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Research Article
Effect of Dietary Fat Sources and Antioxidant Types on Growth Performance and Carcass Quality of Japanese Quails

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Abstract

Background and Objective: The addition of different dietary sources of fat and/or oil have become an inherent practice in poultry production to improve fatty acid content of poultry meat, therefore evaluation of the effects of different dietary fat sources with two antioxidants on growth performance and carcass traits of Japanese quails was the major concern in this study. **Methodology:** A total of 189 one day old unsexed Japanese quail chicks were randomly distributed into 7 treatment groups each with 3 replicates of 9 chicks/replicate (n = 27). The dietary treatments consisted of the basal or control diet without supplementation and the basal diet supplemented with 3% of fish oil, sunflower oil and animal fat accompanied with either vitamin E and selenium mixture (5 g kg^{-1} diet) in T1, T2 and T3 or with L-carnitine (50 mg kg^{-1} diet) in T4, T5 and T6, respectively. Growth performance was evaluated weekly in terms of body weight, body weight gain, feed intake and feed conversion ratio for 42 day of age. At the end of the experiment, 4 birds from each group were randomly selected and sacrificed for determination of carcass traits, the relative weight of internal organs and meat and chemical composition. **Results:** Supplementation of fish oil followed by sunflower oil to quails diet significantly ($p<0.05$) improved the final body weight, cumulative weight gain, dressed carcass weights and dressing percentages. **Conclusion:** Fish oil supplementation regardless of antioxidants type was superior and more effective than sunflower oil and animal fat in improving growth performance, final body weight gain, feed conversion, carcass yield and meat chemical composition in growing Japanese quails.

Key words: Fat sources, antioxidants, performance, carcass traits, Japanese quails

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fats added commonly as economic tools of producing energy rich diets for poultry production. The addition of different dietary sources of fat and/or oil have become an inherent practice in poultry production. Not only as they represent a source of energy but also the beneficial content of polyunsaturated fatty acids for the poultry and human[1].

The benefit from the addition of fish oil to poultry diet is to enrich poultry product (meat and eggs) with omega 3 polyunsaturated fatty acids (PUFA) like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Therefore, the dietary addition of the fish oils is more effective than vegetable oil in producing long-chain n-3 PUFA enrichment poultry product[2]. Animal fat (tallow) is a cheaper fat source can be used in poultry nutrition, however, the plant oils are frequently used because of their high digestibility and fatty acid content[3].

Fats and/or oils are extremely susceptible to rancidity, off flavor and color changes because of the oxidation and this can lead to decrease the quality of food and feed[4]. However, many studies have showed that such undesirable changes resulted from lipid oxidation in poultry product can be fixed by antioxidant addition in poultry diet[5]. Antioxidants are involved in the prevention of cellular damage by removal of the free radicals. The most important natural scavenger systems of the free radicals within the body are vitamin E, beta-carotene and vitamin C. L-carnitine also has some antioxidant properties. Carnitine can be synthesized in animal bodies through several metabolic process. L-carnitine content in the animal origin feedstuff is higher than that present in plant origin like cereal grains and their by-product. Nevertheless, the main component of the poultry diet usually based on cereal grains and their by-product, may attend to potential inadequacy of carnitine in the diet[6]. Dietary L-carnitine reduces lipids peroxidation by transporting unsaturated fats into the mitochondria for oxidation to generate energy[7, 8].

No enough data showed the effects of various dietary fat sources with antioxidants on the growth performance and body composition of poultry especially in quails. The choice of specific fat sources in poultry diet have critical aspects mainly the cost and the quality of selected fat along with the expected effects on both performance and carcass traits. Therefore, the present work was conducted to compare the effects of three different dietary fats sources (fish oil, sunflower oil and animal fat) with two different antioxidants (either vitamin E and selenium mixture or L-carnitine) on Japanese quail's performance, carcass traits and meat chemical composition.

MATERIALS AND METHODS

Birds and housing: This experiment was carried out at Quail Experimental Station, Faculty of Veterinary Medicine, South Valley University, Qena Governorate, Egypt. Chemical analyses were performed in the laboratories of the Department of Nutrition and Clinical Nutrition, Faculty of Veterinary Medicine, Assiut University, Assiut, Egypt. A total of 189 one day old unsexed Japanese quail chicks were randomly distributed into seven dietary treatments each with 3 replicates of 9 chicks/replicate (n = 27). Chicks were obtained from the Quail Experimental Station and assigned to the seven experimental diets. The chicks were wing banded and weighed individually, the initial weight of the chicks was averaged (9.42±0.20 g). The Japanese quail's house was equipped with feeders, water founts, heaters and fans. Prophylactic measures were taken to control diseases and to increase the viability of the birds. Along the experimental period, birds in all experimental groups were subjected to a continuous lighting program, which extended to the end of the experiment (day 42). The ambient temperature at the experimental room was at 37°C during the first week and then decreased 2°C every week.

Experimental design and diets: This experiment was conducted using 3×2 factorial design with three different dietary fat sources and two different antioxidant types as presented in Table 1. The fat sources are fish oil (FO), sunflower oil (SO) and animal fat (AF) at a dietary level of 3%. The antioxidants are vitamin E and Se mixture at the level of

Table 1: Experimental design and dietary treatments

Treatments	Fat source	Fat level (%)	Types of antioxidants	Level of antioxidants
Control	-	-	-	-
T1	Fish oil (FO)	3	Vitamin E and selenium	5 g kg^{-1}
T2	Sunflower oil (SO)	3	Vitamin E and selenium	5 g kg^{-1}
T3	Animal fat (AF)	3	Vitamin E and selenium	5 g kg^{-1}
T4	Fish oil (FO)	3	L-carnitine	50 mg kg^{-1}
T5	Sunflower oil (SO)	3	L-carnitine	50 mg kg^{-1}
T6	Animal fat (AF)	3	L-carnitine	50 mg kg^{-1}

Table 2: Ingredients and chemical composition of the experimental diet for quails

Item* (% unless noted)	Control diet	Experimental diet
Yellow corn	55.20	48.00
Soybean meal	40.40	44.60
Dried fat	1.00	1.00
Supplemented oil or fat	-	3.00
Limestone, ground	1.10	1.10
Dicalcium phosphate	1.45	1.45
Common salt	0.30	0.30
Vitamin-mineral Premix**	0.30	0.30
DL-Methionine	0.15	0.15
L-Lysine	0.10	0.10
Chemical composition		
Dry matter	88.45	88.79
Crude protein	24.00	24.00
ME (Kcal kg^{-1})***	2900.00	2900.00
Crude fat	3.07	5.94
Calcium	0.88	0.88
Available phosphorus	0.43	0.43
DL-Methionine	0.52	0.51
Lysine	1.43	1.52

*Ingredient and nutrient composition are reported on as fed basis. **The vitamin and mineral premix provided kg^{-1} of diet: vitamin A: 4000000 IU, vitamin D3: 667000 IU, vitamin E: 3334 mg, vitamin K3: 1167 mg, vitamin B1: 334 mg, vitamin B2: 1667 mg, vitamin B3: 3334 mg, B6: 500 mg, vitamin B12: 33.4 mg, Folic acid: 334 mg, Biotin: 17 mg, trace elements % (Iron: 10, Copper: 2.167, Zinc: 18.334, Manganese: 20.0, Iodine: 0.167, Cobalt: 0.034 and Selenium: 0.034). ***Based on NRC[9] feed composition tables

5 g kg^{-1} diet (100 mg vitamin E and 0.4 mg Se) and L-carnitine (50 mg kg^{-1} diet). Seven experimental diets were formulated in such a way that control or basal diet without extra fat or antioxidant and six dietary treatments. The dietary treatments consisted of the basal diet supplemented with 3% of FO, SO and AF accompanied with either vitamin E and selenium mixture (5 g kg^{-1} diet) in T1, T2 and T3 or with L-carnitine (50 mg kg^{-1} diet) in T4, T5 and T6, respectively. The basal and experimental diets contained about 24% crude protein and 2900 Kcal ME kg^{-1} diet as recommended by the guidelines recommended by NRC[9] as exhibited in Table 2.

Growth performance and feed conversion: The Initial body weight of individual chick was taken at the beginning of the experiment and the individual weight of chicks was recorded every week till the end the experiment. During the whole experiment, feed intake was recorded weekly per pen and feed conversion ratio was calculated afterward. Mortality was recorded as it occurred.

Carcass traits: Four birds from each treatment were randomly selected and slaughtered at the end of the experiment (day 42). The liver, gizzard, proventriculus and heart were excised and weighed. Afterward, the birds were scalded, defeathered. The weights of hot carcass and dressed carcass (including the carcass weight without feathers, head, neck and feet but containing all the edible offal's) were determined. Dressed carcass was calculated as the following Eq:

Dressed carcass = Weight of eviscerated carcass+Weight of edible giblet (liver without gall bladder, heart, skinned empty gizzard)

Organ weights were expressed as relative percentage to the whole body weight.

Sampling and chemical analysis: Representative samples of the used feed ingredients were chemically examined by the proximate analysis procedures for dry matter, crude protein, crude fat, crude fiber, ash and nitrogen free extract according to AOAC[10].

Meat chemical composition: Samples from breast and thigh of slaughtered birds in all experimental groups were taken separately and kept at -20°C for further analysis. The meat was removed from the bones and then it was homogenized and analyzed for moisture, crude protein, crude fat and ash according to AOAC[10].

Statistical analysis: The obtained data were statistically analyzed using general linear model (GLM) test in a completely random design by the use of Statistical Packages for the Social Sciences (SPSS[11]). The presence of significance differences among treatment means was detected by Duncan's new multiple-range test[12]. Probability values less than 0.05 considered as statistically significant.

RESULTS

Body weight gain: As shown in Table 3, there were significant differences between treatment groups regarding body weight gain. The birds received fish oil with either Se with vitamin E or with L-carnitine as antioxidant showed higher body weight gain than the birds of all other treatment groups including the control group during all experimental periods. Birds fed diets containing 3% sunflower oil with two types of antioxidants achieved nearly equal body weight gain (232.5 and 232.01 g), also birds fed diets supplemented with animal fat nearly achieved the same BWG (227.18 and 227.09 g). No differences were observed in body weight gain of birds fed diets containing two different types of antioxidants with the same source of oil.

Feed intake: At the end of the third week, quails in the third group T3 (AF with vitamin E and selenium mixture) showed

Table 3: Effect of dietary treatments on body weight (BW), feed intake (FI) and feed conversion ratio (FCR) of Japanese quails

Items	Control	T1	T2	T3	T4	T5	T6	p-value
Initial BW (day 1)	9.58±0.19	9.37±0.20	9.34±0.11	9.54±0.11	9.54±0.18	9.12±0 .20	9.47±0.09	0.42
21 days								
Live BW	71.99±1.74^{c}	96.87±0.77^{a}	95.07±0.9^{a}	90.90±1.5^{b}	94.06±1.15^{a}	92.69±0.95^{ab}	88.76±1.4 ^{b}	<0.001
FI (g/bird)	220.50±2.11^{a}	200.00±5.00^{bc}	206.90±1.53^{ab}	187.00±4.04^{c}	201.20±2.42^{bc}	187.30±6.17^{c}	196.00±7.37^{c}	<0.001
BW gain (g/bird)	62.45±1.6^{c}	96.87±0.77^{a}	95.07±0.9^{a}	90.90±1.5^{b}	94.06±1.15^{a}	92.69±0.95^{ab}	88.76±1.4^{b}	<0.001
FCR (g g^{-1})	3.50±0.03^{a}	2.06±0.05^{a}	2.17±0.02^{b}	2.060±0.04^{a}	2.14±0.02^{a}	2.02±0.06^{a}	2.22±0.08^{b}	<0.001
22-42 days								
FI (g/bird)	510.00±10.41^{a}	459.30±11.6^{bc}	480.60±4.33^{bc}	479.40±11.47^{bc}	453.00±6.66^{c}	493.70±7.54^{ab}	471.00±7.64^{bc}	0.01
BW gain (g/bird)	111.46±2.04^{c}	144.82±1.71^{a}	137.43c±2.29^{b}	136.28±2.06^{b}	142.06±2.39^{a}	139.32±1.57^{ab}	138.99±2.43^{ab}	<0.001
FCR (g g^{-1})	4.60±0.09^{a}	3.17±0.08^{b}	3.50±0.03^{a}	3.52±0.08^{a}	3.19±0.05^{b}	3.54±0.05^{a}	3.39±0.05^{ab}	<0.001
1-42 days								
Final BW	183.45±1.26^{d}	241.68±1.63^{a}	232.50±1.99^{bc}	227.18±1.51^{cd}	236.13±2.05^{b}	232.01±1.35^{bcd}	227.09±1.93^{d}	<0.001
FI (g/bird)	730.50±11.31^{a}	659.30±13.72^{b}	687.50±5.04^{b}	666.40±14.84^{b}	654.20±4.38b	681.00±1.53^{b}	667.00±14.98^{b}	<0.001
BW gain (g/bird)	173.91±1.26^{e}	241.68±1.63^{a}	232.50±1.99^{bc}	227.18±1.51^{cd}	236.13±2.05^{b}	232.01±1.35^{bcd}	227.09±1.93^{d}	<0.001
FCR (g g^{-1})	4.20±0.07^{a}	2.72±0.05^{b}	2.96±0.02^{a}	2.93±0.06^{a}	2.77±0.02^{b}	2.93±0.01^{a}	2.94±0.07^{a}	<0.001
Mortality (%)	7.4	3.7	0.00	3.70	3.70	0.00	7.40	

Values are Means±SE, means in the same row with different superscripts are significantly different (p<0.05). T1, T2 and T3: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+Se and Vitamin E. T4, T5 and T6: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+L-carnitine. FI: Feed intake, FCR: Feed conversion ratio

Table 4: Effect of dietary treatments on carcass characteristics (% of live weight) in Japanese quails

Items	Control	T1	T2	T3	T4	T5	T6	p-value
Pre-slaughter weight (g)	209.8 4±8.76	205.05±4.81	226.40±12.8	221.99±12.17	218.69±14.78	217.02±14.37	219.03±15.6	0.91
Hot carcass weight (g)	177.18±9.06	171.98±3.25	193.10±11.09	188.53±14.68	172.39±16.76	193.77±19.31	195.16±18.4	0.78
Dressed carcass weight (g)	134.63±4.25	151.98±4.38	161.84±8.03	155.19±11.0	158.28±9.30	158.68±10.38	155.57±10.6	0.41
Dressing (%)	64.34±2.06^{a}	74.14±1.60^{a}	71.57±0.80^{a}	69.79±2.18^{b}	72.51±1.11^{a}	73.13±0.44^{a}	71.23±2.69^{a}	0.01

*Values are Means±SE, means in the same row with different superscripts are significantly different (p<0.05). T1, T2 and T3: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+Se and Vitamin E. T4, T5 and T6: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+L-carnitine

the lowest feed intake (187.0 g) followed by birds in the fifth group T5 fed diet supplemented with both sunflower oil and L-carnitine (187.3 g) (Table 3). Regarding feed consumption, during the whole experimental period (1-42 day), fish oil supplemented groups showed the lowest feed consumption (659.3 and 654.2 g) compared with the control and other treated groups.

Feed conversion: Concerning FCR from 0-3 weeks of age, T1, T3 and T5 groups recorded, the lowest feed conversion ratio (2.06, 2.06 and 2.02) compared with other treated groups. FCR of the other treated groups (2, 4 and 6) were nearly equal (2.17, 2.14 and 2.22) at the same starting period. As shown in Table 3, feed conversion indices of the quails in the T1 and T4 groups were improved (2.72 and 2.77) than that observed in other treated groups at 1-42 days of age (p<0.05). Fish oil improved feed conversion ratio with both types of antioxidants in comparison with control and other treated groups. No significant (p>0.05) differences in feed conversion indices were observed between other treated groups (T2, T3, T5 and T6) in comparison with the control one they had approximately equal values (2.96, 2.93, 2.93 and 2.94), respectively.

Mortality: Mortality was not affected by dietary fat sources (FO, SO and AF) with antioxidants (vitamin E and Selenium mixture or L-carnitine) during the experimental period (Table 3).

Carcass traits: Non-significant differences were observed of hot and dressed carcass weights as exhibited in Table 4. The highest dressing percentage value (74.14%) (p<0.01) was noted in T1 group fed diet containing a combination of fish oil and vitamin E and selenium mixture followed by birds in the T5 group fed diet containing sunflower oil plus L-carnitine (73.13%). The lowest dressing percentages was recorded in the control group (64.34%).

The relative weight of liver was numerically increased in groups supplemented with sunflower oil and animal fat in their diets (T2, T3, T5 and T6) compared with other treated groups as presented in Table 5. Concerning the heart, the highest relative weight was recorded in birds of T5 (0.95±0.08%) and the lowest one was recorded in the birds of T4 (0.72±0.05%). The best relative weight of gizzard plus proventriculus was recorded in birds of T1 group fed on diets supplemented with fish oil plus vitamin E and selenium mixture (3.01±0.17%) and the worst value was recorded in the T5 group (2.45±0.33%).

Meat chemical composition: Feeding different sources of fat with either vitamin E and selenium mixture or L-carnitine showed no significant impact on moisture content of quail

Table 5: Effect of dietary treatments on relative weights of some internal organs of Japanese quails

Items	Control	T1	T2	T3	T4	T5	T6	p-value
Liver	1.91±0.14	1.87±0.21	2.41±0.56	2.09±0.22	1.75±0.28	2.01±0.33	2.32±0.24	0.717
Heart	0.87±0.03	0.75±0.04	0.88±0.14	0.89±0.07	0.72±0.00	0.95±0.08	0.79±0.09	0.428
Gizzard and proventriculus	2.76±0.24	3.01±0.17	2.80±0.36	2.79±0.21	2.45±0.33	2.54±0.20	2.79±0.23	0.786

Values are Means±SE, T1, T2 and T3: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+Se and Vitamin E. T4, T5 and T6: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+L-carnitine

Table 6: Effect of dietary treatments on meat chemical composition (%) of Japanese quails

Items	Control	T1	T2	T3	T4	T5	T6	p-value
Moisture	71.87±1.59^{b}	70.57±0.44	72.21±0.84	71.76±1.09	72.53±0.74	70.17±0.47	73.9±0.79	0.675
Crude protein	20.24±0.42^{c}	24.03±1.23^{a}	22.41±0.61^{b}	22.84±1.01^{b}	22.35±1.13^{b}	24.59±0.94^{a}	20.90±0.91^{c}	0.037
Crude fat	2.56±0.22	2.78±0.11	2.82±0.30	2.85±0.18	2.53±0.57	2.61±0.32	2.59±0.27	0.675
Ash	2.40±0.45	2.62±0.61	2.56±0.36	2.55±0.55	2.59±0.40	2.63±0.29	2.56±0.40	0.797

*Values are Means±SE, means in the same row with different superscripts are significantly different ($p<0.05$). T1, T2 and T3: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+Se and Vitamin E. T4, T5 and T6: [Fish oil (FO), Sunflower oil (SO) and Animal fat (AF)]+L-carnitine

meat between different groups (Table 6). The highest value of crude protein content in quail meat was recorded in the T5 (24.59%) followed by T1 (24.03%) while, the lowest value was recorded in the control group (20.24%). Feeding different sources of fat with vitamin E and selenium mixture numerically increased crude fat content of quail breast and thigh meat when compared with L-carnitine supplemented groups. Dietary treatments had no significant effect ($p>0.05$) on ash content of the edible quail meat (breast plus thigh) at 42 days of age. There is no significant interaction effect between fat source and antioxidant type as fixed factors was observed in the current study.

DISCUSSION

The improvement of performance and feed efficiency of Japanese quails fed diet supplemented with fish oil with antioxidants in the current study agreed with the results reported by previous studies[13-16]. These studies reported that diets supplemented with fish oil and other plant oils significantly improved the body weight and the weight gain of quails. The increase in body weight and weight gain may be due to the fact that plant and fish oils contain high level of the easily digestible and absorbable unsaturated fatty acids especially omega-3 fatty acids[17].

Reduction in feed intake in fish oil supplemented groups all over the experimental period may be attributed to high amounts of metabolizable energy from polyunsaturated fatty acids in fish oil. These results are in agreement with the findings of Abd-El-Rauof[18] and Sahito *et al.*[19], who reported that supplementation of diets with different levels of fat decreased feed intake in broilers. Liu *et al.*[20] concluded that dietary supplementation with different levels of either fish or sunflower oils had improved feed intake in broiler chicken. On the contrary, El Yamany *et al.*[13] found that incorporating of two levels (2 or 3%) and two sources (linseed and olive oils) of fat in the quail diets increased feed intake. On the other hand, Sarica *et al.*[21,6] found that feeding two sources of fat with addition of L-carnitine had no effect on feed intake in Japanese quails.

Quails fed on diets containing sunflower oil consumed higher amount of feed during the whole experimental period compared to quails fed diets supplemented with either animal fat or fish oil. These results indicate that diets containing sunflower oil are more available and palatable than that of animal fat and fish oil. These results are in harmony with the findings of Monfaredi *et al.*[22] and Jalali *et al.*[23], who recorded that supplementation of sunflower oil in the diets of broiler chicks in the starter period significantly increase the feed intake.

The improvement of feed conversion by the addition of FO, SO and AF was in agreement with the findings of Al-Daraji *et al.*[14] and Ebeid *et al.*[15], who found that supplementation of fish oil in the diet of quails resulted in significant improvement in body weight and feed conversion. Inclusion of different sources of oils (FO and SO) had positive effect on growth performance in terms of high body weight gain, better feed conversion and feed utilization in quails. El Yamany *et al.*[13] stated that supplementation of these oils enhanced the digestibility of all nutrients including organic matter, crude protein, crude fat, nitrogen free extract and had no effect on crude fiber digestibility. Regardless of fat sources, antioxidant type had no significant impact on the body weight gain and feed intake at 1-42 days of age. Sahin *et al.*[24] found that supplementation of vitamin A and vitamin E single or in combination increased feed intake and weight gain of broilers, however, feed efficiency remained the same in all treatment. In contrast, Xu *et al.*[25] found no impact of dietary supplementation of (0, 25, 50, 75 or 100 mg) L-carnitine kg^{-1} on body weight gain, feed intake or feed conversion of

male broilers. Also, Abedpour *et al.*[26] reported that diet supplemented with L-carnitine had no effect on Japanese quail performance. These inconsistencies between the results of previous studies could be due to the differences in the levels of L-carnitine supplementation, differences in ingredients used, metabolizable energy levels, sex of birds and/or the physiological status of the birds. The major metabolic role of L-carnitine is to promote β-oxidation of long chain fatty acids, to generate adenosine triphosphate (ATP), to improve energy utilization, feed efficiency and body weight gain, especially in young animals and poultry[7,27,28].

Mortality did not affected by dietary fat sources (FO, SO and AF) with antioxidants during the experimental period. These results are in harmony with the findings reported by Hamady[16] and Yalcin *et al.*[29], who recorded that supplementation of L-carnitine in the diet of Japanese quail did not affect mortality rate.

The high dressing percentage or carcass yield in quails fed diet supplemented with fish oil accompanied with vitamin E and selenium mixture was in agreement with results obtained by Al-Daraji *et al.*[14], who found that body weight and carcass yield were significantly higher in quails fed diet supplemented with fish followed by flax oils. The addition of vitamin E and selenium in broiler diets increased carcass yield[30]. The highest weight of gizzard in the second group (T2) was in harmony with the findings of Al-Daraji *et al.*[14], who reported that the relative weight of gizzard was higher in quails fed diets containing fish oil compared to those fed diets containing either sunflower or corn oils. On contrary, Lopez-Ferrer *et al.*[17], Tabiedian *et al.*[31] and Shahryar *et al.*[32] reported that gizzard weight of broilers was significantly higher in control birds than those fed on diets supplemented with canola oil and poultry fat. Ahmed[33] found positive but non-significant effect of different dietary levels of fat on liver, gizzard and heart weights of broilers. Rabie and Szilagyi[34], found that dietary L-carnitine supplementation with different energy level had no significant effect on liver, heart, skinned empty gizzard weights.

Feeding different sources of fat with vitamin E and selenium mixture or L-carnitine showed no significant effects on moisture, crude fat and ash content of quail meat. Only the crude protein content in quail meat was higher in T5 (24.59%) followed by T1 (24.03%) while, the lowest value was recorded in the T6 group (20.90%). These findings did not agree with the findings of Sarica *et al.*[6], who noted that decreasing of CP in quail meat with an increasing of dietary energy. Xu *et al.*[25] recorded that two levels (50 and 75 mg kg^{-1}) of L-carnitine supplemented diet significantly increase the EE content in breast meat of male broilers. Feeding different sources of fat with vitamin E and selenium numerically increased crude fat content of quail meat (breast and thigh) when compared with other L-carnitine supplemented groups. In the present experiment, dietary treatments had no significant impact on the ash content of the edible quail meat. These results contradict with the findings of Englmaierova *et al.*[35], who found that dietary supplementation of vitamin E decreased the fat content and increased the ash content of the leg meat of broiler chickens. The numerical decrease in fat percentage of quail meat in groups supplemented with L-carnitine indicating that L-carnitine had a beneficial effect on energy production and utilization[7,25].

CONCLUSION

The results of this study indicated that, fish oil supplementation regardless the type of antioxidants was superior and more effective than sunflower oil and animal fat concerning performance, feed conversion and carcass quality of growing Japanese quails under the conditions of this experiment. It is recommended to use fish oil followed by sunflower oil either with vitamin E and selenium or with L-carnitine in the diet of Japanese quails for better growth performance and carcass traits.

SIGNIFICANCE STATEMENTS

This study discovers what is the best choice from different fat sources and antioxidant types to be applied in formulation of Japanese quail diets. This study help the researchers to find the beneficial combination between fat source and antioxidant which promotes growth performance and improves the meat quality of Japanese quails. Thus, a new theory about the best combination between fat source and antioxidant type may be arrived.

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