to 30% has not affected initial and final body weights, egg production, feed consumption, feed conversion ratio, and egg weight, or egg quality characteristics of Japanese quails.

Esential oils like SFO are not only used as a source of energy but they are also used as feed additives because of its content of bioactive molecules. El-Hack et al. (19) in their study to monitor the effect of black cumin oil (BCO) dietary supplement on biochemical components, growth performance, carcass characteristics and ileal microbial populations of growing Japanese quails, they added black cumin oil at a concentration of 0 g/kg, 0.50 g/kg, and 1.0 g/kg to the diet. Birds fed the diet supplemented with 0.5 g BCO/kg diet reported a significant increase in body weight compared to the control and other treatment group.

In poultry production consumer preferences for the meat quality including meat color and shelf-life are also important. Due to its bioactive molecule content SFO is an attractive feed additive candidate for improving meat quality parameters. Amer et al. (15). evaluated the effects of safflower oil and vitamin C supplementation in broiler chicken diets on growth performance. They reported an increase in final live weight, total live weight gain, total feed intake and relative growth rate ($P<0.05$) with the addition of safflower oil and vitamin C. Ferreira et al. (20) evaluated the intake, performance, carcass characteristics and meat quality of lambs fed finishing feeds containing 0%, 7.5% and 15% safflower seeds instead of corn and soybean meal. Adding safflower seeds to the diets of lambs did not affect performance and carcass characteristics. There is a linear effect in that the amount of safflower increases the redness (a*) of the meat. They reported that the meat color of lambs fed with a diet containing 7.5% safflower improved.

Oxidative stress occurs as a result of the imbalance between free radicals and antioxidants in the organism's body. Oxidative stress affects physiological and biochemical events in animals. It causes disruption and, as a result, low yield and inability to produce quality cultivation (Macit and Akbulut 2015)(21).

This study aims to assess the effects of the addition of safflower oil to quail diets as feed additive at low doses on growth performance, meat quality characteristics, and blood oxidative stress characteristics.

MATERIAL AND METHODS

The study was conducted according to the animal experiments manual of the Siirt University Animal Experiments Local Ethics Committee (Decision no: 2020/05/03). A total of 40 mixed-sex Japanese quail (Coturnix Coturnix Japonica) chicks at 10 days of age were used as material in this study. Each group consisted of 10 quails (5 males, 5 females) kept in separate compartments of the cage and fed individually. The chicks were supplied from Siirt University Wild Animal Research and Application Center. The Chicks were grouped into 10 chicks of similar average body weight (females 67.74-71.74; males 65.24-71.46 g) in each group. The groups were created as a control (0.0%), SFO 0.1%, SFO 0.2%, and SFO 0.3%. A cold press SFO used in the study was purchased from a commercial manufacturer (Tito, Lot No: 0118159). The nutritional content of the diet (Table 1) given to the quails was prepared in accordance with NRC (22). The diets were designed to be isocaloric and isonitrogenous. The diet for the control group was prepared by using 0.0% safflower oil. The diets for the other three groups were prepared by using 0.1% SFO, 0.2% SFO, and 0.3% SFO. The quails were placed in cages with individual compartments of size 30 x 20 x 20 cm (length x width x height) one chick per cage. The ambient temperature was fixed at 21°C. 23 hours of light and 1 hour of the dark program were applied by applying daylight and artificial lighting in the coop environment. The research was continued for 35 days. Diet and water were given ad libitum.

The nutrient amounts of the feed materials and the diet used in the research were determined according to AOAC (23). Metabolizable energy levels were calculated according to Turkish Standardization Institute (TSE)(24).

The live weights of the chicks were determined by an electronic balance (with an accuracy of 0.01 g) on the same day of the week for four weeks. The mean daily body weight

gains of the groups were determined by dividing the body weight differences between the two successive weighings. Feed consumptions were calculated by subtracting residual feed from the amount of feed given to each animal weekly. Average individual for each week was determined by dividing feed consumptions by the number of days (7 days). The feed conversion ratio (g feed/g gain) was calculated for each week and the whole experiment by:

Table 1. The composition of the diets used in the study, their nutritional value (%) and their metabolizable energy content (Kcal/kg)

	Groups			
Raw material (%)	**Control**	**0.1% SFO**	**0.2% SFO**	**0.3% SFO**
Wheat	17.490	17.490	17.490	17.490
Corn, Yellow	43.45	43.45	43.45	43.45
Fish Meal	0.20	0.20	0.20	0.20
SBM (44% HP)	35.30	35.30	35.30	35.30
Plantal oil	0.50	0.40	0.30	0.20
Safflower oil	0.00	0.10	0.20	0.30
Dicalcium Phosphate	1.260	1.260	1.260	1.260
Dl, Methionine	0.10	0.10	0.10	0.10
Limestone	0.97	0.97	0.97	0.97
L-Lysine Hydro	0.06	0.06	0.06	0.06
Sodium bicarbonate	0.12	0.12	0.12	0.12
Salt	0.25	0.25	0.25	0.25
Vitamin-Mineral	0.30	0.30	0.30	0.30
Total	100	100	100	100
Analysis Values (%)				
Dry Matter	86.3	86.3	86.3	86.3
Crude Protein	24.0	24.0	24.0	24.0
Crude Fat	2.69	2.69	2.69	2.69
Crude Cellulose	2.68	2.68	2.68	2.68
Crude Ash	4.73	4.73	4.73	4.73
Calculated Values				
ME	2903	2903	2903	2903
Ca %	0.80	0.80	0.80	0.80
Met+Sistine %	0.86	0.86	0.86	0.86
Lysine %	1.31	1.31	1.31	1.31
Usable Phosphorus %	0.30	0.30	0.30	0.30

***For every 1 kg of feed, as a vitamin-mineral;** Vitamin A 12000 IU; Vitamin D3 5000 IU; Vitamin E 50mg; Vitamin K3 4mg; Vitamin B1 3mg; 6 mg of vitamin B2; niacin 40mg; Calcium D-pantothenate 15 mg; Vitamin B6 5mg; Vitamin B12 0.030mg; Folic Acid 1mg; Biotin 0.075mg; Choline Chloride 400 mg, Vitamin C 50 mg and antioxidant 10 mg, Manganese 120 mg; Iron 40mg; Zinc 110mg; Copper 16mg; Cobalt 0.005mg; Iodine is 0.125 mg and Selenium is 0.003 mg. SBM: Soybean Meal; ME: Metabolic Energy kcal/ kg, DM; SFO: Safflower oil.

Feed Conversion Ratio (g feed/g body weight gain) = Feed Consumptions (g/week/quail) / Body Weight Gain (g/week/quail).

At the end of 35 days of feeding all birds were sacrificed. Heart, gizzard, and hot carcass weight (after slaughter) and carcass characteristics of slaughtered quails were determined. Breast, hip, wing, back, and other part weights were determined according to the carcass fragmentation method reported by Genchev and Mihaylov (25). Values of lightness (L*), red color (a*), and yellow color (b*) of breast meat (without skin) were measured from 3 different points at the 1st and 24th hours using Lovibond (RT SERIES for MODEL SP60). The measurements of pH were done at 1 and 24 hours (Testo 205). The water holding capacity of breast meats was determined according to the method of Genchev and Mihaylov (25). Water-holding capacity (WHC) was estimated by determining expressible juice using a modification of the filter paper press method described by Wierbicki and Deatherage (26) as follows. A meat sample weighing between 200 and 400 mg was placed on a 11 cm diameter filter paper (Whatman No.1 (No.1001110), Whatman Inc., Clifton, NJ 07014) between plexi glass plates and pressed at 2,000 psi for 1 min. The outline area of the expressible juice and the meat film was traced, and the two areas were determined using a compensating polar planimeter (K + E Model 620000, Keuffel & Esser Co., Morristown, NJ). To determine the cooking loss, 20 g of breast meat was placed in polyethylene bags 24 hours after slaughter and kept in a water bath at 72°C for 1 hour. After cooking, the meat was removed from the bags, cooled to room temperature, and weighed again, the weight loss was calculated and recorded as a percentage value (27). The drip loss of the samples were determined as described by Honikel (28). Blood samples were taken from animals during slaughter. The blood collected in ethylenediaminetetraacetic acid (EDTA) tubes during slaughter was centrifuged at 3000 rpm for 10 minutes. After centrifugation, blood plasma and serum were taken to determine the status of oxidative stress and antioxidants such as TAS (Total antioxidant status), TOS (Total oxidative status), OSI (Oxidative stress index), LOOH (Total peroxides), AOPP (Advanced oxidation protein products), and THIOL (Total thiol groups). These samples were kept at -80°C until analysis. Total oxidative stress and total antioxidant capacity were assessed according to the protocol of the commercial kit (Rel assay, Turkey). The oxidative stress index was calculated according to the

protocol specified in the kit. Protein oxidation was determined by Witko's method reported by Başkol et al. (29) Total thiol level was determined by spectrophotometric 2,2-dithiobis nitrobenzoic (DTNB) method. The total peroxides amount was determined according to the method of Costa et al. (30).

Statistical analysis

The data obtained from the groups in the study were recorded in the Microsoft Excel program and processed in the SPSS (31) package program. The GLM procedure Multivariate test type was used to reveal the effect of supplement groups and gender. Duncan's Multiple Comparison Test was used to reveal the difference between the groups.

RESULTS

The effects of the addition of SFO at different levels to quail diets on body weight and daily body weight gain were given in Table 2. There was no difference among the groups in terms of initial body weights. Addition of SFO and gender had a significant effect on body weight in the first week (BW1). However, there was no difference among supplementation groups while differences between males and females in the following weeks remained significant. Average daily body weight gain was not significantly affected by supplementation of SFO whereas the effect of gender was significant in all weeks, females having superior values. Total body weight gain was also affected by gender, along with body weight and daily body weight gain.

Table 2. Effect of safflower oil on body weight and average daily weight gain of quails (g)

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
	Male	67.14±2.22	65.25±2.22	65.24±2.22	71.46±2.22			
SBW	Female	70.59±2.22	67.74±2.22	69.30±2.22	71.74±2.22	NS	NS	NS
	Mean	68.86±1.09	66.50±1.30	67.07±1.17	71.60±0.77			
	Male	111.98±1.30	110.03±1.34^{B}	112.93±1.34	113.37±1.33^{B}			
BW_1	Female	112.50±1.31	115.44±1.30^{A}	112.14±1.45	118.46±1.34^{A}	*	**	*
	Mean	112.24±1.55^{b}	112.74±1.81^{b}	112.54±2.09^{b}	115.92±1.44^{a}			
	Male	147.40±2.63^{B}	144.25±2.71^{B}	149.42±2.71	152.06±2.69^{B}			
BW_2	Female	152.01±2.65^{A}	153.29±2.62^{A}	152.22±2.93	157.32±2.70^{A}	NS	**	NS
	Mean	149.71±2.19	148.77±2.44	150.82±3.91	154.69±2.29			
	Male	166.45±3.40^{B}	164.84±3.49^{B}	174.95±3.49^{B}	173.14±3.47^{B}			
BW_3	Female	190.41±3.42^{A}	180.10±3.39^{A}	180.39±3.78^{A}	187.16±3.49^{A}	NS	***	NS
	Mean	178.43±4.01	172.47±3.06	177.67±3.76	180.15±3.48			
	Male	181.77±4.39^{B}	174.54±4.51^{B}	187.93±4.51^{B}	187.22±4.48^{B}			
BW_4	Female	204.86±4.42^{A}	202.53±4.37^{A}	210.88±4.88^{A}	211.48±4.50^{A}	NS	***	NS
	Mean	193.32±5.41	188.54±4.44	199.41±4.91	199.35±4.52			
	Male	6.20±0.19	5.93±0.19^{B}	6.34±0.19	6.40±0.19^{B}			
$ADWG_1$	Female	6.28±0.19	6.70±0.19^{A}	6.23±0.21	7.13±0.19^{A}	*	**	*
	Mean	6.24±0.21^{b}	6.32±0.20^{b}	6.29±0.21^{b}	6.77±0.19^{a}			
	Male	5.06±0.27^{B}	4.89±0.28^{B}	5.21±0.28	5.26±0.28			
$ADWG_2$	Female	5.64±0.27^{A}	5.41±0.27^{A}	5.73±0.30	5.55±0.28	NS	*	NS
	Mean	5.35±0.28	5.15±0.28	5.47±0.30	5.41±0.28			
	Male	2.72±0.32^{B}	2.94±0.33^{B}	3.64±0.33^{B}	3.01±0.32^{B}			
$ADWG_3$	Female	5.48±0.32^{A}	3.83±0.32^{A}	4.03±0.35^{A}	4.26±0.33^{A}	NS	***	**
	Mean	4.10±0.34	3.39±0.33	3.84±0.35	3.64±0.33			
	Male	2.19±0.37	1.39±0.38^{B}	1.85±0.38^{B}	2.01±0.38^{B}			
$ADWG_4$	Female	2.06±0.37	3.20±0.37^{A}	4.37±0.41^{A}	3.47±0.38^{A}	*	***	**
	Mean	2.13±0.37^{cb}	2.30±0.38^{b}	3.11±0.39^{a}	2.74±0.38^{ab}			
	Male	4.05±0.16^{B}	3.79±0.16^{B}	4.27±0.16^{B}	4.24±0.16^{B}			
TBWG	Female	4.87±0.16^{A}	4.79±0.16^{A}	5.08±0.18^{A}	5.11±0.16^{A}	NS	***	NS
	Mean	4.46±0.16	4.29±0.16	4.68±0.18	4.67±0.16			

^{a,b}: Shows the difference between groups for a feature in the same row. ^{A,B}: Expresses the difference between males and females for a feature in the same column; SBW: Starting body weight; BW: Body weight; ADWG: Average daily weight gain: TBWG: Total body weight gain between days 1 and 35; 1-4: Shows the weighing order; SFO: Safflower oil; NS: Not Significant; (: P<0.05, **: P<0.01, ***: P<0.001).

Feed consumptions and feed conversion ratio were given in Table 3. There was no significant difference in the first and second weeks of feed consumptions and feed conversion ratio between the groups and between genders within the group (P>0.05). In the third and fourth weeks, significant differences in feed consumption and feed conversion ratio between genders were observed (P<0.05). Considering the total feed consumption and general feed conversion ratio characteristics, there was no significant difference between the groups, but highly significant differences were observed between genders.

Table 3. The effect of safflower oil on feed consumption and feed conversion ratio of quails

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
	Male	7.63±0.46^{A}	7.15±0.47^{A}	5.86±0.48	6.89±0.47			
FC_1	Female	4.57±0.46^{B}	5.75±0.46^{B}	5.39±0.51	5.07±0.47	NS	NS	NS
	Mean	6.10±0.46	6.45±0.47	5.63±0.50	5.98±0.47			
	Male	10.26±1.45	13.28±1.49^{A}	14.34±1.50^{A}	9.73±1.48			
FC_2	Female	11.86±1.46	9.26±1.45^{B}	6.11±1.62^{B}	7.26±1.49	NS	NS	NS
	Mean	11.06±1.46	11.27±1.48	10.23±1.60	8.50±1.49			
	Male	17.32±0.57^{B}	17.04±0.59	17.96±0.59^{B}	17.78±0.58			
FC_3	Female	19.01±0.58^{A}	18.13±0.57	19.67±0.64^{A}	18.77±0.59	NS	*	*
	Mean	18.17±0.58	17.59±0.59	18.82±0.65	18.28±0.59			
	Male	4.29±0.10	4.49±0.10^{A}	4.19±0.10	4.22±0.10			
FC_4	Female	3.90±0.10	3.86±0.10^{B}	3.87±0.11	3.67±0.10	**	***	*
	Mean	4.10±0.10	4.18±0.10	4.03±0.11	3.95±0.10			
	Male	7.63±0.46^{A}	7.15±0.47^{A}	5.86±0.48	6.89±0.47			
FCR_1	Female	4.57±0.46^{B}	5.75±0.46^{B}	5.39±0.51	5.07±0.47	NS	NS	**
	Mean	6.10±0.46	6.45±0.47	5.63±0.50	5.98±0.47			
	Male	10.26±1.45	13.28±1.49^{A}	14.34±1.50^{A}	9.73±1.48			
FCR_2	Female	11.86±1.46	9.26±1.45^{B}	6.11±1.62^{B}	7.26±1.49	NS	NS	NS
	Mean	11.06±1.46	11.27±1.48	10.23±1.60	8.50±1.49			
	Male	17.32±0.57^{B}	17.04±0.59	17.96±0.59^{B}	17.78±0.58			
FCR_3	Female	19.01±0.58^{A}	18.13±0.57	19.67±0.64^{A}	18.77±0.59	NS	***	NS
	Mean	18.17±0.58	17.59±0.59	18.82±0.65	18.28±0.59			
	Male	4.29±0.10	4.49±0.10^{A}	4.19±0.10	4.22±0.10			
FCR_4	Female	3.90±0.10	3.86±0.10^{B}	3.87±0.11	3.67±0.10	NS	**	*
	Mean	4.10±0.10	4.18±0.10	4.03±0.11	3.95±0.10			
	Male	7.63±0.46^{A}	7.15±0.47^{A}	5.86±0.48	6.89±0.47			
AFC	Female	4.57±0.46^{B}	5.75±0.46^{B}	5.39±0.51	5.07±0.47	NS	**	NS
	Mean	6.10±0.46	6.45±0.47	5.63±0.50	5.98±0.47			
	Male	10.26±1.45	13.28±1.49^{A}	14.34±1.50^{A}	9.73±1.48			
AFCR	Female	11.86±1.46	9.26±1.45^{B}	6.11±1.62^{B}	7.26±1.49	NS	***	NS
	Mean	11.06±1.46	11.27±1.48	10.23±1.60	8.50±1.49			

^{a,b}: Shows the difference between groups for a feature in the same row. ^{A,B}: Expresses the difference between males and females for a feature in the same column; FC: Feed consumption; FCR: Feed conversion ratio; AFC: Average feed consumption between days 1 and 35; AFCR: Average feed conversion ratio between days 1 and 35; 1-4: Shows the weighing order; SFO: Safflower oil; NS: Not Significant; (: P<0.05, **: P<0.01, ***: P<0.001).

The effect of safflower oil on slaughter and carcass piece weights of quails is given in Table 4. There were significant differences between the genders within the group in terms of body weights and carcass weights on the slaughter day. Differences between the weights of the hip and the wing when the carcass part weights were viewed between the groups were remarkable.

Table 4. The effect of safflower oil on slaughter and carcass piece weights of quails (g).

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
BWS	Male	179.60±7.30^{B}	169.47±7.30^{B}	182.84±7.30^{B}	191.72±7.30^{B}			
	Female	203.92±7.30^{A}	201.27±7.30^{A}	212.14±7.30^{A}	216.40±7.30^{A}	NS	***	NS
	Mean	191.76±5.89	185.38±6.77	197.49±7.78	204.06±6.23			
CW	Male	119.72±4.87	110.68±4.87^{B}	113.22±4.87^{B}	123.79±4.87			
	Female	124.33±4.87	121.69±4.87^{A}	129.76±4.87^{A}	125.11±4.87	NS	*	NS
	Mean	122.03±3.14	116.19±3.20	121.49±4.74	124.45±3.36			
Back	Male	36.72±2.76	36.44±2.76	36.67±2.76	38.77±2.76			
	Female	39.58±2.76	40.95±2.76	42.20±2.76	37.34±2.76	NS	NS	NS
	Mean	38.15±1.82	38.69±1.90	39.44±2.22	38.05±1.86			
Chest	Male	43.25±2.17	40.55±2.17	41.21±2.17	43.07±2.17			
	Female	44.34±2.17	43.87±2.17	44.95±2.17	43.72±2.17	NS	NS	NS
	Mean	43.80±1.06	42.21±1.18	43.08±2.02	43.40±1.58			
Hip	Male	26.60±1.24	25.68±1.24	25.92±1.24^{B}	30.06±1.24			
	Female	26.11±1.24	27.55±1.24	31.72±1.24^{A}	30.09±1.24	*	**	NS
	Mean	26.36±0.79^{b}	26.62±0.70^{b}	28.82±1.21^{ab}	30.07±0.87^{a}			
Wing	Male	7.09±0.43	6.25±0.43	7.28±0.43	9.03±0.43			
	Female	6.81±0.43	6.22±0.43	8.42±0.43	8.34±0.43	***	NS	NS
	Mean	6.95±0.22^{bc}	6.24±0.21^{c}	7.85±0.31^{ab}	8.68±0.43^{a}			
Liver	Male	3.90±0.58	3.02±0.58^{B}	3.56±0.58^{B}	3.90±0.58^{B}			
	Female	4.08±0.58	4.36±0.58^{A}	6.24±0.58^{A}	5.82±0.58^{A}	NS	***	NS
	Mean	3.99±0.30	3.69±0.33	4.90±0.71	4.86±0.50			
Gizzard	Male	4.74±0.27	4.72±0.27	4.67±0.27^{A}	3.59±0.27^{B}			
	Female	4.62±0.27	4.90±0.27	4.05±0.27^{B}	5.25±0.27^{A}	*	***	**
	Mean	4.68±0.19^{ab}	4.81±0.17^{ab}	4.36±0.28^{a}	4.42±0.35^{b}			
Heart	Male	1.53±0.17	1.63±0.17	1.91±0.17	1.58±0.17			
	Female	1.69±0.17	1.71±0.17	1.75±0.17	1.79±0.17	NS	NS	NS
	Mean	1.61±0.09	1.67±0.06	1.83±0.15	1.68±0.14			

a,b: Shows the difference between groups for a feature in the same row. A,B: Expresses the difference between males and females for a feature in the same column; BWS: Body weight on slaughter day; CW: Carcass weight; SFO: Safflower oil; NS: Not Significant; *: P<0.05; **: P<0.01; ***: P<0.001

The highest hip weight was found to be 30.07±0.87 g in the 0.3% safflower oil group, which was significantly higher (P<0.05) than those of the control group (26.36±0.79 g). Similarly, in terms of wing weight, the highest values were determined in the 0.3% safflower oil group with an average of 8.68±0.4 g. The difference between the control group (6.95±0.22 g) and this group was found to be highly significant (P<0.001). Parameters related to breast meat quality and color characteristics of quails were given in Table 5 and Table 6, respectively. The addition of SFO to the diet did not result in significant differences in these properties except for cooking loss at 24th hour.

Table 5. The effect of safflower oil on breast meat quality characteristics

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
pH_1	Male	6.46±0.05	6.49±0.05	6.59±0.05	6.47±0.05			
	Female	6.43±0.05	6.43±0.05	6.47±0.05	6.54±0.05	NS	NS	NS
	Mean	6.45±0.03	6.46±0.03	6.53±0.03	6.51±0.03			
pH_{24}	Male	5.91±0.05	6.00±0.05	5.95±0.05	5.91±0.05			
	Female	5.94±0.05	5.84±0.05	5.93±0.05	5.88±0.05	NS	NS	NS
	Mean	5.93±0.03	5.92±0.03	5.94±0.03	5.89±0.03			
DL_{24}	Male	0.97±0.19	1.28±0.19	1.32±0.19	1.11±0.19			
	Female	0.97±0.19	1.12±0.19	1.18±0.19	1.06±0.19	NS	NS	NS
	Mean	0.97±0.14	1.20±0.14	1.25±0.14	1.08±0.14			
WHC_{24}	Male	22.80±2.88	26.40±2.88	28.40±2.88	22.40±2.88			
	Female	23.20±2.88	24.00±2.88	24.00±2.88	22.40±2.88	NS	NS	NS
	Mean	23.00±2.04	25.20±2.04	26.20±2.04	22.40±2.04			
CL_{24}	Male	27.40±0.88	24.68±0.88	24.84±0.88	28.72±0.88^{A}			
	Female	25.12±0.88	24.32±0.88	26.45±0.88	24.24±0.88^{B}	NS	*	*
	Mean	26.26±0.62	24.50±0.62	25.65±0.62	26.48±0.62			

A,B: Expresses the difference between males and females for a feature in the same column; pH1: First hour pH value; pH24: Twenty-fourth hour pH value; DL24: Twenty-fourth hour drip loss value; WHC24: Twenty-four hour water holding capacity value; CL24: Twenty-fourth hour cooking loss value; SFO: Safflower oil; NS: Not Significant; *: P<0.05.

The changes in total antioxidant status and oxidative stress properties based on the levels of safflower oil were presented in Table 7. It was determined that total oxidative status and total antioxidant status values of quails were significantly affected by the levels of SFO. Significantly higher total antioxidant status values (P<0.01) were observed in SFO groups, while the control group showed higher total oxidative status values (P<0.05).

Table 6. Effect of safflower oil on breast meat color characteristics.

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
	Male	45.37±0.58	44.62±0.58	44.67±0.58	45.04±0.58			
L*[1]	Female	44.81±0.58	45.65±0.58	44.72±0.58	44.62±0.58	NS	NS	NS
	Mean	45.09±0.44	45.13±0.43	44.69±0.28	44.83±0.41			
	Male	45.27±0.94	43.78±0.94	45.11±0.94	46.58±0.94			
L*[24]	Female	44.44±0.94	45.74±0.94	42.37±0.94	45.50±0.94	NS	NS	NS
	Mean	44.86±0.61	44.76±0.80	43.74±0.68	46.04±0.67			
	Male	8.31±0.32	8.48±0.32	7.94±0.32	7.91±0.32			
a*[1]	Female	8.34±0.32	7.79±0.32	7.94±0.32	7.85±0.32	NS	NS	NS
	Mean	8.33±0.30	8.13±0.25	7.94±0.16	7.88±0.14			
	Male	7.95±0.24	8.03±0.24	7.80±0.24	7.28±0.24			
a*[24]	Female	7.87±0.24	7.69±0.24	7.48±0.24	7.47±0.24	NS	NS	NS
	Mean	7.91±0.19	7.86±0.18	7.64±0.16	7.37±0.14			
	Male	11.48±0.35	11.61±0.35	10.87±0.35	11.56±0.35			
b*[1]	Female	10.95±0.35	11.74±0.35	11.74±0.35	11.83±0.35	NS	NS	NS
	Mean	11.21±0.26	11.68±0.23	11.31±0.21	11.70±0.30			
	Male	11.07±0.30	11.10±0.30	11.13±0.30	11.24±0.30			
b*[24]	Female	10.43±0.30	11.55±0.30	11.40±0.30	11.36±0.30	NS	NS	NS
	Mean	10.75±0.18	11.33±0.17	11.27±0.20	11.30±0.27			

L*[1]: First hour brightness value; L*[24]: Twenty-fourth hour brightness value; a*[1]: First hour redness value, a*[24]: Twenty-fourth hour redness value; b*[1]: First hour yellowness value; b*[24]: Twenty-fourth hour yellowness value; SFO: Safflower oil; NS: Not Significant.

Table 7. The effect of safflower oil on stress parameters of quails.

	Gender	Control	0.1% SFO	0.2% SFO	0.3% SFO	Group	Gender	Interaction
	Male	1.40±0.17	1.94±0.17	2.15±0.17	2.04±0.17			
TAS (mmol Trolox equiv/L)	Female	1.55±0.17	2.05±0.17	2.04±0.17	1.94±0.17	**	NS	NS
	Mean	1.47±0.12[a]	2.00±0.12[b]	2.09±0.12[b]	1.99±0.12[b]			
	Male	14.39±0.84	11.86±0.84	11.15±0.84	11.00±0.84			
TOS (µmol H_2O_2 quiv/L)	Female	13.88±0.84	13.00±0.84	12.52±0.84	12.53±0.84	*	NS	NS
	Mean	14.14±0.59[a]	12.43±0.59[b]	11.84±0.59[b]	11.76±0.59[b]			
	Male	1.03±0.10	0.62±0.10	0.52±0.10	0.56±0.10			
OSI Index	Female	0.92±0.10	0.65±0.10	0.72±0.10	0.70±0.10	***	NS	NS
	Mean	0.98±0.07[a]	0.63±0.07[b]	0.62±0.07[b]	0.63±0.07[b]			
	Male	57.52±2.93	48.83±2.93	47.62±2.93	48.02±2.93			
LOOH (µmol/L)	Female	56.36±2.93	44.95±2.93	50.58±2.93	46.84±2.93	**	NS	NS
	Mean	56.94±2.07[a]	46.89±2.07[b]	49.10±2.07[b]	47.43±2.07[b]			
	Male	133.60±8.62	101.92±8.62	78.60±8.62	83.93±8.62			
AOPP (µmol/L)	Female	122.84±8.62	82.36±8.62	85.12±8.62	80.70±8.62	***	NS	NS
	Mean	128.22±6.10[a]	92.14±6.10[b]	81.86±6.10[b]	82.31±6.10[b]			
	Male	0.36±0.03	0.38±0.03	0.41±0.03	0.45±0.03			
THIOL (µmol/L)	Female	0.37±0.03	0.38±0.03	0.43±0.03	0.47±0.03	**	NS	NS
	Mean	0.36±0.02[b]	0.38±0.02[b]	042±0.02[ab]	0.46±0.02[a]			

a-c: Shows the difference between groups on the same row. TAS: Total antioxidant status; TOS: Total oxidative status; OSI: Oxidative stress index; LOOH: Total peroxides; AOPP: Advanced oxidation protein products; THIOL: Total thiol groups; SFO: Safflower oil; NS: Not Significant; *: P<0.05; **: P<0.01; ***: P<0.001.

DISCUSSION AND CONCLUSION

In the study, it was observed that there was a significant (P<0.05) difference between the treatment groups in terms of body weight only in the first week, while gender affected body weight significantly (P<0.01) during all weeks. In terms of daily body weight gain, there was a significant difference between the treatment groups in the first and fourth weeks (P<0.05), while gender significantly affected daily weight gain in all weeks (P<0.01). Addition of SFO at different levels did not affect total body weight gain whereas the effect of gender on daily weight gain was significant throughout the experiment (P<0.01). Similar to the present study, Kara and Bulbul (17) determined that the addition of soy, sunflower, safflower, and olive oil to the quail ratios did not change the live weights, live weight gain, feed consumption, and feed efficiency (P>0.05). Also Amer et al. (15) reported that the safflower oil levels (0%, 1% and 5%) had no significant effect on the body weight gain, body weight, feed conversion ratio and feed intake of broiler chickens (P>0.05). Similarly Ferreira et al. (20) investigated the intake, performance, carcass characteristics and meat quality of lambs fed finishing feeds containing 0%, 7.5% and 15% safflower seeds instead of corn and soybean meal.

They reported that adding safflower seeds to the rations of lambs did not affect performance and carcass characteristics.

As numerous studies have shown female Japanese quails have higher body and carcass weights than males, which is characteristics of this species (32,33).

Significant interactions detected between the treatment and gender groups for body weight, daily body weight gain and feed conversion ratio in different measuring time points indicates different responsiveness of female and male quails to different levels of SFO at different stages of development.

As a source of energy there is no difference between plant oils and animal fats in terms of live weight, feed consumption (34), or feed conversion ratio (35) in broilers. As well as the plant oil types included in the diet of broilers do not have a significant effect on live weight, feed consumption, and feed efficiency (36). Because iso-energic diets were used in this study one would not expect any difference in growth parameters because of plant oil type used.

Statistical differences were found between the groups in terms of hip and wing weights in male and female quails at the end of this study. Gizzard weights showed significant differences among groups. Similarly, it was reported that the addition of thyme oil to the diet of broiler chickens increased the ratio of gizzard and breast meat relative to body weight and did not affect the body weight, carcass weight, and sensory properties of meat (37). Similarly, it was stated that the addition of cinnamon oil at different doses (500 and 1000 mg/kg) to broiler diets did not cause any differences in performance and carcass characteristics (38). In the present study, the decrease in gizzard weight in the 0.2% safflower oil group may be because of an improve in the digestibility of nutrients and a decrease the load on the gizzard (39).

The color of meat is an important issue for consumer choices, and it is a desired feature that the meat does not lose its special color values during storage on market shelfs. Myoglobin and hemoglobin pigments that form the natural color of meat are very sensitive to oxidation (40). In this study, no significant differences were observed among the groups in terms of meat quality characteristics (pH, drip loss, and water holding capacity) and breast meat color characteristics (L*, a*, and b* values) (Tables 5-6). The results were similar to studies using medicinal aromatic plants and their extracts, which reported no effect on meat color and pH values (41). On the other hand, some studies have reported that various aromatic plants have effects on meat color and pH (42). Addition of SFO into quail diet significantly improved TAS and decreased TOS as well as oxidative stress index (OSI) without any effect of gender. Total peroxides advanced oxidation protein products and total thiol groups were also affected by SFO addition (43). Studies have reported that lipid oxidation in poultry meat (44) and serum (45) can be prevented by adding aromatic plant extracts containing phenolic compounds with antioxidant properties (46). The reason for the significant differences might be attributed to the high content of SFO in bioactive molecules having antioxidant properties such as polyphenolic compounds (10-12).

In the present study, the total oxidative status values in the groups having SFO were decreased compared to the control group along with the increasing SFO level in the diet. Similar results have been found by Doğan Daş et al. (47) using peppermint oil in Japanese quails. Doğan Daş et al. (47) found that the oxidative stress index values such as TAS and TOS, in quail groups consuming diets added with peppermint oil were significantly (P<0.01) higher than the control group. Similar to SFO, peppermint oil had a high tocopherol content in addition to polyphenols which may be important for the establishment of a sufficient defense against oxidative stress in quails. On the other hand, Ali et al. (48) reported that various essential oils have different effects on growth performance, meat quality and oxidative stress in poultry. In addition, the researchers reported that the dose ratio was effective in addition to geographical origin, sowing/harvest time, environmental conditions.

The addition of safflower oil to the diet of quail consisted in similar results to the control group on fattening performance, meat quality, and color characteristics. The total oxidative status, however, decreased as the ratio of safflower oil increased in the diet. It also increased the total antioxidant status in blood. For this reason, it is thought that adding safflower oil to quail diets will be beneficial. Although the safflower oil literature is limited in quail, further research is needed regarding the dose rate and possible mechanisms of action.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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