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Performance, Carcass Traits, and Meat Composition of Broiler Chickens Fed Diet Containing Fish Oil and Vitamin E

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ABSTRACT

The study aimed to determine the efficacy of dietary vitamin E and fish oils on performance, carcass yield, cholesterol, omega-3, and omega-6 in the meats of broiler chickens. A total of 400 Lohmann day-old broiler chicks consisted of 200 males and 200 females were reared for 35 days. This experiment employed a completely randomized design with five treatments and four replicates. The treatments were T0: Control diet with 3% crude palm oil without vitamin E; T1: Diet containing 3% fish oil; T2: Diet containing 3% fish oil and 80 IU/kg vitamin E; T3: Diet containing 3% fish oil and 100 IU/kg vitamin E, and T4: Diet containing 3% fish oil and 120 IU/kg vitamin E. The result showed that dietary fish oil and vitamin E had no effect (p>0.05) on feed intake, body weight, weight gain, AME, AMEn, TME, and TMEn, but it tended to decrease the mortality rate. T3 significantly reduced (p<0.05) FCR in the finisher phase and meat cholesterol compared to the control. T1 and T3 significantly (p<0.05) reduced carcass weight percentage. Dietary fish oil and vitamin E increased omega-3 levels, and declined the ratio of omega-6 and omega-3. It is concluded that supplementation of 100 IU Vitamin E in the diet containing 3% fish oil improved feed efficiency by 9.95%, decreased cholesterol of the meat by 44.76%, increased omega-3 of the meat by 81.92%, and yielded the best ratio of omega-6: omega-3 of the meat, i.e., 10.34:1.

Keywords: broiler chickens; cholesterol; growth; omega-3; omega-6, vitamin E

INTRODUCTION

Consumers are becoming increasingly interested in the enrichment of functional compounds in poultry meat due to the improving understanding of the relationship between diet and health. One of the functional compounds that can be improved in poultry meat is omega-3 polyunsaturated fatty acids (PUFAs) through poultry diet manipulation. Omega-3 has been claimed to decrease various diseases such as coronary heart diseases, cognitive decline, cancer, and neurodegenerative diseases (Shahidi & Ambigaipalan, 2018; Lange *et al.*, 2019). In addition, omega-3 in diets reduces the cholesterol content of broiler meat (Chekaniazar & Shahryar, 2018) and it is important for immune response and broiler performance (Ibrahim *et al.*, 2018). In the previous study, it has been proved that the omega-3 content of meat can be improved by the addition of fish oil in broiler diets (Taşdelen & Ceylan, 2017). According to Mansoub & Bahrami (2011), fish oil contains high unsaturated fatty acids, especially omega-3, docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) that can improve animal health and provide energy. The beneficial effect of fish oil was also reported by Navidshad (2009) that the addition of fish oil in the diet raised the thigh, breast, and percentage of small intestine weights. However, PUFAs are easily oxidized due to the existence of multiple double bonds in their chemical structures. Oxidation happens to the unsaturated fatty acids found in fats, oils, and bodies when exposed to oxygen (Ismail *et al.*, 2016). The strategy to protect PUFAs from the oxidation process can be done by the inclusion of vitamin E in the diets as antioxidants.

In animals, vitamin E serves a variety of important roles, including preventing cells from the harmful effects of reactive oxygen species (Voljč *et al.*, 2011; Prastiya *et al.*, 2021) and stimulating humoral and cellular immune responses (Lee & Han, 2018). The addition of vitamin E in the broiler diets showed a positive impact on feed efficiency and body weight (Selvam *et al.*, 2017). Another research found that vitamin E increases broiler meat quality by upregulating the expression of antioxidant-enzyme gene (Niu *et al.*, 2017). However, the study on the effects of a dietary combination of fish oil and vitamin E on the ratio of omega 3 to omega 6 in broiler meat is limited. Therefore, our study aimed to assess the vitamin E efficacy with dietary fish oils on broiler performance, carcass traits, meat cholesterol, omega-3, and omega -6 contents.

MATERIALS AND METHODS

Ethical Approval

All experimental procedures were approved by the Animal Ethics Committee of IPB University (Bogor Agricultural University) under the standards for animal care and usage (Number: 112-2018 IPB).

Experimental Design and Treatments

A total of 400 Lohmann strains consisting of 200 males and 200 females of day-old chicks were used in this study and reared for 35 days. The chicks were raised in an open house system separated into 20 pens of 2 m x 1 m x 1 m with 10 males and 10 females mixed in each pen. During the experiment, each pen was equipped with a feeder tube and two drinker tubes for providing *ad libitum* access to feed and water. The experiment was carried out using a completely randomized design with five treatments and four replicates. The feeding programs were applied for the starter period (0-7 days), grower period (8-21 days), and finisher period (22-35 days) and were arranged to be iso-protein and isocaloric as was recommended by Leeson & Summers (2005). Starter diet contained 23% crude protein with 3200 kcal/kg metabolizable energy, while grower diet contained 22% crude protein with 3050 kcal/kg metabolizable energy, and finisher diet contained 20% crude protein with 3100 kcal/kg metabolizable energy (Table 1). The dietary treatments were: T0 as a control diet containing 3% crude palm oil without vitamin E; T1: Diet containing 3% fish oil; T2: Diet containing 3% fish oil and 80 IU of vitamin E; T3: Diet containing 3% fish oil and 100 IU of vitamin E, and T4: Diet containing 3% fish oil and 120 IU of vitamin E. The feed ingredients used were corn, soybean meal, rice bran, corn gluten meal (CGM), *Lemuru* fish oil, crude palm oil (CPO), meat bone meal (MBM), vitamin E, $CaCO_3$, NaCl, premix, DL-Methionine, L- Lysine, and tryptophan (Table 1). Before formulating, the omega-3 content in *Lemuru* fish oil was analyzed and calculated manually from each ingredient to determine the ratio of omega-6 to omega -3 in the diet. The ratio of omega-6 to omega-3 of basal diet and treatments diet were 7.42 and 1.71 (starter), 9.71 and 1.84 (grower), and 12.67 and 2.06 (finisher), respectively. The parameters measured were body weight (g/bird), body weight gain (g/bird), feed conversion ratio (FCR), feed intake (g/bird), mortality (%), the weight percentage of carcass trait (breast, thigh, back, and wings), omega-6 and omega-3 ratio, and cholesterol level.

Data Collection

Performance. The broiler body weight was measured each week and at 35 days of age as the final body weight. Bodyweight gain was measured as the difference between two successive weighings. Feed intake was accumulated from the first week to the fifth week. FCR was calculated by dividing feed intake by body weight gain. The mortality rate was calculated by dividing the number of dead chickens by the total number of chickens at the beginning of the trial.

Carcass traits. At the end of the experiment, 2 birds from each pen with bodyweight close to the average pen weight were selected and slaughtered manually to evaluate carcass traits (carcass, wings, thigh, breast, and back). After slaughtering and bleeding, the carcasses were de-feathered, and the giblet was eviscerated manually. Then, the carcass was cut into some parts, including breast, thigh, wings, and back weight, and was calculated as the percentage of each yield weight over the carcass weight.

Measurements of meat fatty acids and cholesterol concentrations. Fatty acids and cholesterol concentrations were measured in the mixed breast and thigh meat samples of 2 birds per pen at ages 35 days. Meat cholesterol concentration was analyzed using the Liebermann Burchard method (Kleiner & Dotti, 1962),

Table 1. Composition of ingredients and nutrient contents (as fed) of basal diets containing fish oil and vitamin E

Ingredients	Starter diet	Grower diet	Finisher diet
Yellow corn (%)	58.80	55.50	59.50
Rice bran (%)	0.00	4.60	6.50
Soybean meal (%)	11.00	21.40	15.00
Meat and bone meal (%)	13.50	7.60	6.40
Corn gluten meal (%)	12.00	5.80	7.50
Crude palm oil (%)[1)]	3.00	3.00	3.00
CaCO3 (%)	0.20	0.50	0.50
NaCl (%)	0.20	0.20	0.20
Premix (%)[2)]	0.50	0.50	0.50
DL-Methionine (%)	0.20	0.30	0.30
L-Lysine (%)	0.50	0.50	0.50
Tryptophane (%)	0.10	0.10	0.10
Total (%)	100.00	100.00	100.00
Nutrient content			
Metabolizable energy (kcal/kg)	3211.65	3061.5	3104.35
Crude protein (%)	23.08	22.44	20.23
Crude fat (%)	5.69	4.89	5.12
Crude fiber (%)	2.21	2.80	2.97
Lysine (%)	1.18	1.33	1.15
Methionine (%)	0.58	0.61	0.60
Cystine (%)	0.25	0.26	0.23
Methionine + Cysteine (%)	0.83	0.87	0.83
Calcium (%)	1.45	1.00	0.87
Available phosphorus (%)	0.80	0.57	0.51
Natrium (%)	0.21	0.17	0.17
Chloride (%)	0.23	0.21	0.20

Note: [1)] The treatment diets were created from the basal diets by substituting crude palm oil with 3% lemuru fish oil and adding vitamin E (0, 80,100, and 120 IU/kg).
[2)] Premix content (per kg premix)= vitamin D 100.000 IU, vitamin A 500.000 IU, vitamin E 150 mg, vitamin K 50 mg, vitamin B1 50 mg, vitamin B2 250 mg, vitamin B12 250 mcg, niacinamide 375 mg, Ca-d-pantothenate 125 mg, folic acid 25 mg, choline chloride 5.000 mg, glycine 3.750 mg, Dl-methionine 5.000 mg, Mg sulphate 1.700 mg, Fe sulphate 1.250 mg, Mn sulphate 2.500 mg, Cu sulphate 25 mg, Zn sulphate 500 mg, and K iodine 5 mg.

and the methylation technique was used to assess fatty acid concentration (AOAC, 1984). Then, the absorbance was read using a spectrophotometer, while fatty acid used gas chromatography.

Measurement of metabolizable energy. The measurement of feed digestibility was carried out using the Farrell method (Farrell, 1978). Twenty male broilers were fed experimental feed, while five fasted male broiler chickens were used to measure endogenous energy. Individual metabolic cages were used to adapt chickens for 3 days. After 3 days of adaptation, 25 broilers were fasted from feed for 24 hours but were allowed free access to drinking water. Then, 20 chickens were fed the experimental feed, and 5 chickens continued to be fasted for 24 hours with *ad libitum* water. The excreta of each broiler were collected and sprayed with a 0.01% H2SO4 solution every 2 hours. Then, the excreta were weighed and stored in the freezer for 24 hours to prevent decomposition. All samples were thawed, dried at 60 ^{o}C for 48 hours, ground, and weighed. Furthermore, dry matter, crude protein, and gross energy of feed and excreta were measured. The apparent metabolizable energy (AME), apparent metabolizable energy corrected by nitrogen (AMEn), true metabolizable energy (TME), and true metabolizable energy corrected by nitrogen (TMEn) were calculated using the Sibbald and Wolynetz method (Sibbald & Wolynetz, 1985).

Statistical Analysis

One-way analysis of variance (ANOVA) was used to analyze the data. When significant differences between treatments were identified (p<0.05), Duncan's multiple range test was used to determine the significant difference between the mean values. Statistical analysis was carried out using the computer software of SPSS Statistics Version 21.0.

RESULTS

The inclusion of vitamin E and fish oil in the ration did not affect feed intake, body weight, weight gain, mortality, AME, AMEn, TME, and TMEn (Table 2; Table 3). However, T4 significantly reduced (p<0.05) FCR in the finisher phase. T1 had no mortality, while T2 and T4 had decreased mortality until day 35. Table 4 demonstrates that there was a significant effect of vitamin E and fish oil supplementations (p<0.05) on the proportion of carcass weight. Meanwhile, the treatments did not affect the percentage of thighs and wings weights. Dietary 3% fish oil without vitamin E (T1) and dietary fish oil with 100 IU vitamin E (T3) significantly reduced the percentage of carcass weight compared to the other treatments. The addition of fish oil had a significant (p<0.05) effect on meat cholesterol. T3 and T4 were able to decrease meat cholesterol content. The inclusion of

Table 2. Mean±standard deviation values of growth traits of broiler chicken fed dietary treatment containing fish oil and vitamin E

Variables	Phases	Treatments				
		T0[1)]	T1	T2	T3	T4
Body weight (g/bird)	Starter	166.25±4.35	176.66±5.89	179.50±8.27	176.68±12.59	176.00±2.45
	Grower	716.28±24.98	726.78±32.89	748.88±15.04	752.42±15.20	728.50±28.49
	Finisher	1371±103.86	1430 ±79.83	1430 ±39.30	1511 ±56.69	1477±46.79
Weight gain (g/bird)	Starter	120.25±4.50	130.16±6.68	132.75±8.54	129.93±12.39	129.25±3.30
	Grower	670.28±24.21	680.28±33.36	702.13±15.88	705.67±15.40	681.75±29.05
	Finisher	1325±103.37	1384±79.40	1384±40.14	1464±57.03	1430±47.01
Feed intake (g/bird)	Starter	149.90±6.98	157.18±2.62	155.86±7.42	154.30±7.24	158.95±5.25
	Grower	1043±25.58	1029±30.16	1051±30.33	1019±36.08	1018±21.95
	Finisher	2657±64.12	2586±87.69	2665±57.00	2652 ±54.44	2696 ±74.12
Feed conversion ratio (FCR)	Starter	1.25±0.07	1.21±0.08	1.18±0.02	1.19±0.10	1.23±0.07
	Grower	1.56±0.05	1.51±0.06	1.50±0.07	1.44±0.06	1.49±0.05
	Finisher	2.01±0.14$^{b2)}$	1.87±0.08^{ab}	1.93±0.08^{ab}	1.81±0.06^{a}	1.89±0.05^{ab}
Mortality (%)		1.25±0.96	0.00±0.00	0.50±1.00	1.25±0.96	0.25±0.50

Note: [1)]T0: Control diet with crude palm oil and without vitamin E; T1: Treatment diet containing 3% fish oil; T2: Treatment diet containing 3% fish oil with 80 IU vitamin E; T3: Treatment diet containing 3% fish oil with 100 IU vitamin E; and T4: Treatment diet containing 3% fish oil with 120 IU vitamin E. [2)]Mean values with diferent superscripts were significantly (p<0.05) diferent.

Table 3. Mean±standard deviation values of dietary metabolizable energy of broiler fed lemuru fish oil and vitamin E

Variables[1)]	Treatments				
	T0[1)]	T1	T2	T3	T4
AME (kcal/kg)	2857±72.16	2906±8.06	2739±99.02	2842±109.05	2877±51.48
AMEn (kcal/kg)	2851±72.17	2899±8.52	2733±99.55	2836±109.29	2871±49.83
TME (kcal/kg)	3028±75.02	3050±53.16	2937±142.41	2997±126.19	3051±14.62
TMEn (kcal/kg)	3023±75.22	3043±55.42	2932±143.32	2991±126.72	3045±15.82

Note: [1)]AME: apparent metabolizable energy; AMEn: apparent metabolizable energy corrected by nitrogen; TME: true metabolizable energy; TMEn: true metabolizable energy corrected by nitrogen. [2)]T0: Control diet with crude palm oil and without vitamin E; T1: Treatment diet containing 3% fish oil; T2: Treatment diet containing 3% fish oil with 80 IU vitamin E; T3: Treatment diet containing 3% fish oil with 100 IU vitamin E; and T4: Treatment diet containing 3% fish oil with 120 IU vitamin E.

fish oil and vitamin E increased omega-3 and decreased omega-6, reducing the ratio of omega-6: omega-3 (Table 5).

DISCUSSION

Broiler Performances and Metabolizable Energy

The beneficial effects of dietary vitamin E have been widely observed on broiler performance. Considering vitamin E is the only antioxidant deposited in the animal body, this vitamin has been employed to increase the nutritional value of animal products while also providing a functional nutrient for human health (Felipe *et al.,* 2015). Our study revealed that the inclusion of vitamin E and the usage of fish oil did not influence body weight, body weight gain, and feed intake. Our findings were consistent with those reported by Voljč *et al.* (2011), Mandal *et al*. (2014), Cheng *et al*. (2018), and Pitargue *et al*. (2019). However, our results contradicted to those reported by Selvam *et al.* (2017) and Ismail *et al***.** (2014) that dietary vitamin E improved broiler body weight and feed efficiency. This difference may be caused by a difference in the level of vitamin E inclusion and environmental conditions, where they utilized a dosage of 70 g/ton vitamin E under heat stress circumstances. According to Khan *et al.* (2011), the positive effects of vitamin E inclusion are more noticeable under stressful conditions. Moreover, Pompeu *et al.* (2018) found that the bioavailability of vitamin E depends on the type of vitamin E and diet composition. Another explanation for the lack of vitamin E effects on the whole performance in a recent study might be due to the similar amounts of feed intake as well as the similar content of metabolizable energy and crude protein levels among the treatments. The results also indicate that the administration of fish oil up to 3% did not reduce palatability and could be used to substitute crude palm oil. In our study, it was obtained that vitamin E and fish oil decreased FCR and mortality rate during the finisher phase. A similar finding by Panda *et al*. (2016) found a reduction in FCR due to 3% fish oil inclusion in the broiler diet. A lower mortality rate of birds fed diets containing vitamin E and fish oil might be related to the beneficial impact on the immune response and might be effective in promoting growth, as was evidenced by the tendency to be greater body weight in T3 than the other treatments. It was reported by Bhatti *et al.* (2016) that vitamin E stimulated antibody production thus, it contributed significantly to the enhancement of both cell-mediated and humoral immunity. In addition, according to Silvi *et al.* (2011), vitamin E stimulated glutathione peroxidase enzyme and promoted T lymphocytes activity. The immunomodulatory action of PUFAs is induced through intercellular communication, which affects leukocyte reactivity (Al-Khalaifah, 2020).

Our study revealed no significant difference in AME, AMEn, TME, and TMEn values by including fish

Table 4. Mean±standard deviation values of carcas traits of broiler at 35 days of age fed dietary treatment containing fish oil and vitamin E

Variables		Treatments				
		T0[1)]	T1	T2	T3	T4
Carcass	(g)	995.25±53.22	958.25±97.25	1008.50±55.01	969.50±47.82	979.25±40.26
	(%)	66.77±0.85[a2)]	63.50±3.56[b]	66.76±0.35[a]	63.71±0.45[b]	65.49±1.32[ab]
Breast	(g)	360.25±34.36	352.00±43.10	362.75±24.01	348.25±21.75	354.75±31.74
	(%)	36.73±1.68	36.81±1.59	36.36±1.23	36.22±1.57	36.52±1.81
Thighs	(g)	313.25±17.00	305.00±30.54	301.00±25.29	306.50±28.29	306.25±23.68
	(%)	31.48±0.56	31.83±0.30	29.85±1.15	31.60±1.54	31.29±2.39
Back	(g)	205.25±4.43	193.25±16.32	222.00±13.09	202.75±6.60	199.75±13.94
	(%)	20.67±1.21	20.19±0.46	22.04±0.94	20.96±0.92	20.39±0.91
Wings	(g)	110.75±8.66	107.00±10.86	118.25±9.03	108.50±5.20	115.25±10.44
	(%)	11.12±0.56	11.17±0.50	11.75±0.96	11.22±0.66	11.80±1.42

Note: [1)]T0: Control diet with crude palm oil and without vitamin E; T1: Treatment diet containing 3% fish oil; T2: Treatment diet containing 3% fish oil with 80 IU vitamin E; T3: Treatment diet containing 3% fish oil with 100 IU vitamin E; and T4: Treatment diet containing 3% fish oil with 120 IU vitamin E. [2)]Mean values with diferent superscripts were significantly ($p<0.05$) diferent.

Table 5. Mean±standard deviation values of cholesterol, omega-3, and omega-6 contents of broiler meat at 35 days of age fed dietary treatments containing fish oil and vitamin E

Variables	Treatments				
	T0[1)]	T1	T2	T3	T4
Cholesterol (mg/100g)	18.70±0.94[a2)]	17.85±0.47[ab]	17.43±0.10[ab]	10.33±0.35[c]	8.65±0.33[d]
Omega-6 (%)	16.22	16.38	15.13	15.62	13.52
Omega-3 (%)	0.83	1.43	1.35	1.51	1.14
Ratio of omega-6: omega-3	19.54	11.45	11.21	10.34	11.86

Note: [1)]T0: Control diet with crude palm oil and without vitamin E; T1: Treatment diet containing 3% fish oil; T2: Treatment diet containing 3% fish oil with 80 IU vitamin E; T3: Treatment diet containing 3% fish oil with 100 IU vitamin E; and T4: Treatment diet containing 3% fish oil with 120 IU vitamin E. [2)]Mean values with diferent superscripts were significantly ($p<0.05$) diferent.

oil and vitamin E. It is known that feed intake, feed efficiency, and broiler performance are influenced by the levels of metabolizable energy (Abudabos *et al.*, 2014). Therefore, this is the reason why the experiment did not show significant differences in feed intake and body weight gain, which could be attributed to the similarity of the metabolizable energy content of dietary treatments. Furthermore, it seemed that *Lemuru* fish oil could replace the use of crude palm oil. No difference in metabolizable energy could be due to low oxidation levels in fish oil and palm oil. Ehr *et al*. (2015) supported this argument, stating that feeding peroxidized maize oils to broiler chicks reduced AMEn levels. Many lipid peroxidation compounds contained in the diet might have different effects on lipid metabolism (Liu *et al.,* 2014). Moreover, due to high proportions of unsaturated and polyunsaturated fatty acids, fish oils and palm oil would have contributed to the better composition of poultry diet. The higher concentration of unsaturated fatty acids provides optimal conditions for emulsification and micelle production in the intestine. On the other hand, animal fats having higher saturated fatty acids proportion have lower energy values (Araujo *et al.,* 2019).

Carcass Traits

In our study, the percentages of the breast, thigh, and wing weights were not different. The findings are consistent with Rayani *et al.* (2017) report that supplementation of broiler meals with vitamin E up to 80 IU had no impact on carcass weight. Moreover, the combination of vitamin E and selenium (Se) also did not affect carcass weight under heat stress conditions (Tayeb & Qader, 2012). The inclusion of 3% fish oil without vitamin E (T1) produced the lowest percentage of carcass weight. Our findings were consistent with the results reported by Attia *et al.* (2020) that dietary fish oil produced the lowest carcass weight compared to dietary coconut oil and canola oil. Enhancing omega-3 contents in the diet had a detrimental impact on growth and meat production due to the lower palatability of the diet (Ayed *et al.,* 2015). In this study, there was a positive impact of supplementation of 80 IU/kg vitamin E to the diet containing 3% fish oil on the percentage of carcass weight. However, the addition of vitamin E at a dose of 100 IU/kg (T3) decreased the percentage of carcass. This suggests that combining vitamin E with PUFAs determines the optimum level and efficacy of vitamin E. At the right dose, vitamin E can play an optimum role as an antioxidant (Voljč *et al.,* 2011) and support intestinal growth, including height of villus and crypt depth (Hassanpour *et al*., 2016), which are important for nutrient absorption, broiler growth, and carcass traits. Nevertheless, the excessive supplementation of vitamin E causes hypervitaminosis E that reduces thyroid activities and raises vitamin K and vitamin D requirements in chicks (Nobakht, 2012). NRC (1994) and Aviagen (2014) recommended the vitamin E requirement for broiler diet range from 10.0 IU/kg to 80.0 IU/kg. However, the optimum needs for vitamin E levels are not established because of the effects of various factors, including environmental conditions, production phase, the temperature of processing, the concentration of PUFAs in the diet, and the interactions with the other antioxidants elements such as selenium, zinc, and vitamin C (Felipe *et al.*, 2015).

Meat Composition

Cholesterol, an essential molecule for steroid hormone precursor and bile acids, can be acquired directly from the feed or produced *via de novo* biosynthesis (Ganeco *et al.,* 2020). In our study, vitamin E treatment (T3 and T4) decreased the cholesterol content of meat. According to Ganeco *et al*. (2020), tocopherol may reduce blood cholesterol content in chicken reared in the pasture. Such findings may indicate that vitamin E can be an antioxidant to protect PUFAs against oxidation; thus, it contributes to reducing meat cholesterol. Omega-3 fatty acids may also restrict triacylglycerol metabolism by inhibiting 9-desaturase activity, which reduces the conversion of hepatic very-low-density lipoprotein cholesterol (Long *et al.,* 2018; Chekaniazar & Shahryar, 2018; Sumiati *et al.,* 2021). Voljč *et al.* (2011) confirmed that dietary concentration of 0.2 g/kg of vitamin E enhanced higher oxidative stability of broiler meat receiving a high polyunsaturated fatty acid content in the diet during heat stress. Mariana *et al.* (2018) mentioned that the antioxidant activity of vitamin E might be accomplished by increasing the concentration of glutathione peroxidase enzyme, which prevents tissues from reactive oxygen species.

It is clearly shown in Table 5 that fish oil inclusion rich in omega-3 either with vitamin E addition or without vitamin E can improve omega-3 deposition in the broiler meat. Omega-3 content in the broiler meat fed ration supplemented with 3% fish oil increased approximately by 37% to 82% over the control. These findings are supported by the previous study that dietary fish oil enhances the omega-3 content of poultry meat (Voljč *et al*., 2011; Narciso-Gaytán *et al.,* 2010; Abd El-Samee *et al.,* 2019). Rahimi *et al.* (2011) found that the deposition of omega-3 in broiler meat also increased by dietary supplementations of flaxseed and canola seed. Diets rich in omega-3 fish oil decreased omega-6 content and the ration of omega-6:omega-3. In our study, the lowest ratio of omega-6:the omega-3 was 10.34 (T3). Numerous studies have found that consumption of food with a high ratio of omega-3:omega-6 harms human health because it can increase the production of pro-inflammatory cytokine (Ibrahim *et al.,* 2018). According to Taşdelen & Ceylan (2017), the recommended ratio for human health is between 4:1 and 10:1. Moreover, according to Candela *et al.* (2011)**,** omega-3 series (DHA, EPA, and linolenic acid) and omega-6 (arachidonic acid and linoleic acid) have important functions to prevent and manage cardiovascular disease, diabetes, hypertension, cancer, and other inflammatory-related diseases.

CONCLUSION

Supplementation of 100 IU Vitamin E in the diet containing 3% fish oil improved feed efficiency by 9.95%, decreased cholesterol content of the meat by

44.76%, increased omega-3 content of the meat by 81.92%, and yielded the best ratio of omega-6: omega-3 of the meat, i.e., 10.34:1.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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