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Effects of Dietary Olive Oil on Growth Performance, Carcass Parameters, Serum Characteristics, and Fatty Acid Composition of Breast and Drumstick Meat in Broilers

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ABSTRACT: This experiment was conducted to evaluate the effects of dietary olive oil on growth performance, carcass parameters, serum characteristics, and fatty acid composition of breast and drumstick meat in broiler chickens. A total of 480 broilers were randomly allotted into three dietary treatments, including T (basal diet, 5% tallow), O1 (2% olive oil+3% tallow), and O2 (5% olive oil). During d 0 to 21, broilers fed the diet supplemented with 5% olive oil showed lower ($p<0.05$) body weight gain (BWG) and feed intake (FI) compared with those fed the T diet. Serum triglyceride concentration was reduced ($p<0.05$), while high density lipoprotein (HDL)-cholesterol concentration was increased ($p<0.05$) in the O2 treatment group compared with the T and O1 treatment groups. The addition of olive oil to the diets induced a reduction ($p<0.05$) in the total saturated fatty acid (SFA) contents in breast and drumstick meat, and increased ($p<0.05$) the total unsaturated fatty acid (USFA) contents and USFA/SFA ratios. In conclusion, a diet with 5% olive oil could decrease BWG and FI of broilers during the starter period (wk 0 to 3), and cause an increase in the serum HDL-cholesterol level, while decreasing the serum triglyceride concentration. Furthermore, USFA level and USFA/SFA ratios in breast and drumstick meat were increased by dietary supplementation of 2 or 5% olive oil. (**Key Words:** Carcass Parameters, Fatty Acid Composition, Growth Performance, Serum Characteristics, Olive Oil, Broiler)

INTRODUCTION

Fat supplementation in diets has been proven a valuable method for fulfilling the high energy requirements of rapidly growing broiler chickens. It has been well documented that the growth performance and feed conversion ratio of the broilers are influenced by dietary supplementation with fat (Sahito et al., 2012). High energy diets have been shown to improve growth and feed efficiency (Zaman et al., 2008; Hosseini-Vashan et al., 2010). However, the effects of dietary fat content remain controversial. In previous research, it has been determined that dietary fat supplementation induces an increase in growth and an alteration in meat quality (Cherry, 1982). Sanz et al. (2000a) reported that fat content from 1 to 5% did not improve performance or meat quality in broilers.

Differences in fat deposition as the result of different dietary oil levels may also be associated with the same metabolic differences between lean and fat chicken lines (Foglia et al., 1994). Thus, the effects of different dietary oil profiles on serum very low density lipoprotein (VLDL), insulin, cholesterol, and glucose were assessed in an effort to determine whether the changes observed in broilers fed on saturated fatty acids (SFA)- or monounsaturated fatty acids (MUFA)-rich diets, and those fed on polyunsaturated fatty acids (PUFA)-rich diets are accompanied by changes in these metabolic parameters (Sanz et al., 1999; Crespo and Esteve-Garcia, 2003).

Olive oil with an abundant quantity of MUFAs is thought to not only contribute nutrients to the diets (Stark et al., 2002), but also to influence the fatty acids profiles in muscles and fat in monogastric animals (Krejčí-Treu et al., 2010). However, limited information is available regarding the efficacy of olive oil in broilers. Therefore, the principal objective of this study was to evaluate the effects of olive oil supplementation on growth performance, carcass traits, serum characteristics, and meat fatty acids composition in broiler chickens.

MATERIALS AND METHODS

Experimental animals

A total of 480 1-d-old male Arbor Acres broiler

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chickens (body weight (BW) of 45.2±0.5 g) acquired from a commercial hatchery were weighed and allotted to three treatment groups, each treatment included 8 replicate pens with 20 birds per pen. Broilers were kept in temperature-controlled rooms. The temperature of the room was maintained at 33±1°C for the first 3 d, after which the temperature was gradually reduced by 3°C a week until reaching 24°C. The temperature of the room was then maintained at 24°C for the remainder of the experiment. Artificial light was provided 24 h/d by the use of fluorescent lights. The experiment was conducted in 2 phases consisting of a starter phase from d 0 to 21 and a finisher phase from d 22 to 35. The birds were provided feed and water *ad libitum*. The Animal Welfare Committee of Dankook University approved the animal care protocol used for this experiment.

Experiment design and diets

The three treatments consisted of T (5% tallow), O1 (2% olive oil+3% tallow), and O2 (5% olive oil) treatments. The experimental diets were administered from d 1 to 35. All diets were formulated to meet or exceed the NRC (1994) requirements for broilers (Table 1). The lipid profiles of the experimental diets are provided in Table 2.

Table 1. Ingredient composition and nutrient content of diets

Item	T[1]	O1[1]	O2[1]
Ingredients (%)			
Corn	48.69	48.69	48.69
Wheat	20.00	20.00	20.00
Soybean meal (CP 44%)	18.14	18.14	18.14
Corn gluten meal (CP 60%)	3.72	3.72	3.72
Meat and bone meal	2.40	2.40	2.40
Salt	0.17	0.17	0.17
Limestone	1.12	1.12	1.12
Tallow	5.00	3.00	-
Olive oil	-	2.00	5.00
Vitamin-mineral premix[2]	0.24	0.24	0.24
Antioxidant (Ethoxyquin, 25%)	0.05	0.05	0.05
Avilamycin	0.02	0.02	0.02
DL-MHA (88%)	0.18	0.18	0.18
Lysine (78.4%)	0.24	0.24	0.24
Threonine (98.5%)	0.03	0.03	0.03
Chemical composition[3] (%)			
ME (Mcal/kg)	3.21	3.11	3.05
CP	20.79	20.65	20.88
Lysine	1.02	1.00	1.01
Methionine+cysteine	0.82	0.80	0.81
Ca	0.85	0.84	0.84
P	0.73	0.76	0.75

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.

[2] Supplied per kilogram of diet: riboflavin, 8.0 mg; niacin, 50 mg; pantothenic acid, 15 mg; 50% cholinechloride, 1,000 mg; cobalamin, 15 μg; cholecalciferol, 82.5 μg; vitamin E (DL-α-tocophery acetate), 25 IU; vitaminA (trans-retinyl acetate), 10,000 IU; biotin, 0.1 mg; folic acid, 0.75 mg; $FeSO_4 \cdot 7H_2O$, 300 mg; MnO, 100 mg; $CuSO_4 \cdot 5H_2O$, 20 mg; $ZnSO_4$, 150 mg; $Na_2SeO_3 \cdot 5H_2O$, 0.15 mg; KI, 0.5 mg; ethoxyquin, 100 mg; avoparcin, 15 mg.

[3] Analysed values.

Sampling and measurements

The broiler chicks were weighed and feed intake (FI) was recorded on d 0, 21, and 35. This information was then used to calculate body weight gain (BWG), FI, and feed conversion ratio (FCR). At the end of the experiment, three birds per pen were selected randomly for blood collection. Blood samples were collected from the wing vein into a sterile syringe and stored at -4°C until cholesterol was analyzed. The concentrations of triglyceride, high density lipoprotein (HDL) cholesterol, and low density lipoprotein (LDL) cholesterol and total cholesterol in the serum samples were analyzed with an automatic biochemical analyzer (RA-1000, Bayer Corp., Tarrytown, NY, USA) using colorimetric methods. After blood collecting, broilers were euthanized via cervical dislocation and two thighs plus drumsticks, deboned breast, and two wings were collected in accordance with the protocols described by Romboli et al. (1996). The abdominal fat was evaluated as the percentage of carcass weight. In order to avoid variations in the cutting procedures, the same operator was employed.

To determine the fatty acid composition of the breast meat and drumstick meat, two 10-g samples collected from each part were extracted using a choloroform:methanol (2:1, vol/vol) mixture according to the method described by Velasco et al. (2010). Next, 20 to 25 mg of the extracted fat

Table 2. Fatty acid composition of experimental diets (g/100 g fat)

Fatty acids[2]	T[1]	O1[1]	O2[1]
Myristate (C14:0)	1.27	0.88	0.88
Palmitate (C16:0)	19.64	18.57	17.66
Stearate (C18:0)	6.68	5.69	5.67
Arachidate (C20:0)	0.47	0.36	0.33
Total SFA	28.06	25.50	24.54
Myristoleate (C14:1 n-5)	0.17	0.13	0.14
Palmitoleate (C16:1 n-7)	-	-	-
Oleate (C18:1 n-9)	33.09	35.29	35.63
11-eicosenoate (C20:1 n-9)	1.31	1.58	1.61
Erudate (C22:1 n-9)	0.04	0.05	0.07
Linoleate (C18:2 n-6)	22.25	24.72	25.19
11,14-eicosadienoate (C20:2 n-6)	0.12	0.13	0.15
Arachidonate (C20:4 n-6)	0.04	0.04	0.06
Linolenate (C18:3 n-3)	0.27	0.24	0.29
Total USFA	57.12	62.05	63.00
USFA/SFA	2.04	2.43	2.57

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.

[2] SFA = Saturated fatty acid; USFA = Unsaturated fatty acid.

was saponified with 0.5 M methanolic sodium hydroxide and then methylated with boronitrifluoride in methanol using the method described by Ao et al. (2010). The fatty acid methyl esters obtained were then separated and analyzed by gas chromatography. The abdominal fat was directly saponified and methylated, after which the fatty acid composition determined by gas chromatography. The fatty acid content was determined using gas chromatography HP6890 (Agilent, Waldbronn, Germany) equipped with a flame ionization detector and an HP 19091 to 136 capillary column (60 m×0.25 mm internal diameter) with a film thickness (0.25 μm) in the stationary phase. Helium was used as the carrier gas. Oven temperature was programmed as follows: from 140 to 160°C at 1.5°C/min; from 160 to 180°C at 0.50°C/min; and from 180 to 230°C at 2.50°C/min. The other chromatographic conditions were: injector and detector temperatures, 280°C; sample volume injected, 1 μl. Fatty acids were identified by matching their retention times with those of their relative standards, as well as by mass spectrometry (HP5973; Agilent, Waldbronn, Germany) of each peak.

Statistical analyses

All data were analyzed by ANOVA using the General Linear Models (GLM) procedure of SAS (SAS Institute, 1996). Differences in the mean values among the dietary treatments were assessed via by repeated measures and Duncan's multiple range tests. Probability values less than 0.05 were considered significant.

RESULTS

Growth performance

During d 0 to 21, BWG and FI in broilers fed the O2 diet was decreased ($p<0.05$) by 4.7 and 5.4% as compared with those fed the T diet, respectively (Table 3). During d 22 to 35 and overall period (d 0 to 35), no differences ($p>0.05$) in BWG, FI, or feed conversion ratio were detected among treatments.

Table 4. Effect of olive oil on carcass parameters of broiler chickens

Item (%)	T[1]	O1[1]	O2[1]	SEM[2]
Eviscerated carcass[3]	65.8	64.7	66.2	2.0
Breast	25.9	25.7	25.6	3.3
Leg	45.4	45.8	46.3	2.9
Abdominal fat	1.4	1.2	1.5	0.1

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.
[2] Standard error mean.
[3] Eviscerated carcass = Carcass without head, neck, and feet.

Carcass parameters of broiler chickens

The eviscerated carcass yield, which was calculated after removing the head, neck, and feet, was not affected by dietary treatments (Table 4). The relative weight of breast, leg, and abdominal fat did not differ ($p>0.05$) among the treatment groups.

Serum characteristics

Serum triglyceride concentration in the O2 treatment was 27.9% lower ($p<0.05$) than that in the T treatment (Table 5) at the end of the experiment. Broilers fed the O2 diet had 11.5 and 12.7% higher ($p<0.05$) HDL-cholesterol concentration than those fed the T and O1 diets, respectively. No difference ($p>0.05$) in the concentration of total cholesterol and LDL-cholesterol was observed among dietary treatments.

Fatty acid composition of breast meat

The addition of 2 or 5% olive oil to the diets reduced ($p<0.05$) the content of total SFA in breast meat by 7.8 and 6.3% (Table 6), myristate (C14:0) by 22 and 21%, and

Table 3. Effect of olive oil on growth performance of broiler chickens

Item	T[1]	O1[1]	O2[1]	SEM[2]
Starter (d 0 to 21)				
Body weight gain (g)	636[a]	612[ab]	606[b]	8
Feed intake (g)	903[a]	866[ab]	854[b]	20
Feed conversion ratio	1.42	1.42	1.41	0.03
Finisher (d 22 to 35)				
Body weight gain (g)	900	910	909	24
Feed intake (g)	1,722	1,736	1,738	28
Feed conversion ratio	1.91	1.91	1.91	0.04
Overall (d 0 to 35)				
Body weight gain (g)	1,536	1,522	1,514	25
Feed intake (g)	2,625	2,602	2,592	37
Feed conversion ratio	1.71	1.71	1.71	0.02

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil. [2] Standard error mean.
[ab] Means in the same row with difference superscripts differ significantly ($p<0.05$).

Table 5. Effect of olive oil on serum characteristics of broiler chickens

Item (mg/dl) [2]	T[1]	O1[1]	O2[1]	SEM[3]
Total cholesterol	123	127	135	6
HDL-cholesterol	81.4[b]	80.6[b]	90.8[a]	2.0
LDL-cholesterol	22.6	26.0	20.2	2.8
Triglyceride	104[a]	90.5[ab]	75.0[b]	8.6

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.
[2] HDL = High density lipoproteins; LDL = Low density lipoproteins.
[3] Standard error mean.
[ab] Means in the same row with difference superscripts differ significantly ($p<0.05$).

palmitate (C16:0) by 7.3 and 6.3%, respectively. An increase ($p<0.05$) in the total USFA and SFA/USFA ratio of breast meat by dietary addition of olive oil was observed. Breast meat oleate (C18:1 n-9) levels were increased by 9.2 and 9.0% by dietary addition of 2.0 and 5.0% olive oil, and erudate (C22:1 n-9) level was 20.0 and 33.3% higher ($p<0.05$) in O2 treatment group as compared with T and O1 treatment groups. However, breast meat palmitoleate (C16:1 n-7) level was decreased by dietary addition of 5% olive oil, besides breast 11-eicosenoate (C20:1 n-9) and 11,14-eicosadienoate (C20:2 n-6) levels were reduced by dietary addition of 2 and 5% olive oil.

Fatty acid composition of drumstick meat

Total SFA concentrations of drumstick meat of broilers fed O1 and O2 diets were 6.6% and 7.7% lower ($p<0.05$) than that of broilers fed T1 diet (Table 7). Myristate (C14:0) and palmitate (C16:0) levels were reduced by 21.7%, 18.5% and 7.0%, 7.5% respectively in O1 and O2 treatments as compared with that in T treatment. Furthermore, total USFA level of O1 and O2 treatment groups was 5.8% and 5.5% higher ($p<0.05$) than that of T treatment group while oleate (C18:1 n-9) and erudate (C22:1 n-9) levels were 11.1%, 10.2% and 4.1%, 5.2% higher ($p<0.05$) in O1 and O2 treatments than that in T treatment group. However, myristoleate (C14:1 n-5) and 11-eicosenoate (C20:1 n-9) levels were reduced ($p<0.05$) by 3.1%, 2.3% and 10.3% and 12.8% respectively in O1 and O2 treatments as compared with T treatment. Broilers fed T and O2 diets had a higher ($p<0.05$) 11,14-Eicosadienoate (C20:2 n-6) level than those fed O1 diet. Total USFA level and SFA:USFA ratio were increased ($p<0.05$) by dietary addition of olive oil.

DISCUSSION

Previous studies have reported that plant oils (corn oil, seed oil, palm oil) fed at the levels of 0.5 to 1.0% in the diet improved growth performance, feed efficiency, meat production, or a combination thereof in rats, mice, and pigs (Dugan et al., 1997; Ostrowska et al., 1999). Crespo and Esteve-Garcia (2001) found that olive oil at the rate of 6 and 10% had no effect on final live weight and feed conversion ratio in broilers. El-Deek et al. (2005) also found that different levels (0.0 vs 2.5 and 5.0%) of olive oil did not affect growth performance of broilers under heat stress. In contrast to these studies, El Shanti et al. (2011) reported that the BWG was improved by 6% olive oil sediments. In the current study, the inclusion of 5% olive oil in the diet decreased the BWG and FI during the starter phase (d 0 to 21). In agreement with our results, Zhang et al. (2003) observed a marked reduction in BWG and feed

Table 6. Effect of olive oil on fatty acid composition of breast meat (g/100 g fat)

Fatty acids[3]	T[1]	O1[1]	O2[1]	SEM[2]
Myristate (C14:0)	1.00[a]	0.78[b]	0.79[b]	0.01
Palmitate (C16:0)	24.21[a]	22.45[b]	22.68[b]	0.25
Stearate (C18:0)	5.70	5.47	5.52	0.18
Arachidate (C20:0)	0.34	0.31	0.32	0.01
Total SFA	31.25[a]	28.81[b]	29.31[b]	0.35
Myristoleate (C14:1 n-5)	0.27[a]	0.20[b]	0.20[b]	0.01
Palmitoleate (C16:1 n-7)	5.99[a]	5.42[ab]	5.22[b]	0.20
Oleate (C18:1 n-9)	40.21[b]	43.92[a]	43.84[a]	0.36
11-eicosenoate (C20:1 n-9)	0.83[a]	0.72[b]	0.72[b]	0.01
Erudate (C22:1 n-9)	0.10[b]	0.09[b]	0.12[a]	0.01
Linoleate (C18:2 n-6)	14.73	14.65	14.50	0.20
11,14-eicosadienoate (C20:2 n-6)	0.11[a]	0.07[c]	0.08[b]	0.01
Arachidonate (C20:4 n-6)	0.06	0.07	0.07	0.01
Linolenate (C18:3 n-3)	0.06	0.06	0.04	0.01
Total USFA	62.37[b]	65.20[a]	64.81[a]	0.45
USFA/SFA	2.00[b]	2.27[a]	2.21[a]	0.04

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.
[2] Standard error mean. [3] SFA = Saturated fatty acids; USFA = Unsaturated fatty acids.
[ab] Means in the same row with difference superscripts differ significantly ($p<0.05$).

Table 7. Effect of olive oil on fatty acid composition of drumstick meat (g/100 g fat)

Fatty acids[3]	T[1]	O1[1]	O2[1]	SEM[2]
Myristate (C14:0)	0.92[a]	0.72[b]	0.75[b]	0.02
Palmitate (C16:0)	23.64[a]	21.98[b]	21.86[b]	0.29
Stearate (C18:0)	6.32	6.13	5.88	0.24
Arachidate (C20:0)	0.38	0.37	0.35	0.03
Total SFA	31.26[a]	29.19[b]	28.84[b]	0.40
Myristoleate (C14:1 n-5)	0.26[a]	0.18[c]	0.20[b]	0.01
Palmitoleate (C16:1 n-7)	5.70	5.24	5.44	0.24
Oleate (C18:1 n-9)	38.72[b]	43.02[a]	42.66[a]	0.42
11-Eicosenoate (C20:1 n-9)	0.78[a]	0.70[b]	0.68[b]	0.01
Erudate (C22:1 n-9)	0.73[b]	1.03[a]	1.11[a]	0.08
Linoleate (C18:2 n-6)	15.41	15.04	14.87	0.23
11,14-Eicosadienoate (C20:2 n-6)	0.14[a]	0.07[b]	0.15[a]	0.02
Arachidonate (C20:4 n-6)	0.18[b]	0.23[a]	0.21[a]	0.01
Total USFA	61.93[b]	65.51[a]	65.33[a]	0.44
USFA/SFA	1.98[b]	2.25[a]	2.27[a]	0.04

[1] T = Basal diet, 5% tallow; O1 = 2% olive oil+3% tallow; O2 = 5% olive oil.
[2] Standard error mean. [3] SFA = Saturated fatty acids; USFA = Unsaturated fatty acids.
[ab] Means in the same row with difference superscripts differ significantly ($p<0.05$).

conversion ratio when broiler chickens were fed diets containing 2 to 5% plant oils. This result is attributable to the fact that these oils form a portion of the membrane cytoarchitecture of a variety of cells. Moreover, it is important to note that the olive oil levels adopted for these previous studies were very different as well as the source of olive oil being different which may explain the inconsistent results.

Saturated or unsaturated fatty acids induce tissue damage in the lung, liver, and kidney (Abaelu et al., 1991). In agreement with the results reported by El-Deek et al. (2005), the percentage of abdominal fat of the carcasses was almost stable, and ranged from between 1.2 and 1.5% without statistical differences among the groups. Despite these results, El Shanti et al. (2011) found that the abdominal fat pad was significantly decreased with 3 and 6% olive oil inclusion in broiler diets. It has been well documented that dietary PUFA or olive oil addition promotes lean tissue deposition (Park et al., 1997), inhibits lipid synthesis (Crespo and Esteve-Garcia, 2002), and increases fatty acid oxidation (Sanz et al., 2000b). These effects could explain the reason why the fat content of the carcass was reduced by dietary plant oils inclusion (Sanz et al., 2000a). Furthermore, as the result of visual evaluation, the firmness of abdominal fat was dramatically enhanced in the group fed on dietary olive oils.

Hornstra and Sundram (1989) demonstrated that palm oil did not significantly elevate blood cholesterol when used to replace the habitual fat in the Dutch diet. Other experiments have demonstrated that plant oil diets lower the plasma levels of triglycerides and LDL-cholesterol, and do not reduce the levels of HDL-cholesterol (Lindsey et al., 1990; Osim et al., 1996). HDL forms a class of lipoproteins that vary somewhat in size (8 to 11 nm in diameter). These lipoproteins carry fatty acids and cholesterol from the body's tissue to the liver. In this study, the triglyceride level in blood decreased in response to treatment with olive oil, which was consistent with Bölükbaşı and Erhan (2007) who reported that 3% olive oil caused a decrease in LDL and triglyceride did not reduce the HDL level. Triglycerides are secreted from the liver into the blood by triglyceride-rich lipoproteins; therefore, impaired hepatic lipogenesis results in decreased triglyceride concentrations in plasma (Zhou et al., 2009). This result was also similar to Schuman et al. (2000) who found that laying hens fed with flaxseed, flax oil, or n-3-fatty aicd supplement had a reduction in liver lipid content.

The results of this experiment demonstrated that total USFA contents were increased and total SFA contents were decrease in broilers fed on diets with olive oil as compared to those fed on the control diet. This is consistent with the results presented by other investigators (Shimomura et al., 1990; Sanz et al., 2000b). This suggests that USFA content was improved when higher levels of vegetable oils are included in the diet (Sibbald and Kramer, 1980). Crespo and Esteve-Garcia (2002) also reported that digestibility of SFA was higher, and endogenous synthesis of SFA was much lower in broilers fed the olive oil, which could result in lower serum SFA. Chamruspollert and Sell (1999) reported that changes in USFA might be attributed to plant oils, which inhibit the delta-9 desaturase enzyme system which is responsible for SFA desaturation, thereby converting them into USFA. Epidemiological and scientific evidence has shown a strong relationship between total fat intake and composition and a number of diseases, including coronary heart disease (CHD), cancer, diabetes, and depression

(Katan, 2000). In addition, clinical data strongly support a relationship between CHD and the dietary intake of cholesterol and SFA (Zhou et al., 2009). In the present study, the breast and drumstick meat of broilers receiving the diets with 2 or 5% olive oil had a lower concentration of SFA than those fed the control diet. This indicates that broilers consumption of diets with olive oil posed a lower risk of CHD.

In conclusion, dietary inclusion of 5% olive oil could increase serum HDL-cholesterol concentration, decrease triglyceride level but impair the BWG and FI of broilers during the starter period (d 0 to 21). However, 2 or 5% olive oil could decrease SFA level, and increase USFA contents in the breast and drumstick meat. Thus olive oil could be used as a beneficial fatty acid source for human diet.

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