Dietary lipid sources and vitamin E affect fatty acid composition or lipid stability of breast meat from Muscovy duck

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Schiavone, A., Marzoni, M., Castillo, A., Nery, J. and Romboli, I. 2010. **Dietary lipid sources and vitamin E affect fatty acid composition or lipid stability of breast meat from Muscovy duck**. Can. J. Anim. Sci. **90**: 371–378. A trial was conducted in order to assess the fatty acid composition and lipid stability of breast meat from Muscovy ducks (*Cairina moschata domestica* L.) fed a basal diet supplemented with 20 g kg^{-1} of soybean oil or fish oil and 30 or 230 mg kg^{-1} α-tocopheryl acetate (α-TA). A total of 120 one-day-old female muscovy ducklings were distributed over 12 pens (10 birds/pen). Growth performance traits were measured through the study. Each dietary treatment was randomly administered to three replicates when birds were 43 d until the slaughtering age of 66 d. Dietary treatments did not induce differences in growth performances and slaughter traits. Similarly, proximate composition and pH of breast muscle were not influenced by the diets. Significant increases in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) contents in breast meat of ducks fed fish-oil-supplemented diets was observed. Lipid oxidation, expressed as thiobarbituric acid reactive substances (TBARS), of breast meat from birds fed 230 mg kg^{-1} α-TA-supplemented diets was significantly lower, compared with those fed diets supplemented with 30 mg kg^{-1} α-TA, both 1 and 7 d after slaughter.

Key words: Duck, meat, fatty acid, vitamin E, thiobarbituric acid reactive substances

Schiavone, A., Marzoni, M., Castillo, A., Nery, J. et Romboli, I. 2010. **Effet des sources de lipides et du contenu en vitamine E des régimes alimentaires sur la composition en acides gras et la stabilité des lipides du filet de canard de Barberie**. Can. J. Anim. Sci. **90**: 371–378. Le but de l'étude était de déterminer la composition en acides gras et la stabilité oxidative des lipides du filet chez le canard de Barbarie (*Cairina moschata domestica* L.). Les régimes ont inclut une aliment de base supplémenté avec 20 g kg^{-1} de huile de soya ou de huile de poisson et avec 30 ou 230 mg kg^{-1} de α-tocophéryl acétate (α-TA). 120 femelles de canard de Barberie d'un jour d'âge ont été divisés en 12 parquets (10 animaux/parquet). Les paramètres de performance de croissance ont été mesurés pendant toute la durée de l'étude. Chaque traitement alimentaire était fournit à 3 groupes de 43 à 66 jours d'âge. La performance de croissance et les paramètres d'abatage n'ont pas été influencés par le régime. Similairement, la composition et le pH du filet n'ont pas varié en fonction de l'aliment. Les régimes intégrés avec l'huile de poisson ont provoqué une augmentation de la concentration des acides eicosapentaénoïque (EPA) et docosahexaénoïque (DHA) au niveau du filet. L'oxydation des lipides du filet, mesuré par la méthode des substances réagissant avec l'acide thiobarbiturique (TBARS), a été inférieur pour les canards dont le régime était intégré avec 230 mg kg^{-1} de α-TA que pour ceux nourris avec l'aliment de base, contenant 30 mg kg^{-1} de α-TA. Ceci a été observé a 1 jour et à 7 jours de conservation de la viande.

Mots clés: Canard, viande, acides gras, vitamine E, substances réagissant avec l'acide thiobarbiturique

The biological effect of n-3 long-chain (LC) polyunsaturated fatty acids (PUFAs) has received great interest in human nutrition, as they play an active role in the prevention and management of several pathologies, such as coronary heart disease, hypertension, type 2 diabetes, renal disease, ulcerative colitis, chronic obstructive pulmonary disease and Crohn's disease (Simopoulos 2000). The enhancement of eicosapentaenoic (EPA) and docosahexaenoic (DHA) acid levels with non-fish foods is one way of increasing the human consumption of these fatty acids (FAs). Several studies have shown the possibility of modifying PUFAs composition of chicken

Abbreviations: **α-TA**, α-tocopheryl acetate; **ANOVA**, analysis of variance; **DHA**, docosahexaenoic acid; **EPA**, eicosapentaenoic acid; **FA**, fatty acid; **FCR**, feed conversion ratio; **FO**, 20 g kg^{-1} fish oil + 30 mg kg^{-1} α-TA; **FO-E200**, 20 g kg^{-1} fish oil + 230 mg kg^{-1} α-TA; **LC**, long chain; **ME**, metabolizable energy; **MDA**, malonaldehyde; **MUFAs**, monounsaturated fatty acids; **PUFAs**, polyunsaturated fatty acids; **SFAs**, saturated fatty acids; **SO**, 20 g kg^{-1} soybean oil + 30 mg kg^{-1} α-TA; **SO-E200**, 20 g kg^{-1} soybean oil + 230 mg kg^{-1} α-TA; **TBARS**, thiobarbituric acid reactive substances; **VLDL**, very low density lipoproteins

and turkey meat by changing the FA composition of the diet. This leads to higher amounts of n-3 LC-PUFAs and therefore to an increase in the n-3/n-6 ratio (Leskanich and Noble 1997; Hargis and Van Elswyk 1993). Lipid stability of animal products during storage depends on its pro-oxidant and antioxidant content, on fat content, on the FA profiles of fat, and on the degree of processing and the storage conditions of products (Jensen et al. 1997; Bou et al. 2009). It is well known that the quality of dietary lipids and dietary supplementation with supranutritional amounts of antioxidants, like α-tocopheryl acetate (α-TA), leads to a significant improvement in the quality of poultry products (meat and eggs), through the improvement of lipid stability during storage (Bou et al. 2009). The supplementation of duck diets with α-TA assumes a particular importance, because duck meat presents a higher overall fat content (Chartrin et al. 2006). Therefore, meat stability during storage assumes a greater importance in this species, despite the lower consumption of duck meat by humans. Compared with chicken and turkey, which are consumed in larger amounts by humans, few studies concerning the manipulation of FA composition and lipid stability of Muscovy duck meat by dietary strategies have been undertaken (Farrell 1991; Schiavone et al. 2004, 2007; Huang et al. 2006).

The aim of this investigation was to determine the effect of different dietary oils (soybean oil or fish oil) and α-TA supplementation (30 or 230 mg kg^{-1} of diet) on FA composition and lipid stability of Muscovy duck breast meat.

MATERIALS AND METHODS

An experimental study with female Muscovy ducks (*Cairina moschata domestica* L.) selected for meat production (S.A. Grimaud Frère, France) was designed. The study was carried out in a controlled environment farm at the Avian Experimental Station of the Department of Animal Production of the University of Pisa (Italy). The experimental protocol was approved by the Ethics Committee of the University of Pisa. Housing conditions were in accordance with the European Union guidelines.

A total of 120 one-day-old female ducklings were distributed over 12 pens (1.8 m × 1.4 m). The stocking density in each pen was 4 birds m^{-2}. Feed and water were provided ad libitum. Individual body weight and feed intake per pen were recorded weekly to calculate the daily weight gain and the feed conversion ratio (FCR). Control of health status was carried out daily.

All animals received the same diet (12.3 MJ ME kg^{-1} and 225 g of crude protein kg^{-1}) until the age of 42 d (Table 1). The next day (43 d) four dietary treatments were assigned to three pens each. The trial lasted until 66 d of age, when birds were slaughtered. The experimental diets were formulated to meet or exceed the requirements indicated by the National Research Council (1994). The same basal diet was supplemented with: 20 g kg^{-1} soybean oil (soybean oil super refined – Croda Italia S.p.A.) + 30 mg kg^{-1} α-TA (Rovimix® E-50 Adsorbate, F. Hoffman-La Roche Ltd., Basel, Switzerland) (group SO); 20 g kg^{-1} soybean oil + 230 mg kg^{-1} α-TA (group SO-E200); 20 g kg^{-1} fish oil (herring oil stabilized with 350 ppm BHT – Golden Oil, Prodotti Gianni S.p.A., Milano-Italy) + 30 mg kg^{-1} α-TA (group FO); 20 g kg^{-1} fish oil + 230 mg kg^{-1} α-TA (group FO-E200). The four experimental diets were isoenergetic and isonitrogenous (ME: 12.5 MJ kg^{-1} feed and crude protein: 200 g kg^{-1}).

Table 1. Ingredients and chemical composition of diets

	0–42 days	43–66 days
Ingredients of basal diet (g kg^{-1})		
Corn meal	598	600
Soybean meal	335	314
Alfalfa meal		20
Dicalcium phosphate	20	20
Calcium carbonate	17	17
Sodium chloride	2	2
DL-methionine	2	1
L-lysine	1	1
Vitamin and mineral premix[z]	5	5
Oil	20[y]	–
Dietary treatments		
Oil (g kg^{-1})		20[x]
α-tocopheryl acetate (mg kg^{-1})		200[w]
Proximate composition (g kg^{-1})		
Dry matter	877	878
Crude protein	225	200
Ether extract	34	37
Crude fibre	23	32
Ash	67	65
Metabolizable energy (MJ kg^{-1})	12.3	12.5

[z]Provided per kilogram of diet: retinol 3 mg; cholecalciferol, 45 mg; DL-α-tocopheryl acetate 30 mg; thiamine 1.5 mg; riboflavin 3 mg; pyridoxine 1.5 mg; cobalamin 0.015 mg; pantothenic acid 8.0 mg; niacin 25 mg; choline chloride 500 mg; Fe ($FeSO_4 \cdot 7H_2O$), 30 mg; Cu ($CuSO_4 \cdot 5H_2O$) 1.5 mg; Mn ($MnSO_4 \cdot H_2O$) 80 mg; Zn ($ZnSO_4 \cdot 7H_2O$) 30.0 mg; I (KI) 1.4 mg.
[y]Composition: 10 g kg^{-1} soybean oil + 10 g kg^{-1} fish oil.
[x]Composition: 20 g kg^{-1} soybean oil in groups SO and SO-E200; 20 g kg^{-1} fish oil in groups FO and FO-E200.
[w]Supplementation in groups SO-E200 and FO-E200.

Proximate composition of the diets was evaluated according procedures of the Association of Official Analytical Chemists (AOAC 1995), and FA composition of the oils was determined as described below for FA composition of breast meat. The α-TA in feed samples was extracted as described by Jensen et al. (1999) starting from 2 g of sample. Chromatographic separation was achieved on a HS-5-Silica column (125 × 4 mm) (Perkin-Elmer, D-88662 Überlingen, Germany). The mobile phase was heptane modified with 2-propanol (99.5:0.5 vol/vol) degassed with helium. HPLC quantification was performed according to the conditions described by Jensen et al. (1999). Fluorescence quantification was performed with an excitation wavelength of 290 nm and emission wavelength of 327 nm.

At the age of 66 d 10 birds per dietary treatment were sacrificed by electrical stunning followed by decapitation, after a 12-h fasting period. Eviscerated and plucked carcasses were weighed after removal of the head, neck, feet and abdominal fat to obtain ready-to-cook carcasses.

Carcasses were stored in a cool chamber, at 0 to 4°C, until the next day, when carcass yield and pH (Hanna Instruments 8417 pH-meter supplied with a Hamilton Biotrode electrode) of m. pectoralis major of the left side were determined.

The m. pectoralis major of the right side was vacuum packaged and immediately frozen (-20°C) and then analysed to determine the proximate composition and FA composition. Association of Official Analytical Chemists methods (1995) were used to assess moisture, ash, protein and ether extract and results were expressed as percentage on a fresh matter basis. The FA profiles of dietary oils and breast samples were determined by capillary gas chromatography after lipid extraction (Folch et al. 1957) and esterification (Christie 1982) using sodium methoxide as catalyst. Fatty acid methyl esters were analysed by a Perkin-Elmer AutoSystem gas-chromatograph, equipped with a flame ionisation detector and a Supelco Omegawax 320 capillary column (30 m $\times$ 0.32 mm, 0.25 μm film). Each FA peak was identified by pure methyl ester standards (Supelco and Restek Corporation, Bellefonte, PA) and data were conveyed as relative values.

The m. pectoralis major of the left side was overwrapped and stored in a cool chamber, at 0 to 4°C, in order to assess lipid peroxidation of meat at two storage time: 1 and 7 d after slaughter. Lipid peroxidation of meat was evaluated by means of thiobarbituric acid reactive substances (TBARS) assessment according to a modified method as described by Pikul et al. (1983) and Salih et al. (1987). Briefly 10 g of minced breast was homogenized (Polytron PT 3000) for 2 min in 34.25 mL of a 4% (wt/vol) KCl chilled solution and 0.75 mL of butyl hydroxy toluene (0.5% wt/vol in ethanol), filtered through Whatman no. 1 filter paper and the final volume was raised with KCl at 50 mL. Five millilitres of meat extract and 5 mL of thiobarbituric acid solution (0.288% wt/vol were incubated in a boiling bath for 60 min. After centrifugation, the absorbance of samples was read at 532 nm (Perkin-Elmer). Liquid malonaldehyde bis (diethyl acetal) (MDA) (Aldrich Chemical Co Ltd., Dorset, UK) was used as the standard to determine the linear standard response and recovery. The TBARS values are expressed as mg MDA kg^{-1} fresh meat.

Each pen was considered the experimental unit for growth performance traits. The individual animal was the experimental unit for slaughter traits and breast meat proximate composition, TBARS and FA composition. Data were analysed using SPSS software (2003). Two-way ANOVA was applied to data considering the dietary oil and the level of α-TA supplementation (and their interaction) as the main factors. Moreover, individual slaughter traits, and breast meat proximal composition and TBARS were clustered according to their original replicate. Results are presented as mean $\pm$ standard deviation.

RESULTS

Proximate composition of the diets and FA composition of dietary oils are reported in Table 1 and Table 2, respectively. As expected, soybean oil was characterized by high proportion of oleic (18:1n-9) and linoleic acid (18:2n-6) and no LC-PUFAs were found. Fish oil was characterized by the presence of EPA (20:5n-3) and DHA (22:6n-3) (Table 2). The α-TA content of the diets resulted 28.5 mg kg^{-1} for SO, 224.3 mg kg^{-1} for SO-E200, 29.3 mg kg^{-1} for FO and 227.8 mg kg^{-1} for FO-E200. Growth performances (live body weight at 2 d, 42 d and 63 d, average daily weight gain and feed conversion ratio), slaughter traits (live body weight at 66 d; ready-to-cook carcass weight and breast muscles weight) and breast muscle traits (pH and proximate composition) were not influenced by either dietary treatments (Tables 3 and 4) or pen of origin.

Fatty acid composition of breast meat is reported in Table 5. Supplementation with α-TA did not affect FA composition of breast meat. Dietary oils influenced the proportion of some FAs. Compared with SO and SO-E200, FO and FO-E200 groups presented higher muscle amount of miristic (14:0) ($P < 0.001$), palmitoleic (16:1n-7) ($P < 0.01$), eicosenoic (20:1n-9) ($P < 0.001$), eicosapentaenoic (20:5n-3) ($P < 0.05$) and docosahexaenoic (22:6n-3) ($P < 0.001$) acids. A lower concentration of linoleic (18:2n-6) ($P < 0.001$) and arachidonic (20:4n-6)

Table 2. Fatty acids composition of the dietary oils (% of total fatty acid)

	Soybean oil	Fish oil
C14:0	0.1	7.8
C16:0	10.5	12.2
C16:1n-7	0.1	4.1
C18:0	4.5	1.1
C18:1n-9	24.2	10.9
C18:2n-6	52.4	2.2
C18:3n-3	6.9	1.4
C18:4n-3	–	1.4
C20:0	–	0.2
C20:1	0.2	15.1
C20:4 n-6	–	0.4
C20:5n-3	–	6.6
C22:1	–	22.0
C22:5n-3	–	5.8
C22:6n-3	–	8.4
SFA[1]	15.1	21.3
MUFA[1]	24.3	52.1
PUFA[1]	59.3	26.2
n-6	52.4	2.6
n-3	6.9	23.6

[z]SFA, MUFA, PUFA, saturated, monounsaturated and polyunsaturated fatty acids, respectively.

Table 3. Effects of dietary treatments[z] for 3 wk on growth performance of Muscovy ducks ($n=3$ pens) (mean ± SD)

					Main effects		
	SO[z]	SO-E200[z]	FO[z]	FO-E200[z]	Oil	α-TA	Oil × α-TA
LBW[y] day 2 (g)	72 ± 5	70 ± 2	74 ± 2	74 ± 1	NS	NS	NS
LBW[y] day 42 (g)	1865 ± 46	1893 ± 13	1897 ± 47	1859 ± 74	NS	NS	NS
LBW[y] day 63 (g)	2468 ± 78	2498 ± 56	2536 ± 32	2521 ± 19	NS	NS	NS
ADG[x] (2–42 d) (g)	46.6 ± 1.1	47.3 ± 0.3	47.4 ± 1.2	46.5 ± 1.8	NS	NS	NS
ADG[x] (43–63 d) (g)	117.5 ± 3.7	118.9 ± 2.7	120.8 ± 1.5	120.0 ± 0.9	NS	NS	NS
FCR[w] (2–42 d)	2.8 ± 0.2	2.7 ± 0.1	2.9 ± 0.3	2.7 ± 0.1	NS	NS	NS
FCR[w] (43–63 d)	5.5 ± 1.0	5.5 ± 0.4	5.3 ± 0.5	5.0 ± 0.6	NS	NS	NS

[z]Dietary treatments: SO = 20 g kg^{-1} soybean oil + 30 mg kg^{-1} α-tocopheryl acetate (α-TA); SO-E200 = 20 g kg^{-1} soybean oil + 230 mg kg^{-1} α-TA; FO = 20 g kg^{-1} fish oil + 30 mg kg^{-1} α-TA; FO-E200 = 20 g kg^{-1} fish oil + 230 mg kg^{-1} α-TA.
[y]LBW, live body weight.
[x]ADG, average daily weight gain.
[w]FCR, feed conversion ratio.

($P<0.05$) acids were found in breast samples from birds fed diets supplemented with fish oil. Birds fed soybean oil-supplemented diets presented higher rate of total n-6 FAs, lower n-3 FAs and consequently higher n-6/n-3 ratio ($P<0.001$).

Meat susceptibility to lipid oxidation (TBARS values) increased during storage for all dietary treatments (Table 4). TBARS was influenced by the α-TA level both at day 1 and day 7 of storage. SO-E200 and FO-E200 displayed the lowest TBARS mean values at both day 1 and day 7 after slaughter ($P<0.001$). Consequently, breast samples from birds fed diets supplemented with 230 mg kg^{-1} α-TA displayed the lowest increment of TBARS concentrations over storage (+1.3-fold and +1.5-fold for SO-E200 and FO-E200, respectively) compared with samples from birds which received diets without α-TA supplementation (+2.4-fold and +2.1-fold for SO and FO, respectively).

DISCUSSION

The incorporation of different lipid sources did not affect growth and slaughtering performances in agreement with results of Huang et al. (2007) for mule duck fed 1.5% fish oil and our previous findings for Muscovy duck (Schiavone et al. 2004, 2007). Huang et al. (2007) observed in mule duck that a level of 3% fish oil in the diet significantly deteriorated feed efficiency and body weight. Chen and Hsu (2004) reported that laying Tsaiya duck fed n-3 PUFAs enriched diet (4% fish oil) supplemented with different levels of α-TA (100, 200,

Table 4. Effects of dietary treatments[z] for 3 wk on slaughter traits[y], breast meat chemical composition and TBARS[x] of Muscovy ducks ($n=10$; for chemical composition $n=5$) (mean ± SD)

					Main effects		
	SO[z]	SO-E200[z]	FO[z]	FO-E200[z]	Oil	α-TA	Oil × α-TA
LBWs (g)[y]	2654 ± 188	2576 ± 170	2612 ± 180	2662 ± 165	NS	NS	NS
RCC (g)[y]	1659 ± 127	1611 ± 119	1642 ± 126	1644 ± 105	NS	NS	NS
RCC (%)[y]	62.5 ± 1.15	62.5 ± 1.4	62.9 ± 1.5	61.7 ± 1.2	NS	NS	NS
BM (g)[y]	328 ± 21	332 ± 28	325 ± 35	331 ± 37	NS	NS	NS
BM (%)[y]	19.8 ± 1.1	20.6 ± 1.6	19.8 ± 1.5	20.1 ± 1.4	NS	NS	NS
Breast pH_{24h}	5.75 ± 0.05	5.76 ± 0.39	5.76 ± 0.40	5.80 ± 0.07	NS	NS	NS
Proximate composition							
moisture (%)	75.3 ± 1.5	76.5 ± 1.6	74.9 ± 1.9	75.2 ± 1.1	NS	NS	NS
protein (%)	20.5 ± 0.9	19.9 ± 1.2	21.0 ± 0.7	20.9 ± 1.1	NS	NS	NS
lipid (%)	1.5 ± 0.3	1.5 ± 0.2	1.5 ± 0.4	1.6 ± 0.2	NS	NS	NS
ash (%)	1.3 ± 0.1	1.4 ± 0.1	1.3 ± 0.0	1.2 ± 0.3	NS	NS	NS
TBARS[x] (*mg MDA kg^{-1} of meat*)							
TBARS day 1[w]	3.27 ± 0.50	2.41 ± 0.64	3.90 ± 0.65	2.45 ± 0.43	NS	<0.001	NS
TBARS day 7[w]	7.80 ± 0.21	3.25 ± 0.83	8.20 ± 1.05	3.76 ± 0.65	NS	<0.001	NS

[z]Dietary treatments: SO = 20 g kg^{-1} soybean oil + 30 mg kg^{-1} α-tocopheryl acetate (α-TA); SO-E200 = 20 g kg^{-1} soybean oil + 230 mg kg^{-1} α-TA; FO = 20 g kg^{-1} fish oil + 30 mg kg^{-1} α-TA; FO-E200 = 20 g kg^{-1} fish oil + 230 mg kg^{-1} α-TA.
[y]Slaughter traits: LBW, live body weight at slaughter (66 d); RCC, ready to cook carcass; RCC (%), calculated on LBW; BM, breast muscles; BM (%), calculated on RCC.
[x]TBARS, thiobarbituric reactive substance.
[w]TBARS day 1, TBARS 1 day after slaughter; TBARS day 7 = TBARS 7 days after slaughter.

Table 5. Effects of dietary treatments[z] for 3 wk on fatty acid composition (% of total fatty acids) of the pectoralis major muscle from Muscovy ducks ($n=3$) (mean ± SD)

					Main effects		
	SO[z]	SO-E200[z]	FO[z]	FO-E200[z]	Oil	α-TA	Oil × α-TA
C14:0	0.60 ± 0.10	0.53 ± 0.06	1.17 ± 0.11	1.03 ± 0.06	<0.001	NS	NS
C16:0	22.03 ± 0.76	22.73 ± 0.88	23.60 ± 0.65	22.70 ± 0.26	NS	NS	NS
C16:1n-7	2.27 ± 0.11	2.10 ± 0.26	2.93 ± 0.11	2.57 ± 0.29	<0.01	NS	NS
C18:0	10.13 ± 0.68	10.10 ± 0.43	9.00 ± 0.35	9.43 ± 0.74	NS	NS	NS
C18:1n-9	34.83 ± 0.80	34.36 ± 4.28	36.70 ± 0.26	34.86 ± 2.88	NS	NS	NS
C18:2n-6	19.33 ± 0.40	17.30 ± 1.60	14.83 ± 1.36	15.47 ± 0.78	<0.001	NS	NS
C18:3n-3	1.03 ± 0.29	1.07 ± 0.21	0.93 ± 0.15	0.87 ± 0.06	NS	NS	NS
C20:0	0.13 ± 0.06	0.10 ± 0.00	0.10 ± 0.00	0.10 ± 0.00	NS	NS	NS
C20:1n-9	0.20 ± 0.00	0.20 ± 0.00	0.83 ± 0.15	0.86 ± 0.06	<0.001	NS	NS
C20:4n-6	4.17 ± 0.15	5.23 ± 1.43	2.80 ± 0.65	3.40 ± 0.62	<0.05	NS	NS
C20:5n-3	0.10 ± 0.00	0.10 ± 0.00	0.63 ± 0.11	0.83 ± 0.11	<0.05	NS	NS
C22:6n-3	0.53 ± 0.06	0.57 ± 0.21	2.13 ± 0.65	2.90 ± 0.62	<0.001	NS	NS
SFA[y]	33.40 ± 1.42	33.73 ± 1.21	34.40 ± 0.36	33.80 ± 0.61	NS	NS	NS
UFA[y]	62.80 ± 0.79	61.23 ± 1.52	62.33 ± 0.06	62.37 ± 1.16	NS	NS	NS
SFA/UFA	0.53 ± 0.03	0.55 ± 0.02	0.55 ± 0.01	0.54 ± 0.02	NS	NS	NS
MUFA[y]	37.50 ± 0.60	36.80 ± 4.30	40.87 ± 0.29	38.70 ± 3.29	NS	NS	NS
PUFA[y]	25.30 ± 0.30	24.43 ± 3.00	21.47 ± 0.32	23.67 ± 2.13	NS	NS	NS
n6	19.53 ± 0.40	17.53 ± 1.65	14.97 ± 1.32	15.67 ± 0.78	<0.001	NS	NS
n3	1.80 ± 0.40	1.47 ± 1.65	3.70 ± 1.32	4.60 ± 0.78	<0.001	NS	NS
n6/n3	10.90 ± 0.84	12.27 ± 1.88	4.15 ± 1.05	3.46 ± 0.48	<0.001	NS	NS

[z]Dietary treatments: SO = 20 g kg^{-1} soybean oil + 30 mg kg^{-1} α-tocopheryl acetate (α-TA); SO-E200 = 20 g kg^{-1} soybean oil + 230 mg kg^{-1} α-TA; FO = 20 g kg^{-1} fish oil + 30 mg kg^{-1} α-TA; FO-E200 = 20 g kg^{-1} fish oil + 230 mg kg^{-1} α-TA.
[y]SFA, UFA, MUFA, PUFA, saturated, unsaturated, monounsaturated, polyunsaturated fatty acids, respectively.

300 and 400 mg kg^{-1}) did not display any effect for egg weight, feed intake, body weight change and abdominal fat weight, while egg production, egg mass and feed efficiency significantly improved as dietary α-TA levels increased.

Our results for moisture, protein, lipid and ash contents in breast meat, ranging between 74.9 and 76.5%, 19.9 and 21.0%, 1.5 and 1.6% and 1.2 and 1.4%, respectively, are similar to those reported by other authors (Koci et al. 1982; Baéza et al. 2002) as well as our previous findings (Schiavone et al. 2004, 2007).

The susceptibility of avian tissues and yolk lipids to FA manipulation has been widely reviewed by Bou et al. (2009), Leskanich and Noble (1997) and Hargis and Van Elswyk (1993). The possibility of modifying FA composition in chicken tissues was discovered long ago (Marion and Woodroof 1963; Atkinson et al. 1972). When fat inclusion in feeds increases, FA composition of the body is more similar to FA composition of the diets. Several authors have increased the proportion of certain FA, modifying or increasing the inclusion of certain fat sources (Lopez-Ferrer et al. 2001a, b; Cortinas et al. 2004; Villaverde et al. 2006). However, FA composition changes are lower in body tissues than in the diets (Lopez-Ferrer et al. 2001a, b) and SFAs are less modifiable than unsaturated FAs.

Fatty acid composition of avian tissue is a combination of the de novo synthesis of FA, from carbohydrate and protein precursors, and direct precursor from the diet. Saturated FAs (SFA) and monounsaturated FAs (MUFA) have this double origin, whilst PUFA deposition depends mostly on dietary supplementation when no essential FAs deficiency exists. The main FAs resulting from hepatic lipogenesis are 16:0, 16:1n-7, 18:0 and 18:1n-9 (Bartov 1979; Crespo and Esteve-Garcia 2002). In birds, the absorption of dietary fats as portomicrons into the portal blood allows the liver to buffer the FA composition of triglycerides prior to the provision of other tissues through exported very low density lipoproteins (VLDL). This buffering is due to the preference of the liver for oxidizing some types of FAs and esterifying others into triglycerides of VLDL. Dietary linoleic and linolenic acids are good substrates for hepatic diacyltransferase, its concentrations are enriched in VLDL, and consequently also in tissue lipids. This enzyme shows discrimination against PUFAs, such as EPA, and PUFA content in triglycerides is diluted relative to dietary concentrations. However, this discrimination is incomplete; birds that consume fish or fish oils have adipose tissue that contains most of the same FAs prevalent in the diet, although at lower levels of enrichment (Klasing 2000; Poureslami et al. 2007). Studies concerning FA manipulation of duck meat by dietary strategies are limited compared with chicken and turkey. Therefore, the present study was designed first to compare the effect of dietary strategies, which have been studied in species more commonly used in human nutrition, to improve FA profile of duck meat.

Chicken meat can be enriched in linoleic acid using sunflower oil (Lopez-Ferrer et al. 1999), rapeseed oil and soybean oil (Zollitsch et al. 1997), and in EPA and DHA using fish oil (Lopez-Ferrer et al. 2001b) or

marine algae (Mooney et al. 1998). Fish oil is known for its high n-3 FA content, deposition of which in body fat can range from 35 to 45% in broilers (Poureslami et al. 2007). However, several studies on the supplementation of fish oils during fattening indicate negative effects on the palatability of poultry products (Hargis and Van Elswyk 1993). The interest in integrating fish oils into duck diets would therefore be related to increasing concentrations of n-3 FA in meat, but practical issues concerning palatability of meat would need further studies.

In the present study, different dietary oil sources induced no or weak modification of C14:0, C16:0, C18:0 and C20:0 in breast meat, as observed previously in chicken (Lopez-Ferrer et al. 2001a, b). Considering unsaturated FA, the variation found in C18:2n-6, C20:5n-3 and C22:6n-3 meat concentrations showed a similar trend to those observed in chicken (Mooney et al. 1998). The greater amount of C20:4n-6 in breast meat from animals belonging to SO and SO-E200 groups relates to the abundance of C18:2n-6 in the dietary soybean oil, which is the precursor of C20:4n-6. The amount of C20:4n-6 is lower in breast meat from FO and FO-E200 due to the high proportion of DHA and EPA in dietary fish oil. This inhibits the activity of elongase and desaturase enzymes, which are responsible for the endogenous synthesis of C20:4n-6 (Klasing, 2000).

Results of FA composition of breast meat confirmed previous findings concerning the FA manipulation of duck meat by dietary lipids (Schiavone et al. 2004, 2007; Huang et al. 2007). Orosz et al. (2007) observed decreased MUFAs and increased n-6 and n-3 PUFAs in the intramuscular fat of table ducks fed 45% oats compared with birds fed 45% barley, as a consequence of the high dietary proportion of soluble non-starch polysaccharides, which negatively affect digestibility of MUFAs.

Besides the health benefit of PUFAs compared with SFAs, it has recently been observed in chickens that inclusion of PUFAs in the diet reduces abdominal fat and total body fat compared with SFA-rich diets (Crespo and Esteve-Garcia 2001; Ferrini et al. 2008). The hypothesis proposed for such effects is that PUFAs produce greater heat losses than SFA (Takeuchi et al. 1995), increase FA catabolism (Crespo and Esteve-Garcia 2002) or decrease FA synthesis (Sanz et al. 2000). This would have an important impact on duck meat production because duck carcasses have higher fat contents. However, to confirm this, further studies concerning the effects of PUFA supplementation on total body fat would have to be conducted in duck.

Numerous studies reported the protective effect of dietary α-TA against lipid oxidation both in vivo and in muscle in order to promote the shelf life of meat. Among poultry species, the majority of studies have been performed in chicken followed by turkey. In particular, these studies assessed the effect of dietary tocopherol supplementation on lipid stability of chicken meat (Lauridsen et al. 1997; Morrissey et al. 1997; Rebolé et al. 2006). Similar results have been found in turkey, where dietary tocopherols act as protective agent against post mortem lipid oxidation (Higgins et al. 1998; Mercier et al. 1998). Additionally, the protective effect of α-TA-supplemented diets has been shown in vivo in chicken by the evaluation of the improved resistance of erythrocytes to haemolysis and lipid peroxidation (Soto-Salanova and Sell 1996; Schiavone et al. 2010).

The higher fat content of duck meat compared with other species (Chartrin et al. 2006), such as chicken and turkey, leads to a higher susceptibility of this product to peroxidation during storage. Therefore, improving duck meat antioxidant capacity through α-TA supplementation would be of great interest for meat conservation, especially in the context of meat enrichment with LC-PUFA. However, to our knowledge, lipid peroxidation in duck meat, has been studied to a lesser extent. For these reasons, the second objective of the present study was to compare the benefits of α-TA supplementation obtained with chicken and turkey on the oxidative stability of duck meat.

In the present study, breast samples from duck fed 230 mg kg^{-1} α-TA-supplemented diets showed the lowest TBARS value at both days 1 and 7 after slaughter. Our results corroborate the findings of Russel et al. (2004), where a similar trend was found for both thigh and breast from ducks fed diets supplemented with 400 and 1000 mg kg^{-1} α-TA. In our study, TBARS values are numerically higher in samples from birds fed fish oils (with or without α-TA supplementation). These data could be related to the greater amount of LC-PUFAs in the breast meat of groups fed FO and FO-E200 diets, because the extent of the oxidation of different unsaturated FAs is related both to the total number of double bonds and to the FA chain length (Liu et al. 1997).

Data from the present study suggest that Muscovy duck, similarly to other poultry species, responds positively to dietary modification of FA composition. Moreover, meat shelf life could be improved by supranutritional amounts of α-tocopheryl acetate. This is of particular importance owing to the higher fat content of duck meat compared with meat from species more commonly used in human nutrition.

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