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Carcass characteristics and meat quality assessment in different quail lines fed on canola seed supplemented diets

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ABSTRACT

The effect of dietary supplementation with canola seed on carcass and meat quality characteristics in three quail lines was studied. Ninety quails aged 4-weeks were selected from three lines (white, black and brown) and randomly allocated to 3 feeding groups. One group was fed a basal diet as control, while the other two groups were fed on basal diet with 1 or 3% canola seed supplementation. Quails were slaughtered at 10 weeks of age. At 24 h postmortem, breast and thigh meat samples were separated; vacuum packaged and stored at -40°C until meat quality analyses. Results showed that carcass characteristics did not differ ($P>0.05$) between dietary treatments. However, the inclusion of canola seed increased ($P<0.05$) the concentration of total omega-3 fatty acid in meat and decreased widely the omega-6: omega-3 ratio compared to the control diet. Feeding 3% canola seeds decreased the level of malondialdehyde (MDA) in the breast and thigh muscles of quails at day 5 of post-mortem. Regardless of dietary treatments, no carcass and meat quality characteristics except carcass weight differed between 3 quail lines. Brown quails exhibited significantly higher ($P<0.05$) carcass weight than white and black ones. These results indicate that feeding canola seed might modify meat fatty acid profile with better shelf life during postmortem aging. Likewise, due to high carcass weight, brown quail lines may be preferred for meat production purposes.

Key words: Canola seed, Carcass traits, Meat quality, Quail

Over the past millennium, the poultry industry has revolved rapidly from backyard household production to highly sophisticated commercial production systems (Mnisi and Mlambo 2017). The industry continues to advance with the addition of new bird species, such as the Japanese quail, to complement the existing species. Despite being a relatively recent addition to the world poultry industry, quail farming already makes a significant contribution of high quality protein to the human diet (Khosravi *et al.* 2016). Resistance to various diseases, attainment of sexual maturity at only 6 weeks of age and easy adaptation to various rearing conditions make quail farming economically and technically feasible. Nonetheless, the foremost challenge in the long-term sustainability of quail production remains the cost of dietary protein and the supply of essential amino acids (Rezaeipour *et al.* 2016). Quails require high quality dietary protein; which increases the cost of their feed thus the inclusion of canola seed by some producers so as to reduce the costs. Containing approximately 400 g/kg oil and 210–230 g/kg protein makes canola seed an attractive feed ingredient for poultry. The seed has a valuable amino acid composition, with a high content of essential amino acids such as lysine, threonine, tryptophan and sulphur amino

acids (Khaouchene *et al.* 2016). Additionally, canola seed is the main source of α -linolenic acid of terrestrial origin. This fatty acid is the precursor for the synthesis of eicosapentaenoic acid (EPA 20:5n-3) and docosahexaenoic acid (DHA 22:6n-3), which play a major role in the control of cardiovascular diseases and in neural and retinal development. Consumption of n-3 polyunsaturated fatty acids has a positive influence on the immune function, blood pressure, cholesterol and triglyceride levels, in addition to cardiovascular function in humans. Recently, as a result of a number of factors including an improved balance of fatty acid composition and the need for an economical source of energy and protein, interest has developed in the use of canola seeds in broiler chicken diets. However, there is dearth of information regarding the effects of dietary canola seed supplementation on carcass traits and tissue fatty acids in quails. Consequently, this study was conducted to determine the effect of dietary supplementation with canola seed on carcass characteristics and meat quality in three local quail lines.

MATERIALS AND METHODS

Birds and diets: The study was conducted following Ethics and Animal welfare committee guidelines at Animal Resource, Faculty of Agriculture, Salahaddin University-Erbil, Iraq. Ninety female quails aged 4-weeks and belonging to three lines (white, black and brown) were obtained from a commercial farm (Quail Farming,

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Qushtapa, Erbil-Kurdistan Region of Iraq) and randomly allocated to 18 replicate cages (experimental units), with each cage (50 cm×30 cm×30 cm) carrying 5 birds. The three dietary treatments were randomly allocated to the cages (2 replicate cages per diet per line). The quails were allowed to adapt to the cages and diets for a week before the experiment commenced and they were reared until 10 weeks of age. The dietary treatments were as follows: CS0 (control), basal diet with no canola seed inclusion; CS1, basal diet with 1% of canola seed inclusion and CS3, basal diet with 3% of canola seed inclusion. The composition of the basal diet is shown in Table 1. Feed and fresh water were provided *ad lib* throughout the study. Floor feeders and nipple drinkers were used for feeding and drinking, respectively. A 24-h lighting plan was implemented using

Table 1. Meatball Formulations

Ingredient (%)	Treatments			
	CM	M1	M2	M3
Minced Lean Pork	70%	69%	68.5%	68.0%
Rice Bran Oil	7.0%	7.0%	7.0%	7.0%
Ice Flakes	8.70%	8.70%	8.70%	8.70%
Salt	1.6%	1.6%	1.6%	1.6%
Tripolyphosphate	0.3%	0.3%	0.3%	0.3%
Sugar	0.3%	0.3%	0.3%	0.3%
Dry Spice Powder	1.8%	1.8%	1.8%	1.8%
Condiment mixture	4.0%	4.0%	4.0%	4.0%
Refined Wheat Flour	3.0%	3.0%	3.0%	3.0%
Egg Albumin	1.285%	1.285%	1.285%	1.285%
Sodium Nitrite	0.015%	0.015%	0.015%	0.015%
Starfruit Powder	0%	1.0%	1.5%	2.0%

natural light and fluorescence lights during the day and night, respectively. A temperature of 20–24°C with relative humidity between 50% and 60% was maintained throughout the experimental period. The average feed intake was almost the same for control diet (25.7, 25.6 and 25.4 g/day for white, black and brown, respectively), diet supplemented with 1% of canola seed (24.5, 24.3 and 24.2 g/day for white, black and brown, respectively) and diet supplemented 3% of canola seed (25.6, 25.4 and 25.3 g/day for white, black and brown, respectively).

Slaughter procedure and carcass traits assessment: At 10 weeks of age, 6 female quails from each line per diet were randomly selected and weighed prior to slaughter. The slaughter process was conducted at the Department of Animal Science, Faculty of Agriculture, Salahaddin University-Erbil. The birds were slaughtered following the halal slaughter procedure. The process involved severing the carotid artery, jugular vein, trachea and esophagus. After evisceration, carcasses were immediately taken to the laboratory for carcass assessment. Dressed carcasses were weighed (hot carcass weight; HCW) within 45 min postmortem, chilled at 4°C for 24 h and reweighed (cold carcass weight; CCW). Chilling loss was estimated as the difference between hot and cold carcass weight, expressed

as percentage. The dressing out percentage was determined as the proportion of HCW and CCW to the slaughter weight. For meat quality characteristics, the breast muscle was separated into two parts. The first part was properly labeled, vacuum packaged and stored at 4°C for determination of drip loss. The second portion was stored at –40°C until subsequent determination of other meat quality such as pH, cooking loss, shear force, chemical composition, lipid oxidation, and omega-3 and omega-6 fatty acids.

Meat pH determination: The pH of meat was recorded immediately after 24 h postmortem on the breast muscle using a portable pH meter (HANNA® instruments, Woonsocket, United States) following the method described by Abdulla *et al.* (2017).

Determining water holding capacity and meat tenderness: The water holding capacity of the breast samples were evaluated by measuring cooking and drip losses following the procedure Sabow *et al.* (2016). After determination of cooking losses, replicate of blocks of 1 cm (height) × 1 cm (width) × 2 cm (length) were cut from each breast sample parallel to the direction of the muscle fibres and each block was sheared in the center perpendicular to the longitudinal direction of the fibres to determine tenderness using a Brookfield Texture Analyzers (CT3™, USA). The reported value represented the average peak positive peak force (kg) of all blocks value of each individual sample.

Proximate analysis: Proximate composition of the breast and thigh meat was determined following the procedures of Abdulla *et al.* (2017). Moisture was determined using the oven method. Crude protein was determined by the Kjeldahl method. The crude protein was obtained as 6.25 × N%. Fat content of the meat was determined by Soxhlet extraction method using petroleum ether. Ash content of the meat was determined by igniting the sample in a muffle furnace at 550°C for 3 h.

Determination of thiobarbituric acid reactive substances (TBARS): TBARS of the breast and thigh meat were determined according to the method of Aminzade *et al.* (2012) with some modification. Ground meat (5 g) was homogenized for 2 min with 48 ml of distilled water and 1.25 ml of 4N HCl. The mixture was distilled until 25 ml was obtained. Then, 2.5 ml of the distillate and 2.5 mL of TBA reagent (15% trichloroacetic acid, 0.375% thiobarbituric acid) were heated in a boiling water bath for 35 min. After cooling under running tap water for 10 min, the absorbance was measured at 538 nm against a blank with a spectronic®20 GENESYS™ spectrophotometer (Spectronic instruments, USA). TBARS values were obtained by multiplying optical density by 7.843. Oxidation products were quantified as malondialdehyde equivalents (mg MDA per kg meat).

Determination of Omega-3 and omega-6 fatty acids: The total lipid in breast meat samples was extracted in chloroform: methanol (2:1, v/v) mixture following the method of Kinsella *et al.* (1977). The omega-3 and omega-6 fatty acids were converted to their fatty acid methyl esters

(FAME) using 0.5 M NaOH in methanol and 12% methanolic boron trifluoride (BF₃) following the method described by Joseph and Ackman (1992). The FAME was separated in a gas chromatograph (Hitachi mark) equipped with a flame ionization detector (FID) and a splitless injector. The column used was fused silica capillary (Acclaim™ C18, 250 mm × 3 mm ID, 3 µm film thickness). High purity nitrogen was used as the carrier gas at 1 ml/min. Compressed air and high purity hydrogen were used for the FID in the chromatograph.

Statistical analysis: Data were analyzed by two-way analysis of variance (ANOVA) to evaluate strains and canola seed supplementation on selected quality of carcass characteristics and meat in quails. General liner model procedure was applied in SAS (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA) statistical software package. Means were separated by Duncan's multiple range test at significance level of 0.05. Results were presented as mean±standard error.

RESULTS AND DISCUSSION

Carcass Characteristics: Data presented in Table 2 shows the effect of dietary canola seed supplementation on carcass parameters of three local quail lines. There were no significant dietary effects ($P > 0.05$) on slaughter weight, carcass yield, chilling loss and dressing percentage. However, quails fed basal diet supplemented with 1 or 3% of canola seed had higher carcass characteristics compared to those fed the basal diet with no canola seed inclusion. These findings are in agreement with the report of Khaouchene *et al.* (2016) and Saleh *et al.* (2015) in broiler chicken, where carcass characteristics of broiler chickens

were not influenced by various levels of canola seed. Upon examining quality characteristics of carcass collected from quails from different lines, the differences between line groups were significant ($P < 0.05$) as the brown line exhibited higher values for carcass weight than the white and black lines. This could be most likely due to differences in slaughter body weight which is influenced by recessive gene action. In terms of slaughter body weight, brown quails were significantly heavier than the black and white quails. Additionally, the differences in some carcass traits among the quail lines fed on the same diet, under similar farm conditions may be attributed to various factors with high heritability. Inci *et al.* (2015) indicated that recessive-gene action has a depressive effect on quail body weight. The results of the present study are in line with those of Inci *et al.* (2015) and Sogut *et al.* (2015) who found that carcass characteristics were significantly different among quails with different feather colours. In this study, no significant line × dietary interaction occurred for carcass parameters (Table 2).

Meat quality traits: The effect of dietary treatments on meat quality characteristics of breast muscles from the different quail lines measured 24 h post slaughter are shown in Table 3.

The quails fed the basal diet supplemented with canola seed exhibited the same ($P > 0.05$) water holding capacity and shear force values as those fed basal diet with no canola seed inclusion. The similarity in drip loss, cooking loss and shear force could perhaps be due to the similarity in ultimate pH (pH_{24 h}) across the treatment groups. Ultimate pH of breast meat did not significantly differ between quails fed control and experimental diets. The ultimate pH is an

Table 2. Carcass traits of three local quail lines fed diet of canola seed supplementation

Parameter	Line	Treatment			P value		
		CS0	CS1	CS3	Treatment	Line	Treatment × Line
Slaughter weight (g)	White	212.25±16.91 ^y	218.00±19.13 ^y	237.75±16.93 ^y	0.820	0.015	0.681
	Black	216.00±20.70 ^y	220.25±15.22 ^y	224.75±19.98 ^z			
	Brown	239.00±15.26 ^x	242.25±26.02 ^x	242.00±15.30 ^x			
Hot carcass weight (g)	White	138.00±13.24 ^y	142.00±6.17 ^y	151.75 12.44 ^y	0.717	0.011	0.453
	Black	138.50±13.02 ^y	148.75±17.38 ^y	150.00±13.78 ^y			
	Brown	157.75±7.71 ^x	160.00±7.25 ^x	164.75 17.23 ^x			
Cold carcass weight (g)	White	136.89±6.53 ^y	140.32±3.27 ^y	150.06±2.57 ^y	0.722	0.013	0.464
	Black	137.25±4.01 ^y	147.27±7.00 ^y	148.08±3.45 ^y			
	Brown	156.70±0.65 ^x	158.72±17.01 ^x	163.20±7.83 ^x			
Chilling loss (%)	White	1.11±0.21	1.69±0.27	1.68±0.41	0.677	0.853	0.335
	Black	1.25±0.45	1.48±0.39	1.92±0.55			
	Brown	1.55±0.37	1.04±0.26	1.28±0.31			
Dressing percentage [#]	White	65.01±1.75	65.13±1.85	63.82±4.14	0.862	0.358	0.411
	Black	64.12±3.33	67.53±1.80	66.74±1.64			
	Brown	66.00±2.81	66.04±1.32	68.07±1.83			
Dressing percentage [§]	White	64.49±1.85	64.36±1.87	63.11±4.00	0.907	0.336	0.376
	Black	63.54±3.09	66.86±1.98	65.88±1.36			
	Brown	65.56±2.79	65.61±1.47	67.43±1.94			

CS0 (control), basal diet with no canola seed inclusion; CS1, basal diet with 1% of canola seed inclusion and CS3, basal diet with 3% of canola seed inclusion.[#]Hot carcass weight / Slaughter weight × 100. [§]Cold carcass weight / Slaughter weight × 100.

^{x,y}Means in the same column with different letters are significantly different at $P < 0.05$.

important factor which influences the physical and chemical traits of meat. The observed similarity in meat physicochemical properties (Table 3) is in agreement with the findings of Choi *et al.* (2016) who reported a similarity between different Japanese quail lines for ultimate muscle

pH and water holding capacity in terms of drip loss and cooking loss. Repeated measures analysis showed no significant ($P>0.05$) diet \times line interaction effect on quality characteristics of meat (Table 3).

Nutritional composition: With the exception of fat

Table 3. Meat physicochemical properties of three local quail lines fed diet of canola seed supplementation

Parameter	Line	Treatment			P value		
		CS0	CS1	CS3	Treatment	Line	Treatment \times Line
pH (unit)	White	5.90 \pm 0.13	5.87 \pm 0.16	5.87 \pm 0.13	0.069	0.909	0.811
	Black	6.02 \pm 0.19	5.97 \pm 0.21	5.96 \pm 0.16			
	Brown	5.92 \pm 0.08	5.89 \pm 0.14	5.87 \pm 0.11			
Drip loss (%)	White	1.43 \pm 0.22	1.53 \pm 0.22	1.65 \pm 0.15	0.973	0.861	0.733
	Black	1.64 \pm 0.25	1.71 \pm 0.03	1.66 \pm 0.11			
	Brown	1.75 \pm 0.14	1.72 \pm 0.18	1.61 \pm 0.12			
Cooking loss (%)	White	17.43 \pm 1.62	19.11 \pm 0.65	17.47 \pm 1.23	0.125	0.097	0.753
	Black	17.68 \pm 1.13	17.85 \pm 1.03	16.63 \pm 1.49			
	Brown	17.50 \pm 0.99	18.28 \pm 1.41	18.95 \pm 0.80			
Shear force (kg)	White	0.84 \pm 0.10	0.99 \pm 0.02	0.97 \pm 0.01	0.811	0.617	0.341
	Black	1.00 \pm 0.01	0.97 \pm 0.01	0.98 \pm 0.05			
	Brown	0.81 \pm 0.09	0.95 \pm 0.04	0.97 \pm 0.02			

CS0 (control), basal diet with no canola seed inclusion; CS1, basal diet with 1% of canola seed inclusion and CS3, basal diet with 3% of canola seed inclusion.

Table 4. Breast and thigh meat proximate composition of three local quail lines fed diet of canola seed supplementation

Parameter	Line	Treatments			P value		
		CS0	CS1	CS3	Treatment	Line	Treatment \times Line
<i>Breast meat chemical composition (%)</i>							
Moisture	White	71.51 \pm 2.11	70.44 \pm 2.52	70.18 \pm 2.61	0.389	0.617	0.515
	Black	70.93 \pm 2.32	70.51 \pm 2.22	70.42 \pm 1.89			
	Brown	70.25 \pm 1.97	70.06 \pm 2.03	70.37 \pm 1.74			
Protein	White	22.57 \pm 1.45	22.12 \pm 1.57	22.79 \pm 1.91	0.195	0.477	0.391
	Black	22.44 \pm 1.37	22.56 \pm 1.44	22.09 \pm 1.62			
	Brown	23.28 \pm 1.16	22.94 \pm 1.28	22.83 \pm 1.46			
Fat	White	3.03 \pm 0.27 ^b	3.40 \pm 0.30 ^{ab}	4.28 \pm 0.38 ^a	< 0.05	0.555	0.222
	Black	3.63 \pm 0.32 ^b	3.82 \pm 0.47 ^{ab}	4.50 \pm 0.32 ^a			
	Brown	3.47 \pm 0.50 ^b	4.00 \pm 0.41 ^b	5.16 \pm 0.55 ^a			
Ash	White	2.37 \pm 0.18	2.35 \pm 0.23	2.24 \pm 0.16	0.700	0.963	0.740
	Black	2.49 \pm 0.16	2.60 \pm 0.19	2.48 \pm 0.11			
	Brown	2.49 \pm 0.21	2.39 \pm 0.17	2.12 \pm 0.15			
<i>Thigh meat chemical composition (%)</i>							
Moisture	White	70.01 \pm 2.29	69.54 \pm 2.82	69.18 \pm 1.99	0.606	0.380	0.102
	Black	69.93 \pm 2.54	69.51 \pm 1.73	68.82 \pm 2.36			
	Brown	69.25 \pm 2.13	69.46 \pm 2.08	68.28 \pm 2.29			
Protein	White	22.27 \pm 1.77	22.40 \pm 1.68	22.09 \pm 1.37	0.341	0.119	0.401
	Black	22.14 \pm 1.58	22.56 \pm 1.72	22.39 \pm 1.55			
	Brown	22.88 \pm 1.75	22.94 \pm 1.91	22.53 \pm 1.62			
Fat	White	5.03 \pm 0.70 ^b	5.40 \pm 0.42 ^{ab}	5.98 \pm 0.43 ^a	< 0.05	0.178	0.512
	Black	5.13 \pm 0.63 ^b	5.32 \pm 0.33 ^b	6.00 \pm 0.39 ^a			
	Brown	5.07 \pm 0.54 ^b	5.03 \pm 0.61 ^b	6.66 \pm 0.51 ^a			
Ash	White	2.67 \pm 0.22	2.65 \pm 0.21	2.74 \pm 0.11	0.341	0.119	0.401
	Black	2.79 \pm 0.20	2.60 \pm 0.18	2.78 \pm 0.23			
	Brown	2.79 \pm 0.19	2.56 \pm 0.17	2.52 \pm 0.25			

CS0 (control), basal diet with no canola seed inclusion; CS1, basal diet with 1% of canola seed inclusion and CS3, basal diet with 3% of canola seed inclusion.

^{a-c} Means in the same row with different letters are significantly different at $P<0.05$.

^{x-z} Means in the same column with different letters are significantly different at $P<0.05$.

content, proximate compositions of breast and thigh meat samples are not significantly different ($P>0.05$) among the treatments (Table 4). The fat content in breast and thigh meat from quail fed basal diet with 3% of canola-seed supplementation was the highest ($P<0.05$) followed closely with a non-significant difference in 1% canola-seed supplementation group. The significantly higher fat content observed in the diets containing canola-seed as compared to the control group are in line with the reports of Saleh *et al.* (2015) in chickens.

In this study, feeding canola-seed diet improved significantly the total omega-3 fatty acids of the breast and thigh meat from different lines of quails though the total omega-6 fatty acids were not affected (Table 5). The concentration of n-3 fatty acids was higher in breast and thigh meat samples obtained from quails fed on basal diet with 3% canola seed supplementation followed by those fed on diet with 1% canola seed supplementation. The increase in total omega-3 fatty acids content in quail breast and thigh meat could be due to rich α -linolenic acid (C18:3 n-3) in canola seeds. Saleh *et al.* (2015) reported that α -linolenic acid was significantly increased by more than two-fold in the breast muscle of chickens fed diet containing canola seeds compared with the control. The high total omega-3 fatty acids observed in quails fed diet with canola seed supported the findings of Saleh *et al.* (2015) in chickens who reported that diets with canola seed were significantly effective in increasing omega-3 fatty acids in the breast muscle. The ratio of omega-6 to omega-3 was significantly

lower in the breast and thigh muscles of quails fed on canola seed; as a result of their relatively high concentrations of total omega-3 fatty acids. The current ratio of n-6 to n-3 fatty acids in the diets of North American adults ranges from 10:1 to 50:1, thus the ratios observed in this experiment fall within this range. The lower ratio observed in birds fed canola seed would therefore appear to be more desirable. Regardless of the treatment, the effect of the line variation on nutritional composition was insignificant. A similar trend was also reported by Tavaniello *et al.* (2017) who found no effect of different lines of Japanese quail on breast muscle total lipid content and fatty acid profiles. Repeated measures analysis showed no significant ($P>0.05$) diet \times line interaction effect on nutritional composition of breast and thigh meat proximate composition and omega-3 and omega-6 (Table 4 and 5).

Lipid stability of meat: The effects of dietary treatments on lipid oxidation (MDA values) of breast and thigh meat obtained from three different quail lines during refrigerated storage at 4 °C are given in Fig. 1.

In general, lipid oxidation values increased ($P<0.05$) with storage time, and are in line with other studies in broiler chicken (Khaouchene *et al.* 2016; Sohaib *et al.* 2017). No significant difference was observed in lipid oxidation of breast and thigh muscle at 1 d postmortem among experimental and control diets. The MDA concentrations increased in all breast and thigh meat samples during storage at 4°C, but samples collected from quails fed 3% canola seed supplementation had lower ($P<0.05$) MDA values than

Table 5. Breast and thigh meat polyunsaturated fatty acids of three local quail lines fed diet of canola seed supplementation

Parameter	Line	Treatments			P value		
		CS0	CS1	CS3	Treatment	Line	Treatment \times Line
<i>Breast meat n-3 and n-6 fatty acids (%)</i>							
n-3	White	0.67 \pm 0.01 ^c	0.79 \pm 0.01 ^b	0.91 \pm 0.04 ^a	< 0.05	0.124	0.212
	Black	0.65 \pm 0.01 ^c	0.71 \pm 0.03 ^b	0.84 \pm 0.01 ^a			
	Brown	0.64 \pm 0.02 ^c	0.76 \pm 0.01 ^b	0.88 \pm 0.01 ^a			
n-6	White	16.67 \pm 1.15	16.96 \pm 1.57	17.69 \pm 1.13 ^{ax}	0.144	0.112	0.472
	Black	16.38 \pm 1.75	16.44 \pm 1.37	16.69 \pm 1.19			
	Brown	17.86 \pm 1.08	16.06 \pm 1.75	17.36 \pm 1.08			
n-3/n-6	White	24.88 \pm 1.55 ^a	21.46 \pm 1.58 ^b	19.43 \pm 1.55 ^c	< 0.05	0.093	0.451
	Black	25.20 \pm 1.21 ^a	23.15 \pm 1.83 ^b	19.86 \pm 1.66 ^c			
	Brown	26.53 \pm 2.82 ^a	21.13 \pm 1.41 ^b	18.59 \pm 1.89 ^c			
<i>Thigh meat n-3 and n-6 fatty acids (%)</i>							
n-3	White	0.60 \pm 0.02 ^c	0.71 \pm 0.01 ^b	0.80 \pm 0.01 ^a	< 0.05	0.118	0.568
	Black	0.62 \pm 0.03 ^c	0.75 \pm 0.03 ^b	0.86 \pm 0.01 ^a			
	Brown	0.61 \pm 0.01 ^c	0.71 \pm 0.01 ^b	0.87 \pm 0.01 ^a			
n-6	White	15.30 \pm 1.57	17.00 \pm 1.88	15.30 \pm 1.57	0.101	0.221	0.448
	Black	16.46 \pm 1.06	17.68 \pm 1.77	16.46 \pm 1.06			
	Brown	16.90 \pm 1.35	16.85 \pm 1.81	16.90 \pm 1.35			
n-3/n-6	White	27.13 \pm 1.79 ^a	23.94 \pm 1.47 ^b	23.48 \pm 1.23 ^b	< 0.05	0.278	0.318
	Black	26.54 \pm 1.67 ^a	23.65 \pm 1.90 ^b	21.35 \pm 1.49 ^c			
	Brown	27.71 \pm 1.83 ^a	23.73 \pm 1.12 ^b	21.42 \pm 2.01 ^c			

CS0 (control), basal diet with no canola seed inclusion; CS1, basal diet with 1% of canola seed inclusion and CS3, basal diet with 3% of canola seed inclusion.

^{a-c} Means in the same row with different letters are significantly different at $P<0.05$.

^{x-z} Means in the same column with different letters are significantly different at $P<0.05$.

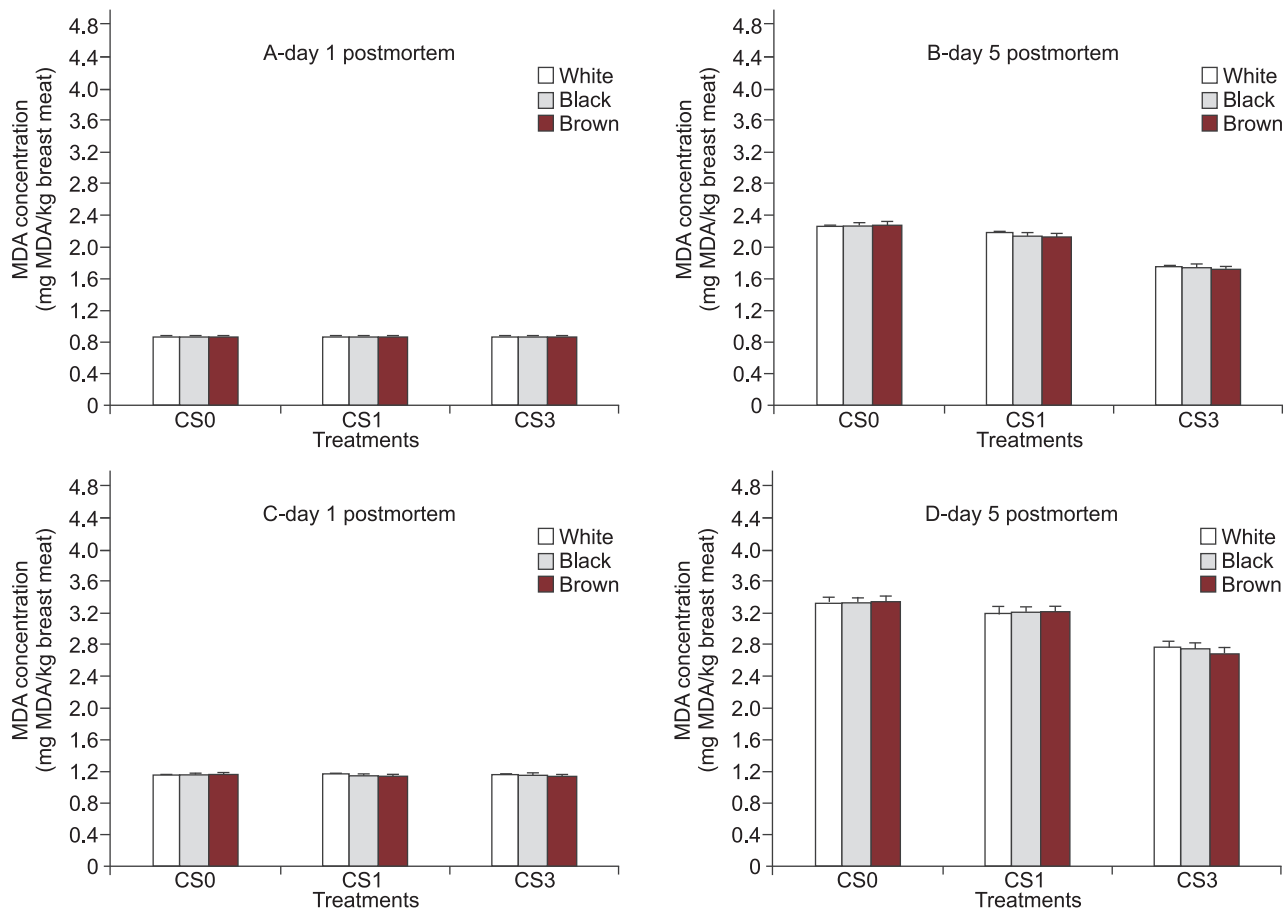


Fig. 1. Lipid stability of breast (A and B) and thigh (C and D) meat obtained from three local quail lines fed diet of canola seed supplementation.

those offered 1% canola seed and controls; which reflected better meat storage stability. Although feeding 1% canola seed did not affect the MDA values of meat, the lipid stability was improved. The ability of canola seed to decrease muscle TBARS could be due to n-3 PUFA content in canola seed as reported by Ebeid *et al.* (2011) who explained that lipid oxidation is greatly affected by muscle n-3 PUFA and muscles with high n-3 PUFA give lower TBARS values than those with low n-3 PUFA. The result of lipid oxidation observed in the present study agrees the report of Khaouchene *et al.* (2016) and Saleh *et al.* (2015) who reported that lipid oxidation during storage reduced in broiler chickens fed diet supplemented with canola seed. Regardless of dietary treatments, different quail lines had no effect ($P>0.05$) on MDA concentrations in breast and thigh meat. These observations are inconsistent with those of Nasr *et al.* (2017) who observed that TBARS in the white quails were lower when compared among brown, black and golden quail lines. This discrepancy in TBARS results might be due to the difference in feeding pattern.

The results of this study showed that dietary supplementation of canola seed did not affect quality characteristics of carcass and meat but increased the omega-3 polyunsaturated fatty acid content and improved lipid stability during postmortem aging. Regardless of dietary

treatments, no carcass and meat quality parameters except carcass weight differed between three quail lines. Carcass weight was higher ($P<0.05$) in brown quails than white and black quails. The results of this study suggest that simultaneous use of canola seed may enrich quail meat with n-3 fatty acid and reduce the lipid oxidation during storage.

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