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Tadelen, EÖ; Ceylan, N

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■ Author(s)

Taşdelen EÖ¹
Ceylan N¹

¹ Department of Animal Science, Faculty of Agriculture, Ankara University, Turkey

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■ Mail Address

Corresponding author e-mail address
Necmettin Ceylan
Ankara University, Faculty of Agriculture,
Animal Science, Dışkapı, Ankara-Turkey
06110
Tel: +90-312-5961753
Email: ceylan@agri.ankara.edu.tr

■ Keywords

Rapeseed oil, vitamin E, performance and meat quality, oxidative stability, omega-3 fatty acids.

Effects of Dietary Inclusion of Oil Sources With or Without Vitamin E on Body Composition and Meat Oxidation Level in Broilers*

ABSTRACT

The objective of this study was to investigate the effects of rapeseed oil substitution and vitamin E supplementation on performance and meat quality. 4 replacement levels of rapeseed oil with sunflower oil (0, 33.3, 66.7 and 100%) and 2 levels of vitamin E (0 (50 I.U. from vitamin premix) 300 mg/kg) in a 2 x 3 factorial arrangement for a total of 8 treatments with 4 replicates each, containing 10 day-old male Ross 308 broilers, were examined in the experiment. Dietary treatments had no significant effect on carcass parameters, feed conversion (FCR) and mortality ($p>0.05$). However, a significant interaction was observed between oil replacement and vitamin E: the negative effect of 100% sunflower oil on BWG ($p<0.01$) was alleviated by the addition of vitamin E. On the other hand, inclusion of rapeseed oil improved BWG ($p<0.01$). Rapeseed oil substitution significantly increased amount of total n-3 PUFA and decreased n-6:n-3 ratio in thigh and breast meat ($p<0.01$). Vitamin E supplementation contributed to deposition of n-3 PUFA ($p<0.01$). Replacement of rapeseed oil without vitamin E tended to increase ($p<0.01$) malonaldehyde production. However, the dietary supplementation of vitamin E markedly ($p<0.01$) decreased the susceptibility of meat to peroxidation. Inclusion of rapeseed oil did not cause any negative perception on olfactory, texture, and taste of broiler meat. So, it can be concluded that rapeseed oil substitution significantly increased n-3 PUFA deposition without altering performance and sensory properties of broiler meat and, vitamin E had strong potential to prevent the meat lipids from oxidation.

INTRODUCTION

Ancestral human nutrition studies revealed that, compared to today's diets, the amount of fat in a balanced diet did not exceed 20-30% of total energy intake, in which 5-6 g/d of omega-3 poly unsaturated fatty acids (n-3 PUFA) with rich eicosapentanoic acid (EPA, C20:5n-3) + docosahexaenoic acid (DHA, 22:6n-3) and the ratio of n-6:n-3 averaged 1:1 or 1:2 with low saturated and trans fatty acids (FAs). Nowadays, this ratio has changed to 15:1 to 20:1, which points out the significantly reduced amount of n-3 PUFA in the diets (Simopoulos, 2000; Simopoulos, 2008; Molendi-Coste *et al.*, 2011) but the approved ratio for human health is actually between 4:1 to 10:1 (Mazalli *et al.*, 2004).

Broiler chickens generally have a high capacity for lipid biosynthesis which has the propensity to become excessively fat. This fat accumulation has significant health implications, as carcass fat of birds is an important source of dietary fat for man (Newman *et al.*, 2002). Therefore, the FA composition of broiler's thigh and breast muscle is an important quality parameter especially with respect to potentially affecting human health from poultry meat consumption. In this regard, n-3 PUFAs such as EPA,



docosapentaenoic acid (DPA, 22:5n-3), and DHA are some of the most important FA groups (Rahimi *et al.*, 2011).

Fish (especially oily fish such as mackerel, herring, sardine, salmon, trout, and tuna), in spite of containing natural sources of EPA and DHA, has been rarely or never consumed by some people because of its olfactory problems, while demand for other meat productions such as chicken has been increasing (Molendi-Coste *et al.*, 2011; Nyquist *et al.*, 2013). It has been shown that FA composition of broiler meat can be altered by inclusion of different vegetable and fish oil sources in chicken's diet (Lopez-Ferrer *et al.*, 2001a). Therefore, in order to supply human consumer's diet with n-3 PUFAs and antioxidants such as vitamin E, methods must be utilized to enrich chicken's diet with EPA and DHA or their precursor linoleic acid (LA; 18:2n-6). During the last four decades many studies have been conducted to manipulate FA profile of broiler muscle tissues in order to increase n-3 PUFA content and decrease n-6 : n-3 ratio (Miller & Robisch, 1969; Zduńczyk *et al.*, 2011; Haug *et al.*, 2011; Rahimi *et al.*, 2011; Nyquist *et al.*, 2013).

The following order shows the oxidative capacity of different meat types: fish > turkey > chicken > pork > beef > lamb. This ranking depends on the content of the PUFA in muscle tissues (Janssens *et al.*, 1999). Negative effect of enriching meat with "good for health" PUFA results from these compound's sensitivity to oxidation that produces "bad for health" pro-oxidant free radicals which may enhance the development of sensory problems. Oxidative damage increases during storage and cooking process based on the time and temperature (Cortinas *et al.*, 2004; Barroeta, 2007; Roux *et al.*, 2011). Inclusion of the vitamin E in broiler diet leads to increased vitamin E in the meat which improves membrane stability. This may boost meat and meat production's resistance to peroxidation (Coetzee & Hoffman, 2001). That is why the addition of vitamin E has been suggested as a convenient method in improving oxidative stability and increasing the shelf life of meat (Coetzee & Hoffman, 2001; Barroeta, 2007). Diet manipulation or changes in feed processing stages, utilizing methods to decrease feed cost, and quality control of final products during development of new food products often demand sensory evaluation techniques to determine the products acceptability (Srinivassane, 2011). The sensory properties of n-3 FA enriched meat products should be assessed for consumer's acceptance before introduction into the market. Sensory analysis provides

a better understanding of consumer perception of food products (Srinivassane, 2011).

The objective of the current study was to determine the effects of dietary replacing levels of sunflower and rapeseed oils and supplemented or unsupplemented with α -tocopheryl acetate (as a commercial source of vitamin E) on the FA profile and thiobarbituric acid reactive substances (TBARS) level of thigh and breast chicken meat. The other aim of the present study was the determination of the acceptability of n-3 PUFA enriched chicken meat by sensory evaluation.

MATERIALS AND METHODS

All protocols for the experiment were reviewed and approved by the Local Animal Care and Use Committee of Ankara University.

Diet Preparation

Before preparation of the experimental diets, crude protein, crude ash, crude fat and dry matter of corn and soybean were determined (AOAC, 2000). The corn and soybean meal were ground in a mill with a three millimeter sieve for starter (0-3 weeks) periods. Vitamin and mineral premix, vitamin E, lysine, methionine and salt were mixed by a 3 kg capacity laboratory Lödige® mixer at the department of Feed and Animal Nutrition of University of Ankara. During ration preparation at the Ankara University feed factory, the mixture of micro ingredients were mixed with a fine grained soybean meal. Then, this mixture was added to the corn and soybean meal blending in the mixer. Finally, the experimental oil was slowly poured into the mixer. After a 3-minute mixing period, the diet was packed in 40 kg sacks and stored at a dry place at room temperature (20-22°C) during the trial. The same procedure was followed in preparing the diet for grower-finisher (4-6 weeks) periods with only one difference in which the corn and soybean meal were ground in a mill with a five-millimeter sieve. Experimental diet and the composition of starter and grower-finisher diets are shown in Table 1 and 2 respectively. The composition of the diets were adjusted according to the NRC (National Research Council, 1994) and met or exceeded the nutritional recommendations of Ross 308 breeders company catalog for broilers.

The dietary oil level was 6 and 7% for starter and grower-finisher periods respectively. At each feeding period rapeseed oil was replaced by 0, 33.3, 66.7 and 100% levels of sunflower oil. At the same time two different levels of dl- α -tocopherol acetate (0 (only

**Table 1** – Experimental design

Dietary Treatments	Experimental periods					
	Starter			Grower-Finisher		
	Sunflower oil (%)	Rapeseed oil (%)	Vitamin E (mg/kg)	Sunflower oil (%)	Rapeseed oil (%)	Vitamin E (mg/kg)
T1	6.0	0.0	0.0	7.0	0.0	0.0
T2	6.0	0.0	300.0	7.0	0.0	300.0
T3	4.0	2.0	0.0	4.7	2.3	0.0
T4	4.0	2.0	300.0	4.7	2.3	300.0
T5	2.0	4.0	0.0	2.3	4.7	0.0
T6	2.0	4.0	300.0	2.3	4.7	300.0
T7	0.0	6.0	0.0	0.0	7.0	0.0
T8	0.0	6.0	300.0	0.0	7.0	300.0

Table 2 – Composition of starter and grower-finisher diets, g/kg air-dry diets

Ingredients	Dietary treatments ¹							
	Starter period (0-3 weeks)				grower-finisher period (4-6 weeks)			
	T1	T2	T3	T4	T1	T2	T3	T4
Maize	509.99	509.99	509.99	509.99	545.83	545.83	545.83	545.83
Soyabean meal (46 %CP)	374.80	374.80	374.80	374.80	347.49	347.49	347.49	347.49
Fish meal (70 %CP)	15	15	15	15	-	-	-	-
Sunflower oil	60	40	20	0.0	70	46.69	23.31	0.0
Rapeseed oil	0.0	20	40	60	0.0	23.31	46.69	70
Limestone	11.15	11.15	11.15	11.15	12.3	12.3	12.3	12.3
Dicalcium phosphate	15.89	15.89	15.89	15.89	13.90	13.90	13.90	13.90
DL-methionine	3.17	3.17	3.17	3.17	2.06	2.06	2.06	2.06
L-lysine	2.80	2.80	2.80	2.80	1.42	1.42	1.42	1.42
Vitamin premix ²	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Mineral premix ³	1	1	1	1	1	1	1	1
NaCl	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Anticoccidial	0.2	0.2	0.2	0.2				
Total	1000	1000	1000	1000	1000	1000	1000	1000
Analysed composition								
ME, kcal/kg	3104.56	3097.23	3104.64	3109.45	3193.07	3190.09	3195.39	3211.38
Crude protein,%	22.97	23.06	23.19	23.02	19.94	20.25	20.05	20.06
Crude fat,%	8.71	8.74	8.54	8.719	10.20	10.22	10.13	10.27
Crude fiber, %	3.48	3.47	3.48	3.50	3.17	3.09	3.13	3.13
Crude ash,%	6.50	6.49	6.30	6.60	6.54	6.49	6.30	6.60
Dry matter, %	90.36	90.33	90.44	90.35	90.33	90.66	90.41	90.59
Ca, %, calculated	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90
P _(available) %, calculated	0.45	0.45	0.450	0.450	0.37	0.37	0.37	0.37

¹ see Table 1² Vitamin premix: each 2.5 kg contain: 12 000 000 I.U. Vit. A, 1 500 000 I.U. Vit. D₃, 50 I.U. dl-alpha-tocopherol acetate, 5 000 mg Vit. K₃, 3 000 mg Vit. B₁, 6 000 mg Vit. B₂, 25 000 mg niasin, 12 000 mg calcium-D- pantothenate, 5 000 mg Vit. B₆, 30 mg Vit. B₁₂, 1 000 mg folic acid, 5 mg D-Biotin, 2 500 mg apocarotenoid acid ester, 400 000 mg choline chloride³ Mineral premix: each 2.5 kg contain: 80 000 mg Mn, 30 000 mg Fe, 60 000mg Zn, 5 000 mg Cu, 500 mg Co, 2 000 mg I, and 235.680 mg Ca₂CO₃

50 I.U. comes from vitamin premix) and 300 mg/kg) was also added to each diets. Thus the experiment was conducted as a randomized block design with a factorial arrangement of 4×2. The diets were also analysed for dry matter, protein and crude fat, crude fiber, starch and sugar according to AOAC (2000). The ME content of the diets was then calculated according to the following WPSA Formula (1984); ME [kcal/kg]=[3.69×% crude protein{CP}+8.18×% ether extractable fat{EE}+3.99×% starch+3.11×% sugar)].

Birds and housing

Three hundred and twenty commercial Ross × Ross 308 newly hatched broiler chickens were randomly allocated to eight isocaloric and isonitrogenous dietary treatments with four replicates. Ten chicks were randomly assigned to each of 32 battery wire cages with eight groups of four pens each.

Ambient temperature was gradually decreased from 33 °C at first day to 21-22°C after 3 weeks of age thereafter by thermostatically controlled heater


Table 3 – FA profile of dietary sunflower and rapeseed oil (% of total FAs)

Parameters		Sunflower oil	Rapeseed oil
Miristic	C14:0	0.06	0.04
Palmitic	C16:0	5.87	4.50
Palmitoleic	C16:1	0.09	0.24
Heptadecanoic	C17:0	0.03	0.05
Stearic	C18:0	3.89	1.67
Oleic	C18:1	28.81	61.22
Linoleic	C18:2n-6	60.40	20.82
Linolenic	C18:3n-3	0.09	9.04
Arachidic	C20:0	0.08	1.22
Eicosaenoic	C20:1	-	0.57
Behenic	C22:0	0.68	0.32
Erusic	C22:1	-	0.28
ΣSFA		10.61	7.8
ΣMUFA		28.9	62.31
ΣPUFA		60.49	29.86
ΣPUFA n-6		60.40	20.82
ΣPUFA n-3		0.09	9.04
n-6:n-3		671.11	2.30

fan. Relative humidity was maintained at 50±5%. Initial mean and range of body weight were similar (Table 5) for all pens. Experimental place was artificially ventilated and incandescent light was provided for 24 hours for the first three days and followed by thirty nine days with 23 hours light. Each cage was equipped with two inside nipple drinkers and an outside galvanized

feed trough. The birds had *ad libitum* access to feed (mash form) and water during the experiment. Health status and mortality of birds was controlled daily during the entire experimental period.

Data collection

Performance data, average weekly feed intake (FI) and body weight gain (BWG) were recorded. FCR was calculated from feed consumed per unit of BWG. These data are presented in Table 5 on a periodic basis (1-21, 22-42 and 1-42 day). Mortalities were recorded daily. On day 42 after a 10-hour feed withdrawal, 128 birds (4 birds per replicate) were slaughtered manually and allowed to bleed for 3 minutes. Having soaked in +60°C water for approximately 50 seconds the carcasses were defeathered mechanically. Carcasses were manually eviscerated and refrigerated to reach +4°C. Then, carcass and carcass parts yield data were collected from 128 broilers (4 birds per replicate) which included carcass yield, thigh, breast, and abdominal fat pad weight.

Carcasses were evaluated as follows: the complete deboned skinless right thigh and breast (pectoralis major + pectoralis minor) meat were removed from the chilled carcasses (4 °C) and frozen at -26°C for 7 days before sensory analyses (olfactory, tenderness and juiciness, taste). Organoleptic characteristics of

Table 4 – FA profile of experimental diets, sunflower oil and rapeseed oil (% of total FAs)

		Dietary treatments ¹							
		Starter period				grower-finisher period			
Fatty acids ²		T1	T2	T3	T4	T1	T2	T3	T4
Miristic	C14:0	0.17	0.14	0.11	0.13	0.17	0.18	0.14	0.12
Miristoleic	C14:1	0.14	0.20	0.12	0.12	0.15	0.14	0.14	0.08
Palmitic	C16:0	21.12	19.71	17.08	15.07	20.46	18.07	16.95	13.97
Palmitoleic	C16:1	0.35	0.23	0.25	0.25	0.25	0.25	0.24	0.33
Heptadecanoic	C17:0	0.14	0.14	0.15	0.18	0.11	0.12	0.14	0.10
Stearic	C18:0	8.79	7.50	5.89	4.42	8.24	6.93	5.76	3.72
Oleic	C18:1	46.84	52.05	57.30	61.21	49.45	54.44	57.61	60.83
Linoleic	C18:2n-6	10.62	7.29	6.59	5.58	9.79	9.30	6.66	6.91
Linolenic	C18:3n-3	-	0.17	0.31	0.40	0.16	0.19	0.25	1.51
Arachidic	C20:0	0.39	0.57	0.48	0.57	0.34	0.44	0.45	0.48
Eicosapentaenoic	C20:5n-3	5.18	6.61	6.70	7.02	5.45	5.03	6.66	6.68
Behenic	C22:0	3.89	3.76	3.32	3.86	3.75	2.75	3.18	2.80
Docosapentaenoic	C22:5n-3	0.54	0.61	0.42	0.43	0.53	0.55	0.50	0.37
Docosahexaenoic	C22:6n-3	1.82	1.02	1.27	0.77	1.13	1.60	1.32	2.11
ΣSFA		34.5	31.82	27.03	24.23	33.07	28.49	26.62	21.19
ΣMUFA		47.33	52.48	57.67	61.58	49.85	54.83	57.99	61.24
ΣPUFA		18.16	15.7	15.29	14.2	17.06	16.67	15.39	17.58
ΣPUFA n-6		10.62	7.29	6.59	5.58	9.79	9.30	6.66	6.91
ΣPUFA n-3		7.54	8.41	8.7	8.62	7.27	7.37	8.73	10.67
n-6:n-3		1.41	0.86	0.76	0.65	1.34	1.26	0.79	0.65

¹see Table 1

²ΣSFA=total saturated fatty acids; ΣMUFA=total monounsaturated fatty acids; ΣPUFA=total polyunsaturated fatty acids.


Table 5 – Effects of dietary sunflower and rapeseed oil with or without vitamin E on performance of broilers²

Treatments ¹	BWG, g/day			FI, g/period			FCR, kg feed /kg BWG			
	Initial weight g/bird	0-3	4-6	0-6	0-3	4-6	0-6	0-3	4-6	0-6
T1	45.33±0.48	638.40±20.7	1168.0±76.8 ^c	1806.4±94.4 ^c	811.4±20.6	2118.3±35.2 ^b	2929.7±45.4 ^b	1.27±0.01	1.83±0.09	1.63±0.06
T2	45.20±0.41	681.80±13.4	1275.1±45.9 ^{ab}	1956.9±57.8 ^{ab}	838.4±13.1	2267.8±26.1 ^a	3106.2±42.7 ^a	1.23±0.02	1.78±0.04	1.59±0.03
T3	45.35±0.43	708.90±7.83	1251.0±56 ^{ab}	1959.9±60.4 ^{ab}	885.5±7.59	2290.8±16.7 ^a	3176.2±30.0 ^a	1.24±0.01	1.84±0.07	1.62±0.04
T4	45.12±0.39	717.13±7.56	1264.5±66.5 ^{ab}	1981.6±69.7 ^{ab}	859.6±7.33	2310.7±18.7 ^a	3170.4±23.0 ^a	1.19±0.01	1.84±0.09	1.60±0.05
T5	45.20±0.40	677.00±24.8	1323.0±67.2 ^a	2000.3±82.2 ^a	838.1±24.6	2337.4±65.7 ^a	3175.5±81.9 ^a	1.23±0.02	1.77±0.06	1.59±0.04
T6	45.25±0.35	679.00±11.6	1210.1±77.5 ^{bc}	1889.1±71.1 ^{ab}	835.1±11.8	2228.6±76.2 ^{ab}	3063.7±73.8 ^a	1.23±0.01	1.85±0.06	1.62±0.02
T7	45.25±0.35	683.30±10.5	1277.1±24.8 ^{ab}	1960.3±17.2 ^{ab}	842.4±10.7	2331.6±36.2 ^a	3174.0±46.7 ^a	1.23±0.01	1.82±0.05	1.61±0.03
T8	45.32±0.34	675.20±13.1	1248.2±65.3 ^{ab}	1923.4±69.3 ^{ab}	836.0±13.1	2310.3±40.4 ^a	3146.3±40.7 ^a	1.23±0.01	1.86±0.07	1.64±0.04
p value	ns	ns	0.001	0.001	ns	0.05	0.04	ns	ns	ns
Main effects										
Oil replacement level										
0%	45.26±0.29	660.10±14 ^b	1221.6±46.1	1881.7±58.6	824.9±12.3 ^b	2193.0±34.8 ^b	3017.9±44.1 ^b	1.25±0.01	1.80±0.05	1.61±0.03
33.3%	45.23±0.27	713.01± 5.27 ^a	1257.8±40.3	1970.8±42.9	872.5±9.28 ^a	2300.8±12.2 ^a	3173.3±17.5 ^a	1.22±0.01	1.84±0.05	1.61±0.03
66.7%	45.22±0.24	678.00±12.7 ^b	1266.7±52.1	1944.7±55.2	836.6±12.8 ^a	2283.0±50.9 ^a	3119.6±55.2 ^a	1.23±0.01	1.81±0.04	1.60±0.02
100%	45.28±0.22	679.23± 7.9 ^b	1262.6±32.8	1941.9±33.8	839.2±13.0 ^a	2321.0±25.4 ^a	3160.2±29.1 ^a	1.23±0.02	1.84±0.04	1.63±0.02
P value	ns	0.01	ns	0.059	0.05	0.01	0.01	ns	ns	ns
Vitamin E										
0 mg/kg	45.28±0.18	676.90±10.1	1254.8±30.3	1931.7±36.9	844.4±10.2	2269.5±29.8	3113.8±36.7	1.24±0.009	1.81±0.03	1.61±0.02
300 mg/kg	45.22±0.17	688.28±6.7	1249.5±29.7	1937.7±31.4	842.3±8.4	2279.4±22.4	3121.6±24.1	1.22±0.007	1.83±0.03	1.61±0.01
p value	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Intractions	ns	ns	0.002	0.003	ns	0.02	0.03	ns	ns	ns

¹ see Table 1

² BWG - body weight gain, FI - feed intake and FCR - feed conversion ratio

^{a-c} means followed by different letters within columns are significantly different (p<0.05).



thigh and breast meat were performed with untrained panelists, consisting of 16 bachelor students. Meat samples were prepared according to the method based on Hugo *et al.* (2009). Before cooking, samples were thawed overnight at 4°C. Meat samples were lightly-salted and steamed (200°C) in an oven, until a constant internal temperature of nearly 90°C was reached. The cooked thighs and breasts were cut into smaller cubes of 2.5 × 2.5 × 2.5 cm and then served to the panelists. Each sample was served in a plate, covered with a square of aluminium foil (which are available at local markets for cooking). Tasting was performed at room temperature (20 – 22°C) under white fluorescent lighting. Hedonic scale (1 to 9) was used for acceptability analysis. Numbers 1 to 9 were respectively assigned for dislike extremely, dislike very much, dislike moderately, dislike slightly, neither like nor dislike, like slightly, like moderately, like very much, and like extremely. Three series of questionnaires were prepared based on hedonic scale for the odour, tenderness and juiciness, and taste. Tepid water was used by panellists for palate cleaning between samples.

The complete deboned skinless left thighs and breasts (pectoralis major + pectoralis minor) were also collected and two tissue samples were taken from each. The first set of samples were frozen at -26°C for crude protein, crude fat, and FA profile analysis. The second set of samples of left thigh and breast muscle were stored at +4°C for 1, 3, 6 and/or 9 days until TBARS value determination.

Chemical analysis

All 128 left thigh and breast samples from all treatments were used for FA analysis. The FA profile of the experimental oils and diets were also determined. The total fat of oils, diets, thigh and breast muscles were extracted according to the method described by Blight *et al.* (1959).

The FA profile was determined by means of gas chromatography (Hewlett-Packard Company, Wilmington, DE, A.B.D.) equipped with a BPX70 capillary column (SGE capillary column; length, 25 m; I.D., 0.25 mm, 0.25 µm film) and a flame ionization detector. The operating conditions of the gas chromatograph were as follows: the initial temperature was 190 °C for 5 min, increasing by 3 °C/min to 220 °C remained stable at final temperature for 25 min, the injection temperature was 250 °C and the detector temperature was 260 °C. The FA percentage was integrated and then calculated by means of direct normalization of the peak areas. Each FA was identified in the form of a methyl ester by comparing the retention times with the

Supelco 37 Component FAME Mix standard acquired at Sigma Interlab A.S. (Interlab S.A. Istanbul, Turkey).

The extent of lipid peroxides in thigh and breast meat samples (1, 3, 6 and/or 9 days of storage at +4°C temperature) was assessed by measuring TBARS according to the method described by Tarladgis *et al.* (1960).

Statistical Analysis

Statistical analyses of data was conducted as a randomized block design, with a factorial arrangement of 4×2, taking into consideration main effects of inclusion of replacement levels of sunflower oil by rapeseed oil (% 0, % 33.3, % 66.7 ve % 100) and vitamin E levels (0 and 300 mg/kg) with an equal number of 4 replicates for each treatment. The SAS programme (2001) was used for data analysing. When necessary mean separation was accomplished by using Duncan's multiple-range test a probability value of less than 0.05 was considered significant, unless otherwise noted. All percentage data were subjected to arcsine square root transformation (Steel & Torrie, 1960).

RESULTS AND DISCUSSION

The FA compositions of experimental oils are shown in table (Table 3). The ratio between n-6 and n-3 FA were 671.11 and 2.30 in the sunflower and rapeseed oil, respectively. Rapeseed oil in comparison with sunflower oil contains higher level of MUFA of oleic acid type (61.22 vs 28.81 respectively) and lower level of n-6 PUFA (LA; 18:2n-6) (20.82 vs 60.40 respectively). FA profile of diets (Table 4) clearly reflected the origin of the added oils. As expected, the sunflower oil diet contained a greater proportion of LA (18:2n-6) which was the major FA (60.40%) compared to rapeseed oil diet (20.82%) the only one of the n-6 series.

Body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) of chicks fed the different experimental diets are shown in Table 5. Dietary oil level had significant effect on BWG during the starter period of trail so that, birds fed on diet containing 33.3 % replacing level had the highest BWG ($p=0.01$); the effect of vitamin E and its interaction with dietary oil was not significant for starter period. The interaction of vitamin E and oil was significant in grower-finisher phase ($p=0.002$) and over the whole period ($p=0.003$) (Table 5).

FI was increased in all oil replacing levels (33.3, 66.7 and 100 %) during the starter ($p=0.05$), grower-finisher ($p=0.01$) and whole period of the trail ($p=0.01$). Oil



and vitamin E interaction was significant for grower-finisher ($p=0.02$) and whole period ($p=0.03$).

FCR in the different treatment groups showed no significant differences (Table 5). The vitamin E effect on performance (BWG, FI, and FCR) was also not significant.

Advantages of dietary oil in broiler are: a) increasing the absorption and digestion of lipoproteins, b) lower heat increment of fat toward other energy sources such as carbohydrates or proteins, and c) also they assist vitamin A, vitamin E and Ca absorption (Leeson & Atteh, 1995). Rahimi *et al.* (2011) fed the day old Coob 500 broilers with different levels of full fat canola seed and / or flaxseed for 42 days. They showed that the use of full fat seed in the broiler diet has the lowering ($p<0.01$) effect on FI. This might be due to, in one hand, the higher fat content diet which reduces the digestion, absorption, and FA synthesis. On the other hand it increases rate of lipid catabolism (Sanz *et al.*, 2000). The results related to FCR in the current study are similar to the findings of Viveros *et al.* (2009) and Burlikowska *et al.* (2010) indicating that dietary fat sources had no significant effect on performance parameters (BWG, FI, and FCR). However, Atteh & Leeson (1983) reported that saturation degree of a dietary fat can influence FI, BWG and FCR which results from better availability of energy from PUFA.

Oils with PUFA produce higher energy and upgrade the performance, because compared to oils that contain saturated fatty acids they are absorbed easier consequently, as explained by Dvorin *et al.* (1998), birds fed on diet containing high levels of PUFA have better BWG. Moreover, digestion and absorption of dietary fat depend also on the age of the birds (Burlikowska *et al.*, 2010). The lack of the vitamin E effect on performance in the current study is similar to the findings of Coetzee & Hoffman (2001) and Hsieh *et al.* (2002). As in the current study all dietary treatments were isocaloric and isonitrogenous it seems that dietary vitamin E had no increasing effect on protein or energy utilization in the different treatments. It has been suggested that under commercial conditions, the inclusion of high level of dietary vitamin E is the most beneficial and significantly improved performance will occur more frequently where there is a challenge to the host's defence system (McIlroy *et al.*, 1993). The current study was performed in an experimental facility which high level of hygienic principles. Total mortality during the whole experiment was below 2.5% for all treatments ($p>0.05$).

No statistical differences were observed for carcass yield or abdominal fat between the control and the test diet groups. Additionally, thigh and breast fat and crude protein percentages were unaffected by treatments (Table 6).

Table 6 – Effects of dietary sunflower and rapeseed oil with or without vitamin E on some carcass parameters of broiler

Treatments ¹	Carcass yield (% of live body weight)	Abdominal fat (% of live body weight)	Thigh fat %	Thigh protein %	Breast fat %	Breast protein %
T1	76.8±0.6	1.16±0.10	8.80±0.20	19.97±0.10	6.12±0.20	21.39±0.50
T2	78.9±1.1	1.22±0.10	9.08±0.11	19.57±0.08	6.30±0.12	22.65±0.10
T3	76.9±1.6	0.97±0.11	9.30±0.11	19.43±0.20	6.60±0.10	22.12±0.06
T4	77.6±0.2	1.81±0.12	8.70±0.30	19.95±0.30	6.42±0.08	22.40±0.20
T5	78.3±0.8	1.16±0.20	9.10±0.15	19.78±0.03	6.60±0.20	21.90±0.10
T6	78.2±0.9	1.00±0.07	9.04±0.14	19.88±0.21	6.66±0.21	21.24±0.39
T7	78.3±0.9	0.90±0.13	9.06±0.14	19.52±0.32	6.50±0.13	22.84±0.31
T8	77.1±0.9	1.10±0.13	9.10±0.21	20.12±0.05	6.44±0.12	22.54±0.20
p value	ns	ns	ns	ns	ns	ns
Main effects						
Oil replacement level						
0%	77.8±0.7	1.10±0.10	8.95±0.15	19.77±0.10	6.21±0.1	22.02±0.35 ^b
33.3%	77.2±0.7	0.80±0.08	9.03±0.21	19.69±0.21	6.51±0.11	22.26±0.13 ^b
66.7%	78.2±0.5	1.08±0.10	9.11±0.09	19.78±0.10	6.63±0.15	21.57±0.24 ^b
100%	77.7±0.6	1.05±0.09	9.10±0.13	19.82±0.20	6.47±0.10	22.69±0.20 ^b
p value	ns	ns	ns	ns	ns	0.01
Vitamin E						
0 mg/kg	77.58±0.5	1.05±0.09	9.07±0.09	19.68±0.11	6.46±0.11	22.06±0.19
300 mg/kg	77.99±0.4	1.28±0.07	8.98±0.11	19.88±0.10	6.45±0.07	22.20±0.20
p value	ns	ns	ns	ns	ns	ns
Interactions						
	ns	ns	ns	ns	ns	ns

¹ see Table 1



Some studies have shown that total fat content in tissues are reduced by increasing the dietary PUFA level (Cortinas *et al.*, 2004; Shen *et al.*, 2005). High rate of lipid metabolism and low FA synthesis are the reasons of low fat deposition (Sanz *et al.*, 2000). These observations are inconsistent with the current results. There is also evidence that dietary PUFA level had no effect on the intramuscular lipid content of breast meat (Scaife *et al.*, 1994; Crespo & Esteve-Garcia, 2002).

Fat deposition in the tissues is the result of absorption, de novo synthesis, and oxidation of fatty acids. Studies showed that dietary PUFA decreases hepatic lipogenesis and increases the metabolic rhythm, specifically causing a higher β -oxidation rate and inhibits de novo fatty acid synthesis (Shimomura *et al.*, 1990; Sanz *et al.*, 2000; Barroeta, 2007).

In the addition of vitamin E to the diet and the reduction of lipid oxidation, the following must be taken into consideration: vitamin E reduces linolenic acid (LNA; 18:3n-3) oxidation which leads to the reduction of lipogenesis and β -oxidation of FA in liver, which approximately reduces the total lipid deposition in tissues such as thigh and breast. But, in the present study there was no significant difference in the thigh and breast lipid level among experimental groups. Increases in the level of LNA in the body stimulates n-6 PUFA metabolism which affects n-6: n-3 ratio (Zanini *et al.*, 2003). Our findings showed that increases in dietary rapeseed oil level decreased the n-6: n-3 ratio.

FA composition of chicken tissues is a combination of *in vivo* synthesis of FAs, from carbohydrate and protein precursors, and direct deposition from the diet. SFA and MUFA have this double origin, whereas PUFA deposition depends almost exclusively on dietary supplementation when no essential FA deficiency exists. The main FAs resulting from hepatic lipogenesis are 16:0, 18:0, 18:1n-9 and 16:1n-7 (Villaverde *et al.*, 2006). In the current study the FAs found in thigh and breast meat (Table 7 and 8 respectively) reflected the dietary FA profile so that, increasing dietary PUFA inclusion led to higher deposition of PUFA, while it had the opposite effect on the deposition of SFA and MUFA which as described in literature, is due to an inverse relation between PUFA, SFA and MUFA deposition. Liver is where MUFA is synthesized. The presence of PUFAs in the diet leads to lower conversion of SFA into MUFA due to inhibitory effects of PUFAs on the activity of the enzyme $\Delta 9$ -desaturase in the liver (Ajuyah *et al.*, 1991; Lopez-Ferrer *et al.*, 2001a,b; Villaverde *et al.*, 2006; Smink *et al.*, 2010). The high concentration of LA (18:2n-6) in the diet with only sunflower oil was

reflected in its significantly greater incorporation into thigh and breast muscle compared with the 100% rapeseed oil dietary group ($p=0.001$). Thigh meat in birds fed on diet containing the 100 % of replacement had the highest level of the LNA ($p=0.001$) and EPA ($p=0.001$). The breast meat level of the LNA ($p=0.001$), EPA ($p=0.008$), and DHA ($p=0.001$) were the most highest for the 100 % replacement in comparison to other groups. As it's shown in Table 4, the relative proportions of thigh and breast incorporation of the mentioned FAs were almost similar to the dietary proportion of LNA, EPA, and DHA. The amount of the Σ SFA was the highest both in thigh and breast meat of birds fed on diets containing only sunflower oil (0% replacing) and as it's shown in Table 7 and 8 the Σ SFA amount was decreased by increasing the replacement rate of sunflower oil but the effect of vitamin E and it's interaction with dietary oil were not significant for Σ SFA. In contrast, thigh and breast muscle from birds that recieved only rapeseed oil, had a significantly higher ($p=0.001$) proportion of Σ PUFA n-3 compared to the group that recieved only sunflower oil. The n-6:n-3 ratio for thigh and breast muscle of 66.7 and 100 % replacing group was the lowest ($p= 0.001$) compared to other groups. Our findings are in agreement with other studies (Rahimi *et al.*, 2011; Gallardo *et al.*, 2012). More recently Gallardo *et al.* (2012) fed the broiler chickens with four diets containing 15% oil with different percentages of canola oil (0, 5, 10, 15%), for 31 days. They concluded that canola oil increased the content of n-9 and n-3 FAs and decreased the content of n-6 FAs in meat, fat and plasma.

Our findings also showed that the effect of dietary oil level, vitamin E and their interaction were significant for LNA level in both thigh ($p= 0.001, 0.002, 0.002$) and breast ($p= 0.001, 0.001, 0.02$). The effect of vitamin E and the vitamin E \times oil interaction were also significant for n-6:n-3 ratio (Table 7 and 8). The effect of vitamin E on tissue FA profile is rather contradictory. Some authors reported a higher level of some n-3 PUFA in thighs (Ahn *et al.*, 1995; Surai & Sparks, 2000) and breasts (Ajuyah *et al.*, 1993; Zanini *et al.*, 2003). Some researchers believe that vitamin E not only protects unsaturated FAs from oxidation, but also stimulates FA synthesis since α -tocopherol quinone, as a product of tocopherol metabolism, is an essential cofactor of the FA desaturases (Infante, 1999). More recently it has been shown that supplementation of vitamin E protected PUFA well, increasing DHA deposition in abdominal tissue (Lu *et al.*, 2014). On the other hand some studies reported no variation in


Table 7 – Effects of dietary sunflower and rapeseed oil with or without vitamin E on FA profile of thigh meat (% of total FAs)¹

Treatments ²	Fatty acids ²													
	C16:0	C18:0	C18:1	C18:2n-6	C18:3n-3	C20:5n-3	C22:5n-3	C22:6n-3	ΣSFA	ΣMUFA	ΣPUFA	ΣPUFA n-6	ΣPUFA n-3	n-6:n-3
T1	15.39 ±0.65	4.70 ±0.16	34.77 ±0.61	40.28 ±1.45	0.81 ±0.02 ^e	0.007 ±0.007	0.01 ±0.010	0.01 ±0.01	20.93 ±0.80	37.93 ±0.68	41.13 ±1.48	40.28 ±1.45	0.85 ±0.03	47.22 ±1.29 ^a
T2	14.04 ±0.22	5.06 ±0.29	42.82 ±0.31	40.55 ±1.77	1.37 ±0.06 ^d	0.02 ±0.007	0.03 ±0.006	0.03 ±0.002	20.06 ±0.35	45.11 ±0.63	42.01 ±1.84	40.55 ±1.77	1.46 ±0.06	27.73 ±0.32 ^b
T3	13.55 ±0.81	4.62 ±0.14	35.66 ±0.47	37.50 ±0.88	1.92 ±0.06 ^c	0.01 ±0.009	0.04 ±0.007	0.02 ±0.01	19.27 ±0.89	37.94 ±0.69	39.50 ±0.94	37.50 ±0.88	2.00 ±0.06	18.72 ±0.28 ^c
T4	12.13 ±0.26	3.81 ±0.10	42.65 ±0.33	39.56 ±0.88	2.14 ±0.06 ^c	0.02 ±0.01	0.06 ±0.015	0.20 ±0.16	17.18 ±0.39	44.65 ±0.36	42.00 ±1.09	39.56 ±0.88	2.43 ±0.24	16.60 ±1.18 ^c
T5	14.12 ±0.92	5.00 ±0.40	38.16 ±0.62	32.00 ±1.23	3.46 ±0.15 ^b	0.04 ±0.01	0.07 ±0.013	0.02 ±0.01	19.90 ±1.34	40.43 ±0.92	35.60 ±1.39	32.00 ±1.23	3.60 ±0.18	8.9 ±0.22 ^d
T6	12.64 ±0.49	4.45 ±0.006	48.38 ±0.24	33.98 ±0.47	3.36 ±0.10 ^b	0.04 ±0.01	0.10 ±0.013	0.07 ±0.008	18.05 ±0.47	50.80 ±0.32	37.57 ±0.37	33.98 ±0.47	3.59 ±0.11	9.50 ±0.54 ^{de}
T7	12.26 ±0.16	4.37 ±0.15	38.01 ±0.24	26.97 ±0.18	4.81 ±0.05 ^a	0.07 ±0.012	0.09 ±0.020	0.06 ±0.01	17.79 ±0.30	40.10 ±0.50	32.01 ±0.27	26.97 ±0.18	5.04 ±0.09	5.35 ±0.06 ^e
T8	12.18 ±0.34	4.05 ±0.21	48.29 ±0.20	26.91 ±0.30	4.94 ±0.11 ^a	0.06 ±0.01	0.08 ±0.011	0.06 ±0.01	17.48 ±0.52	50.41 ±0.31	32.08 ±0.23	26.91 ±0.30	5.16 ±0.13	5.23 ±0.17 ^e
p-value	ns	ns	ns	ns	0.07	ns	ns	ns	ns	ns	ns	ns	ns	ns
Main effects														
Oil replacement level														
0%	14.75 ±0.57 ^a	4.85 ±0.21 ^a	35.22 ±0.39 ^d	40.41 ±1.06 ^a	1.09 ±0.11 ^d	0.01 ±0.005 ^b	0.02 ±0.006	0.02 ±0.006	20.41 ±0.75 ^a	37.941 ±0.45 ^d	41.57 ±1.10 ^a	40.41 ±1.06 ^a	1.15 ±0.12 ^d	37.48 ±3.73 ^a
33.3%	13.3 4±0.36 ^{ab}	4.75 ±0.18 ^a	38.09 ±0.30 ^c	38.52 ±0.70 ^a	2.03 ±0.06 ^c	0.02 ±0.009 ^b	0.05 ±0.009	0.11 ±0.08	19.05 ±0.46 ^{ab}	40.270 ±0.49 ^c	40.74 ±0.81 ^a	38.53 ±0.70 ^b	2.22 ±0.14 ^c	17.65 ±0.68 ^b
66.7%	12.90 ±0.45 ^b	4.50 ±0.10 ^{ab}	42.73 ±0.21 ^b	33.00 ±0.71 ^b	3.41 ±0.08 ^b	0.04 ±0.008 ^{ab}	0.09 ±0.01	0.04 ±0.01	18.53 ±0.51 ^{ab}	44.886 ±0.35 ^b	36.59 ±0.76 ^b	32.99 ±0.71 ^b	3.59 ±0.10 ^b	9.20 ±0.26 ^c
100%	12.16 ±0.20 ^b	3.93 ±0.11 ^b	48.34 ±0.14 ^a	26.94 ±0.16 ^c	4.87 ±0.06 ^a	0.06 ±0.008 ^a	0.09 ±0.01	0.06 ±0.008	17.3 ±0.3 ^b	50.609 ±0.22 ^a	32.04 ±0.16 ^c	26.94 ±0.16 ^c	5.10 ±0.08 ^a	5.29 ±0.09 ^d
p-value	0.002	0.003	0.001	0.001	0.001	0.001	ns	ns	0.006	0.001	0.001	0.001	0.001	0.001
Vitamin E														
0 mg/kg	13.77 ±0.38 ^a	4.55 ±0.14	41.04 ±1.34	34.18 ±1.40	2.75 ±0.39	0.03 ±0.008	0.05 ±0.009	0.03 ±0.007	19.36 ±0.46	43.57 ±1.30	37.06 ±1.04	34.18 ±1.40	2.87 ±0.41 ^a	20.05 ±4.25
300 mg/kg	12.80 ±0.32 ^b	4.47 ±0.14	41.16 ±1.26	35.25 ±1.47	2.95 ±0.35	0.04 ±0.007	0.07 ±0.008	0.09 ±0.04	18.30 ±0.42	43.28 ±1.25	38.42 ±1.16	35.25 ±1.470	3.16 ±0.36 ^b	14.77 ±2.22
p-value	0.03	ns	ns	ns	0.002	ns	ns	ns	ns	ns	ns	ns	0.005	0.001
Intractions	ns	ns	ns	ns	0.002	ns	ns	ns	ns	ns	ns	ns	ns	0.001

¹ see Table 1

²ΣSFA=total saturated fatty acids; ΣMUFA=total monounsaturated fatty acids; ΣPUFA=total polyunsaturated fatty acids.

^{a-e}means followed by different letters within columns are significantly different (p<0.05).


Table 8 – Effects of dietary sunflower and rapeseed oil with or without vitamin E on FA profile of breast meat (% of total FAs)

Treatments ¹	Fatty acids ²													
	C16:0	C18:0	C18:1	C18:2n-6	C18:3n-3	C20:5n-3	C22:5n-3	C22:6n-3	ΣSFA	ΣMUFA	ΣPUFA	ΣPUFA n-6	ΣPUFA n-3	n-6:n-3
T1	15.50 ±0.61	4.82 ±0.14	34.74 ±0.61	40.07 ±1.36	0.83 ±0.03 ^e	0.00 ±0.00	0.02 ±0.009	0.02 ±0.009	21.21 ±0.68	37.83 ±0.71	40.96 ±1.40	40.07 ±1.36	0.88 ±0.04	45.32 ±1.04 ^a
T2	14.33 ±0.82	5.03 ±0.33	35.97 ±0.20	39.97 ±1.33	1.42 ±0.10 ^d	0.007 ±0.007	0.04 ±0.002	0.03 ±0.004	20.25 ±1.13	38.28 ±0.41	41.48 ±1.43	39.97 ±1.33	1.51 ±0.09	26.55 ±0.93 ^b
T3	14.15 ±0.15	5.12 ±0.26	38.15 ±0.71	37.23 ±0.88	1.96 ±0.06 ^c	0.02 ±0.008	0.04 ±0.002	0.03 ±0.01	20.26 ±0.27	40.43 ±1.01	39.30 ±0.929	37.23 ±0.88	2.07 ±0.07	17.99 ±0.56 ^c
T4	12.60 ±0.20	4.63 ±0.12	37.91 ±0.26	39.66 ±0.48	2.17 ±0.04 ^f	0.08 ±0.06	0.04 ±0.01	0.03 ±0.01	18.22 ±0.33	39.78 ±0.25	41.99 ±0.51	39.66 ±0.48	2.33 ±0.05	17.04 ±0.34 ^c
T5	13.53 ±0.61	4.68 ±0.11	42.35 ±0.13	32.54 ±0.57	3.39 ±0.17 ^b	0.05 ±0.01	0.07 ±0.01	0.05 ±0.02	19.30 ±0.67	44.57 ±0.20	36.12 ±0.72	32.54 ±0.57	3.57 ±0.21	9.19 ±0.50 ^d
T6	12.34 ±0.14	4.41 ±0.11	42.90 ±0.07	33.50 ±0.25	3.41 ±0.03 ^b	0.06 ±0.01	0.09 ±0.007	0.08 ±0.01	17.87 ±0.16	44.96 ±0.10	37.15 ±0.23	33.50 ±0.25	3.65 ±0.02	9.16 ±0.11 ^d
T7	12.42 ±0.22	3.84 ±0.07	48.24 ±0.34	26.85 ±0.39	4.62 ±0.03 ^a	0.13 ±0.05	0.17 ±0.07	0.04 ±0.01	17.54 ±0.20	50.87 ±0.42	31.83 ±0.35	26.85 ±0.39	4.98 ±0.12	5.40 ±0.18 ^e
T8	12.75 ±0.16	4.11 ±0.22	48.29 ±0.22	26.22 ±0.29	4.84 ±0.10 ^a	0.08 ±0.01	0.10 ±0.007	0.06 ±0.004	18.09 ±0.37	50.57 ±0.45	31.32 ±0.23	26.22 ±0.29	5.09 ±0.12	5.15 ±0.16 ^e
p-value	ns	ns	ns	ns	0.001	ns	ns	ns	ns	ns	ns	ns	ns	0.989
Main effects														
Oil replacement level														
0%	14.91 ±0.52 ^a	4.92 ±0.17 ^a	35.36 ±0.37 ^d	40.02 ±0.88 ^a	1.13 ±0.12 ^d	0.03 ±0.003 ^b	0.03 ±0.005 ^b	0.03 ±0.005 ^b	20.73 ±0.39 ^a	38.06 ±0.39 ^d	41.22 ±0.93 ^a	40.02 ±0.88 ^a	1.20 ±0.12 ^d	35.94 ±3.60 ^a
33.3%	13.38 ±0.31 ^b	4.88 ±0.16 ^a	38.03 ±0.35 ^c	38.44 ±0.65 ^a	2.07 ±0.05 ^c	0.05 ±0.03 ^b	0.04 ±0.008 ^b	0.03 ±0.007 ^b	19.24 ±0.49 ^{ab}	40.10 ±0.49 ^c	40.65 ±0.70 ^a	38.44 ±0.65 ^a	2.20 ±0.065 ^c	17.52 ±0.35 ^a
66.7%	12.9 3±0.36 ^b	4.55 ±0.08 ^a	42.63 ±0.12 ^b	33.02 ±0.34 ^b	3.40 ±0.08 ^b	0.06 ±0.008 ^b	0.08 ±0.009 ^{ab}	0.06 ±0.01 ^a	18.58 ±0.12 ^b	44.76 ±0.12 ^b	36.64 ±0.40 ^b	33.02 ±0.34 ^b	3.61 ±0.10 ^b	9.18 ±0.24 ^c
100%	12.58 ±0.14 ^b	3.97 ±0.12 ^b	48.27 ±0.19 ^a	26.53 ±0.25 ^c	4.73 ±0.06 ^a	0.11 ±0.02 ^a	0.13 ±0.03 ^a	0.05 ±0.008 ^a	17.82 ±0.29 ^b	50.72 ±0.29 ^a	31.57 ±0.21 ^c	26.53 ±0.25 ^c	5.03 ±0.08 ^a	5.28 ±0.12 ^d
p-value	0.001	0.001	0.001	0.001	0.001	0.008	0.008	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vitamin E														
0 mg/kg	13.90 ±0.35	4.62±0.14	40.88 ±1.32	34.18 ±1.35	2.70 ±0.37	0.05 ±0.01	0.08 ±0.022	0.04 ±0.007 ^a	19.58 ±0.41 ^a	43.43 ±1.31	37.05 ±0.99	34.18 ±1.35	2.87 ±0.40 ^b	19.48 ±4.040
300 mg/kg	13.00 ±0.28	4.54±0.13	41.27 ±1.24	34.84 ±1.48	2.96 ±0.33	0.06 ±0.01	0.07 ±0.008	0.05 ±0.006 ^b	18.60 ±0.37 ^b	43.40 ±1.26	37.99 ±1.16	34.84 ±1.48	3.14 ±0.35 ^a	14.48 ±2.12
p-value	ns	ns	ns	ns	0.001	ns	ns	0.034	0.034	ns	ns	ns	0.001	0.001
Intractions	ns	ns	ns	ns	0.02	ns	ns	ns	ns	ns	ns	ns	ns	0.001

¹ see Table 1²ΣSFA=total saturated fatty acids; ΣMUFA=total monounsaturated fatty acids; ΣPUFA=total polyunsaturated fatty acids.^{a-e}means followed by different letters within columns are significantly different (p<0.05).



FA composition of chicken thighs when broiler diets were supplemented with vitamin E (Hsieh *et al.*, 2002; Cortinas *et al.*, 2004). For example Hsieh *et al.* (2002) fed the chicks with MUFA / SFA ratio of 1.2 or 4.8 and supplemented with 0, 10 or 20 mg vitamin E kg⁻¹ for 3 weeks. The Σ SFA, Σ MUFA, and Σ PUFA contents in heart, liver, and breast muscle were not affected by dietary vitamin E level. In most studies, results are expressed as percentages (area normalization), which makes comparison of the results difficult. It is necessary to mention that in the current study FAs were quantified based on internal standard to avoid the inaccuracy associated with area normalization (Cortinas *et al.*, 2004). Dietary polyunsaturation level can affect the fat deposit of the body, there is a difference in lipid digestion between non-ruminant and ruminant animals which has an important effect on transference of fats from the diet into the tissue. Broilers fed by diet containing polyunsaturated fats have lower fat deposition in contrast to the diet containing saturated fats. The reason has been explained to be due to higher rate of lipid catabolism and lower FA synthesis (Sanz *et al.*, 2000; Woods & Fearon, 2009). Similar results have been obtained in a study on rats as they

showed significantly lower metabolic oxidation of lipids which resulted in lower thermogenesis in tissues of rats fed on saturated fats (Shimomura *et al.*, 1990). In intramuscular fat FA is one of the main components of cellular membrane. As for cells, to ensure the fluidity and permeability of different compounds, they have to maintain their physical characteristics of the cell membrane. As a result, modification of FA composition of intramuscular fat has been reported to be limited (Lopez-Bote *et al.*, 1997).

The TBARS level (mg malonaldehyde/100g tissue) was detected in the thigh and breast meat throughout the 1, 3, 6, and 9 days of storage (Table 9). Thigh and breast muscle from birds fed without vitamin E displayed an increased susceptibility to lipid peroxidation *in vitro*, as expected, 100 % rapeseed oil supplementation without vitamin E has the greatest impact ($p < 0.01$) on elevating malonaldehyde production. However, the dietary combination of oil and vitamin E at 300 mg/kg markedly ($p = 0.001$) decreased the susceptibility. These findings indicate that dietary inclusion of vitamin E can be an effective way to increase stability of n-3 PUFA enriched broilers meat across the oxidative damage. Surai & Sparks (2000; in different tissues of cockerels

Table 9 – Effects of dietary sunflower and rapeseed oil with or without vitamin E on TBARS level of the thigh and breast meat (mg malonaldehyde/100g tissue)¹

Treatments ²	Thigh muscle TBARS level				Breast muscle TBARS level			
	day 1	day 3	day 6	day 9	day 1	day 3	day 6	day 9
T1	1.05±0.02	1.13±0.02 ^d	2.16±0.03	3.54±0.02	0.95±0.01	1.03±0.019 ^d	1.87±0.14	3.41±0.03 ^b
T2	0.89±0.02	0.99±0.01 ^e	2.36±0.46	3.08±0.05	0.83±0.01	0.89±0.03 ^e	1.79±0.03	3.04±0.04 ^d
T3	1.03±0.01	1.26±0.037 ^{bc}	2.08±0.073	3.58±0.03	0.97±0.02	1.15±0.01 ^{bc}	2.10±0.03	3.52±0.01 ^{ab}
T4	0.93±0.00	1.13±0.02 ^d	1.87±0.04	2.96±0.03	0.83±0.01	1.05±0.03 ^{cd}	1.79±0.03	2.90±0.07 ^d
T5	1.07±0.01	1.38±0.01 ^a	2.20±0.04	3.68±0.04	0.93±0.03	1.44±0.02 ^a	2.12±0.03	3.58±0.04 ^a
T6	0.99±0.01	1.22±0.01 ^c	1.85±0.03	3.00±0.05	0.87±0.08	1.18±0.01 ^b	1.81±0.03	2.90±0.03 ^d
T7	1.15±0.07	1.32±0.03 ^{ab}	2.51±0.05	3.47±0.10	1.15±0.01	1.22±0.01 ^b	2.16±0.15	3.21±0.01 ^c
T8	1.03±0.09	1.34±0.03 ^{ab}	2.06±0.09	3.04±0.05	1.01±0.01	1.34±0.01 ^a	2.14±0.03	2.98±0.03 ^d
p-value	ns	0.001	ns	ns	ns	0.001	ns	0.01
Main effects								
Oil replacement level								
0%	0.97±0.03 ^b	1.06±0.02 ^c	2.26±0.21	3.31±0.09	0.89±0.02 ^b	0.96±0.03 ^c	1.83±0.06 ^b	3.22±0.07 ^{ab}
33.3%	0.98±0.020 ^b	1.19±0.03 ^b	1.97±0.05	3.27±0.12	0.90±0.02 ^b	1.10±0.02 ^b	1.95±0.06 ^{ab}	3.21±0.12 ^{ab}
66.7%	1.03±0.019 ^{ab}	1.30±0.03 ^{ab}	2.02±0.07	3.34±0.13	0.90±0.02 ^b	1.31±0.04 ^a	1.96±0.06 ^{ab}	3.24±0.13 ^a
100%	1.09±0.059 ^a	1.33±0.02 ^a	2.29±0.09	3.25±0.09	1.08±0.04 ^a	1.28±0.02 ^a	2.15±0.07 ^a	3.10±0.04 ^b
p-value	0.04	0.001	ns	ns	0.001	0.001	0.002	0.002
Vitamin E								
0 mg/kg	1.07±0.021 ^a	1.27±0.02 ^a	2.24±0.04	3.57±0.03 ^a	1.00±0.02 ^a	1.21±0.03 ^a	2.06±0.05 ^a	3.43±0.03 ^a
300 mg/kg	0.96±0.025 ^b	1.17±0.03 ^b	2.03±0.11	3.02±0.02 ^b	0.89±0.02 ^b	1.12±0.04 ^b	1.88±0.04 ^b	2.95±0.02 ^b
p-value	0.001	0.001	ns	0.001	0.001	0.001	0.001	0.001
Intractions	ns	0.01	ns	ns	ns	0.001	ns	0.001

¹ Approximate scales for Interpretation of TBARS values in meat: ≤ 0.2 Good quality ; 0.2 – 0.5 Limited and tolerable ; 0.5 – 1.5 Somewhat oxidized ; 1.5 – 5 Oxidized ; ≥ 5 Rancid (Frigg, 1992)

² see Table 1

^{a-e} means followed by different letters within columns are significantly different ($p < 0.05$).



fed on diet containing PUFA) and Golzar Adabi *et al.* (2013; in stored egg yolk of different avian species) showed that concentration of tissues α -tocopherol was decreased markedly by PUFA inclusion and storage respectively. The current findings corroborate with previous reports (Cortinas *et al.*, 2005; Rahimi *et al.*, 2011). Such effect is a consequence of the higher PUFA content in meat from unsaturated diets because of the TBARS production is mainly increased with the peroxidation of FA with more than two double bonds (Cortinas *et al.*, 2004, 2005, Rahimi *et al.*, 2011). The results of oxidative stability of thigh and breast muscle show that oxidation of these tissues increased by increasing the length of storage time, which is in agreement with other findings (Zanini *et al.*, 2006; Rahimi *et al.*, 2011).

The sensory evaluation for the thigh and breast meat showed no significant differences among the treatments when it came to olfactory, texture, and taste (data not shown). In contrast to our data, some studies showed that dietary inclusion of fish oil or other n-3 PUFAs sources such as linseed have adverse effect on sensory quality (Gonzalez-Esquerra & Leeson, 2000 a,b). One reason of showing contradictory results is related to the perception of fishy off-flavors or odour changes from one country to another for example Lopez-Ferrer *et al.* (2001a) did not find significant differences up to 4% fish oil supplementation.

It can be concluded that the pattern of FA deposition in muscle tissues can be manipulated by changing the FA composition in the diet; because composition and concentration of carcass lipid is significantly affected by lipid type and origin in the diet. In general, the rate and extent of lipid oxidation in muscle can be influenced by the dietary fat type and level, FAs profile of dietary oil, and level of dietary antioxidant. On the other hand, n-3 PUFA increases meat oxidation susceptibility. By adding vitamin E (300 mg/kg/day dry matter) to the diet, lipid oxidation can be significantly reduced.

CONFLICT OF INTEREST

Authors have no conflicts of interest to declare whatsoever.

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