ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 2 (5): 324-334, 2003

Quality of Raw, Frozen and Cooked Duck Meat as Affected by Dietary Fat and α-Tocopheryl Acetate Supplementation

E.A. Russell[1], A. Lynch[1], K. Galvin[1], P.B. Lynch[2] and J.P. Kerry[1]*
[1]Department of Food and Nutritional Sciences, University College Cork,
National University of Ireland, Cork, Ireland
[2]Teagasc Moorepark Research Centre, Fermoy, Co. Cork, Ireland
E-mail: joe.kerry@ucc.ie

Abstract: Poultry meat, particularly that of duck, has relatively high levels of unsaturated fatty acids and low levels of antioxidants. Ducks consume twice as much feed as broilers during growth, therefore, duck meat is more likely to be influenced by diet than chicken meat. The effects of dietary fat differing in unsaturation level (2.5% tallow or olive, sunflower or linseed oils) together with α-tocopheryl acetate (α-TA) at either a control (20 mg α-TA/kg feed) or a supplemented level (400 mg α-TA/kg feed) on α-tocopherol content, fatty acid composition and lipid oxidation of duck muscle in 7 week old birds were investigated. Fat source influenced fatty acid composition of duck meat. Ducks fed tallow had a higher percentage saturated fats, while ducks fed olive oil had a higher percentage monounsaturated fats than other dietary groups. In the absence of supplemental α-TA, duck muscle stability to lipid oxidation was greatest for those receiving diets containing sunflower oil and lowest for those receiving tallow. α-Tocopherol content and oxidative stability of duck muscle were increased ($p < 0.05$) by α-TA supplementation irrespective of fat source. Interestingly oxidative changes were much more extensive in duck breast meat than corresponding thigh meat for all treatment groups. This finding is in contrast when compared with similar dietary trials for chicken and turkey. Therefore, oxidative stability of duck meat differs from that of other poultry meats.

Key words: Duck meat quality, α-tocopherol, dietary fat

Introduction

Feeding diets with added fat to poultry can confer several economic advantages by providing increased energy levels at a lower cost and is becoming common practice (Lopez-Bote *et al*., 1997). Fats added to the diet for fast growing broilers are generally rich in polyunsaturated fatty acids (PUFA) (Lauridsen *et al*., 1997). Increasing the PUFA content of hen diets results in an increase in the degree of unsaturation of meat and other edible parts, thereby increasing susceptibility to oxidation and leading to the development of off-flavours and off-odours, loss of PUFA and lower consumer acceptability (Cherian *et al*., 1996).

Incorporation of PUFA into meat lipids is also favoured for human health reasons. The Food and Agriculture Organization promotes increasing the ratio of polyunsaturated to saturated fatty acids (P:S) in the human diet to prevent arteriosclerosis and coronary heart disease (Department of Health, UK, 1994). In addition, consumption of n-3 PUFA, and in particular, eicospentanoic acid (EPA) and docosahexaenoic acid (DHA), has been shown to have beneficial effects on human health (Kinsella *et al*., 1990). Dietary supplementation with n-3 PUFA (e.g. linseed oil) was shown to decrease plasma triacylglycerols (Boberg *et al*., 1986) and reduce postprandial triglyceridemia (Harris *et al*., 1988) in humans. The fats used in the present study were tallow [rich in saturated fatty acids, (SFA)], olive oil [rich in C18:1 n-9, monounsaturated fatty acids, (MUFA)], sunflower oil (rich in C18:2 n-6 and C18:3 n-3, PUFA) and linseed oil (rich in C18:3 n-3, PUFA). The use of fish oil in poultry diets is limited by its oxidative instability and the risk of causing taint in meat (Huang and Miller, 1993). Linseed oil has a fatty acid composition similar to fish oil but will not cause taint. In poultry, high n-3 fatty acid concentrations in meat are associated with oxidative flavours whose development can be prevented with supra-nutritional levels of the antioxidant α-tocopherol added to feeds in the form of α-TA (Wood and Enser, 1997).

Progression of lipid oxidation is influenced by a number of factors such as content of muscle pro-oxidants (iron and other metals or myoglobin), muscle antioxidants in both chemical and enzymatic forms, fat content and fatty acid profiles, degree of processing (mincing, heating) and storage conditions (light, time, temperature, packaging). Addition of processing aids such as salt and other ingredients also adversely affect lipid oxidation. Supplementation with high levels of α-TA in diets may improve oxidative stability and hence, the storage quality of n-3 fatty acid enriched duck meat. Muscle α-tocopherol levels are easily raised by dietary means, and supplementing diets with 400 mg α-TA / kg diet increases the oxidative stability of duck meat (Russell *et al*., 2003).

Duck is a waterfowl and has a different physiology to that of other poultry. Duck meat has received little attention, in terms of influencing the quality of duck meat during

Table 1: The eight dietary treatments

(Group 1) T20	Tallow Oil (2.5%) + 20 mg α-tocopheryl acetate/kg of feed
(Group 2) T400	Tallow Oil (2.5%) + 400 mg α-tocopheryl acetate/kg of feed
(Group 3) O20	Olive Oil (2.5%) + 20 mg α-tocopheryl acetate/kg of feed
(Group 4) O400:	Olive Oil (2.5%) + 400 mg α-tocopheryl acetate/kg of feed
(Group 5) S20	Sunflower Oil (2.5%) + 20 mg α-tocopheryl acetate/kg of feed
(Group 6) S400:	Sunflower Oil (2.5%) + 400 mg α-tocopheryl acetate/kg of feed
(Group 7) L20	Linseed Oil (2.5%) + 20 mg α-tocopheryl acetate/kg of feed
(Group 8) L20	Linseed Oil (2.5%) + 400 mg α-tocopheryl acetate/kg of feed

Table 2: α-Tocopherol content of duck breast and thigh muscle (μg/g)

Dietary group	Breast	Thigh
T20	4.9	1.0
O20	0.5	1.4
S20	2.3	2.3
L20	1.9	1.1
T400	28.1	27.5
O400	11.1	22.0
S400	24.8	27.5
L400	25.0	32.1

retail storage by means of dietary supplementation. This is somewhat surprising considering the increased consumption of this meat type in recent years through greater availability of ethnic foods offered through restaurants and retail outlets as well as seasonal changes in preference for duck over other poultry meats. The objectives of the present research were to determine the effect of varying dietary oils in the degree of unsaturation (tallow, olive, sunflower and linseed oils) with a control and supplemented level of α-TA on the α-tocopherol content, fatty acid composition and oxidative stability of duck tissues, thereby determining ways to further manipulate and improve duck meat quality.

Materials and Methods

Chemicals: All chemicals used were 'AnalaR' grade obtained from British Drug House, Poole, Dorset, U.K.; Sigma Chemical Co., Ltd., Poole, Dorset, U.K. and Rathburn Chemical Co., Ltd., Walkerburn, Peableshire, Scotland. The feed was manufactured at Teagasc, Moorepark Research Centre, Fermoy, Co. Cork as described previously (Russell *et al.*, 2003).

Animals and diets: Day-old White Peking ducklings (n=100) were obtained from a commercial hatchery and were distributed over 8 pens (2.4m × 1.5m). Ducklings were reared at Teagasc, Moorepark Research Centre, Fermoy, Co. Cork. Ducklings were randomly assigned to eight groups and fed a commercial diet supplemented with a dietary fat source and α-TA at a concentration of either 20mg α-TA/kg feed (control) or 400mg α-TA/kg feed (supplemented) (Table 1). Food and water were offered *ad libitum*.

Sample Preparation: At the end of the feeding period, ducklings were fasted overnight and slaughtered by cervical dislocation. Breast and thigh meat samples were immediately removed from each carcass. Meat was packed in vacuum packs (Cryovac bags 20 polyamide/50 polyethylene, oxygen permeability 45cm^3/m^2/24hours at STP) using a Webomatic vacuum packaging system, (Werner Bonk, Mausegatt 59, type D463, Bochum 6, Germany) and stored at 4 °C (fresh) or -20 °C (frozen and cooked) until required.

Breast and thigh meat from each dietary treatment was chopped using a Stephen UMC 5 electron bowl chopper (A. Stephen Sohne, Gmbh and Co., 31784 Hameln, Germany) at low speed of 800 revolutions x 30 seconds. Meat was formed into patties (~150 g) using a conventional burger former (MINISTEAK O.L., Smith and Co. Ltd., Italy) (three patties per treatment group) and analyzed for both lipid oxidation and colour stability. Patties were over wrapped in oxygen permeable (6000-8000 cm^3/m^2/24hours at STP) polyvinyl-chloride film (Wrap Film Systems Ltd., Halesfield 14, Telford TF7 4QR, Shropshire, England) and held under refrigerated display conditions using fluorescent light (616 lux at 4 °C x 10 days). Two months after slaughter, frozen meat was thawed overnight at 4 °C, chopped, formed into patties and held in a refrigerated display cabinet as described above. In addition breast and thigh patties for each dietary group were cooked in a Zanussi oven (C. Batassi, 31015, Conegliano, Italy) to an internal temperature of 72 °C, as measured by an internal temperature probe. Cooked patties were stored in a refrigerated display cabinet as described above.

Measurement of α-tocopherol: Extraction of α-tocopherol with hexane after saponification at 70 °C from breast, thigh, heart and liver tissue samples was carried out according to the method of Buttriss and Diplock (1984). Reverse-phase High Performance Liquid Chromatography (HPLC) was used to quantify α-tocopherol using a Waters model S10 pump, a Waters 717 auto sampler, a Machery-Nagel Nucleosil 5 C18 (250 x 0.4 mm) reverse phase column and a Waters model 486 UV-visible wavelength detector (Millipore Corporation, Milford, MA, USA) set at 292 nm. The mobile phase was methanol:water (97:3) as described by Sheehy *et al.* (1993). Data were recorded and evaluated

Table 3: Percentage fatty acid composition of breast and thigh meat from the eight dietary treatments

Fatty Acid Content (%)	C14:0	C16:0	C16:1n-7	C18:0	C18:1n-9	C18:2n-6	C18:3n-3
T20 Breast	0.9	22.9	2.4	12.0	41.1	9.6	0.5
T20 Thigh	0.7	20.6	3.3	11.4	46.7	12.0	0.7
O20 Breast	0.5	17.0	3.1	9.4	46.7	11.5	0.9
O20 Thigh	0.4	19.2	3.5	7.4	53.1	11.1	0.6
S20 Breast	0.5	23.2	1.9	12.4	36.2	13.2	0.4
S20 Thigh	0.4	19.5	3.0	8.3	46.8	16.8	0.5
L20 Breast	0.7	24.8	1.9	15.4	34.3	9.5	3.0
L20 Thigh	0.4	18.7	2.9	8.5	45.5	12.8	6.0
T400 Breast	1.0	24.1	2.3	12.4	36.7	10.5	1.1
T400 Thigh	0.5	20.4	3.3	10.0	47.4	12.0	1.4
O400 Breast	0.7	26.1	2.6	10.0	39.9	10.2	0.7
O400 Thigh	0.4	19.8	2.9	8.3	52.5	10.8	0.7
S400 Breast	0.6	23.8	1.7	12.9	33.7	14.5	0.4
S400 Thigh	0.4	19.3	2.9	8.5	43.6	18.3	0.5
L400 Breast	0.5	24.4	1.6	15.5	33.5	10.8	3.0
L400 Thigh	0.4	20.0	3.0	8.7	44.6	12.4	6.0

T20 = tallow + 20 mg α-TA/kg feed, O20 = olive oil + 20 mg α-TA/kg feed, S20 = sunflower oil + 20 mg α-TA/kg feed, L20 = linseed oil + 20 mg α-TA/kg feed. T400 = tallow + 400 mg α-TA/kg feed, O400 = olive oil + 400 mg α-TA/kg feed, S20 = sunflower oil + 20 mg α-TA/kg feed, L20 = linseed oil + 20 mg α-TA/kg feed

Table 4: Degree of saturation of fatty acids in breast and thigh meat from the eight dietary treatments

Degree of Saturation (%)	SFA	MUFA	PUFA	MUFA/SFA	PUFA/SFA
T20 Breast	35.8^{a}	43.6^{a}	20.9^{a}	1.2	0.6
T20 Thigh	32.8^{a}	50.0^{a}	17.3^{a}	1.5	0.5
O20 Breast	26.9^{b}	49.8^{c}	23.3^{b}	0.9	0.9
O20 Thigh	26.9^{b}	56.6^{b}	16.5^{a}	2.1	0.6
S20 Breast	36.1^{a}	38.1^{b}	25.8^{c}	1.1	0.7
S20 Thigh	28.2^{bc}	49.7^{a}	22.1^{b}	1.8	0.8
L20 Breast	40.9^{c}	36.2^{e}	22.9^{ab}	0.9	0.6
L20 Thigh	27.6^{b}	48.4^{ac}	24.1^{b}	1.8	0.9
T400 Breast	37.5^{a}	39.0^{b}	23.5^{b}	1.0	0.6
T400 Thigh	30.9^{ac}	50.7^{a}	18.5^{a}	1.6	0.6
O400 Breast	36.9^{a}	42.5^{ad}	20.7^{a}	1.2	0.6
O400 Thigh	28.5^{bc}	55.3^{b}	16.2^{a}	1.9	0.6
S400 Breast	36.1^{a}	38.1^{b}	25.8^{c}	1.1	0.7
S400 Thigh	28.2^{bc}	46.4^{c}	25.4^{b}	1.7	0.9
L400 Breast	40.9^{c}	36.2^{e}	22.9^{ab}	0.9	0.6
L400 Thigh	29.1^{b}	47.6^{ac}	23.4^{b}	1.6	0.9

$^{a-e}$ Values with different superscripts within each row differ significantly at $p < 0.05$. T20 = tallow + 20 mg α-TA/kg feed, O20 = olive oil + 20 mg α-TA/kg feed, S20 = sunflower oil + 20 mg α-TA/kg feed, L20 = linseed oil + 20 mg α-TA/kg feed. T400 = tallow + 400 mg α-TA/kg feed, O400 = olive oil + 400 mg α-TA/kg feed, S20 = sunflower oil + 20 mg α-TA/kg feed, L20 = linseed oil + 20 mg α-TA/kg feed

on a Millipore Millennium 2010 chromatography management system (Millipore Corporation, Milford, MA, USA).

Measurement of fatty acid composition: Total fat, for fatty acid analysis, was extracted from meat and feeds using the method of Folch *et al.* (1957). Fatty acid methyl esters were prepared according to the procedure of Slover and Lanza (1979). GC analysis was carried out using a Shimadzu (Model GC-14A) gas chromatograph with flame ionization detector, equipped with a Shimadzu (Model AOC-17) auto injector. The column used was an SGE fused silica capillary column (SGE UK Ltd.) (25 m x 0.25 mm i.d., film thickness 0.25 µm). The carrier gas was nitrogen at a pressure of 1.25 PSI. Oven temperature programming was set as follows: 50 °C to 200 °C at 10 °C/minute, held at 200 °C for 17 minutes, 200 °C to 227 °C at 9 °C /minute and held isothermally at 227 °C for 15 minutes. The injector port and detector temperature was 250 °C. Chromatograms were processed using the Millennium 2010 software package (Millipore Corporation, Milford, MA., USA). The content of each fatty acid in the sample was expressed as mg fatty acid/g muscle.

Measurement of lipid oxidation: The extent of lipid oxidation in chopped muscle samples was assessed by the 2-thiobarbituric acid distillation method of Tarladgis, *et al.* (1960) as modified by Ke *et al.* (1977). TBARS were expressed as mg malonaldehyde per kg sample. Two samples from each of three patties were tested for each treatment on days 0, 2, 4, 6, 8 and 10.

Statistical Analysis: Analysis of variance was conducted for each variable measured to investigate the effect of time, dietary treatment and the interaction of both. This was a repeated measures design using "between-subject" factor. The effect of day was measured "within-subjects". Tukey's test was used to adjust for multiple comparisons (Neter *et al.*, 1990). For α-tocopherol and fatty acids, the statistical significance of the difference between treatments was analyzed by general linear model univariate analysis. Tukey's test for multiple comparisons was performed using the general linear model of SPSS 10.0 for Windows (SPSS, Chicago, IL, USA) software package. The level of statistical significance was taken as $p < 0.05$.

Results

Effect of α-Tocopheryl Acetate Supplementation on α-Tocopherol Content of Duck Muscle: The α-tocopherol content of breast and thigh meat from ducks fed diets containing tallow or olive, sunflower or linseed oils is shown in Table 2. The concentration of α-tocopherol deposited in breast and thigh meat from ducks fed the supplemented diet was higher ($p < 0.05$) compared to meat from ducks fed the control diet, irrespective of the dietary fat source fed. Ducks fed olive oil with 400mg α-TA/kg feed had lower ($P < 0.05$) α-tocopherol levels in breast and thigh meat than α-TA supplemented ducks fed other fat sources. α-Tocopherol levels in breast meat decreased in the order: T20 > S20 > L20 > O20 for control groups and in the order: T400 > L400 > S400 > O400 for supplemented groups. In thigh meat, α-tocopherol levels decreased in the order: S20 > O20 > L20 > T20 for control groups and in the order: L400 > S400 > T400 > O400 for supplemented groups. Control groups fed tallow or linseed oil (T20 or L20) and the supplemented group fed tallow (T400) had higher α-tocopherol levels in breast than in thigh. However, thigh meat from groups O400 and L400 had significantly ($p < 0.05$) more α-tocopherol than corresponding breast meat.

Effect of Diet on Fatty Acid Composition of Duck Muscle: The percentage fatty acid contained in duck breast and thigh meat from all dietary groups is shown in Table 3. The group fed tallow had the highest level of saturated fats (C14:0, C16:0 and C18:0) in thigh meat, with significantly ($p < 0.05$) higher levels of C14:0 and C18:0 for ducks receiving control levels of α-TA and of C18:0 for ducks receiving supplemental levels of α-TA. This group also had higher levels of C14:0 in breast meat than ducks fed linseed oil and significantly ($p < 0.05$) higher levels of C14:0 than ducks fed sunflower oil or linseed oil for both control and supplemental levels of α-TA. Breast meat contained higher ($p < 0.05$) levels of C14:0 and C18:0 than thigh meat for all dietary groups. Breast meat also contained more C16:0 than thigh meat for all dietary groups with the exception of the olive oil group receiving the control level of α-TA. Breast meat from the group fed olive oil had higher levels of monounsaturated fatty acids (C16:1n-7 and C18:1n-9) than other dietary groups and significantly ($p < 0.05$) so in combination with control levels of α-TA. Thigh meat from the group fed olive oil with control α-TA had the highest ($p < 0.05$) levels of C16:1n-7 and C18:1n-9. However, for ducks fed supplemental levels of α-TA, the highest ($p < 0.05$) level of C16:1n-7 occurred in the linseed oil dietary group and the highest ($p < 0.05$) level of C18:1n-9 occurred in the sunflower oil dietary group. Thigh meat contained higher ($p < 0.05$) levels of C16:1 and C18:1 than breast meat for all dietary groups.

In general, thigh meat tended to contain higher levels of polyunsaturated fatty acids than breast meat, with the exception of the olive oil dietary group receiving control levels of α-TA. The highest level of polyunsaturated fatty acids occurred in breast and thigh meat from the sunflower oil dietary group (C18:2n-6) and the linseed oil dietary group (C18:3n-3).

Overall, duck breast muscle contained 27-41% SFA, 35-50% MUFA and 20-28% PUFA and thigh muscle contained 27-33% SFA, 46-57% MUFA and 16-25% PUFA (Table 4). The fatty acid composition of breast and thigh muscle was influenced by the fatty acid composition of dietary fat sources. Duck breast meat from the sunflower oil dietary groups had the lowest proportion of SFA, while breast meat from the linseed oil dietary groups had the highest proportion of SFA. Duck thigh meat from the tallow dietary groups had the highest level of SFA. Duck breast and thigh meat from the olive oil dietary groups had the highest proportion of MUFA, while breast meat from the linseed oil dietary groups had the lowest levels of MUFA. Duck breast meat from the sunflower oil dietary groups had the highest levels of PUFA and thigh meat from the olive oil dietary group had the lowest levels of PUFA. The level of α-TA added to the diet appeared to have some influence on the fatty acid composition duck meat. Duck breast meat from dietary groups T400 and O400 had higher proportions of SFA than the corresponding control groups. Duck thigh meat from dietary groups O400 and L400 had higher proportions of SFA than the corresponding control groups. Dietary groups T400 and O400 had higher proportions of MUFA than the corresponding control groups. Dietary supplementation with α-TA did not significantly affect the proportion of MUFA in thigh meat. Dietary group T400 had a higher proportion of PUFA in breast meat than the

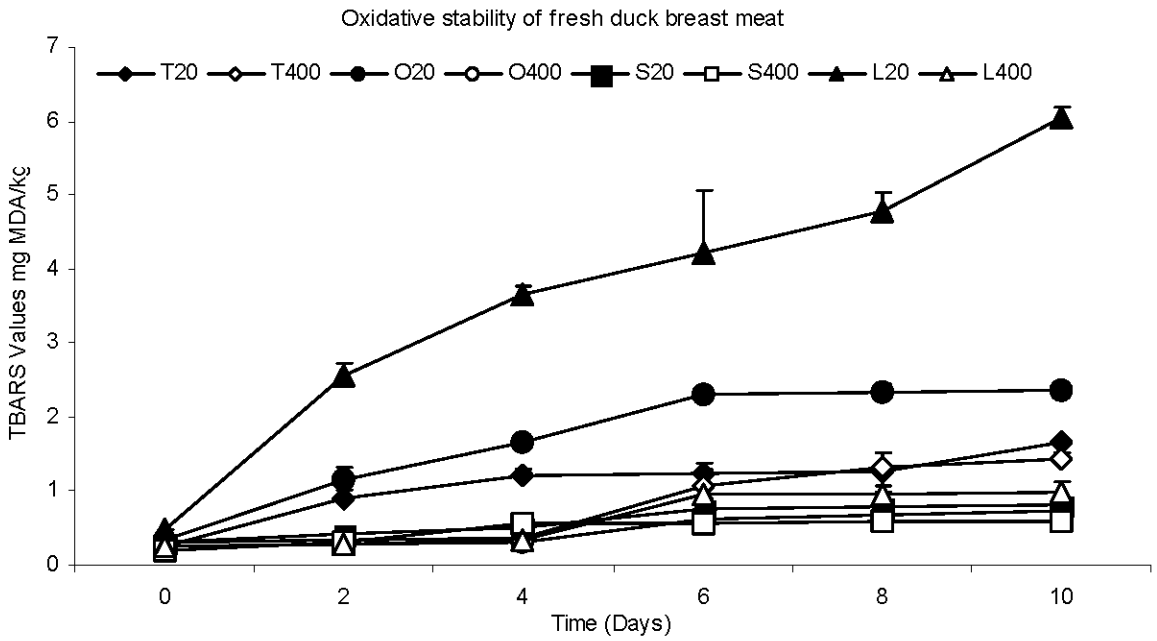

Fig. 1: Oxidative stability of duck breast meat stored under refrigerated display conditions for 10 days

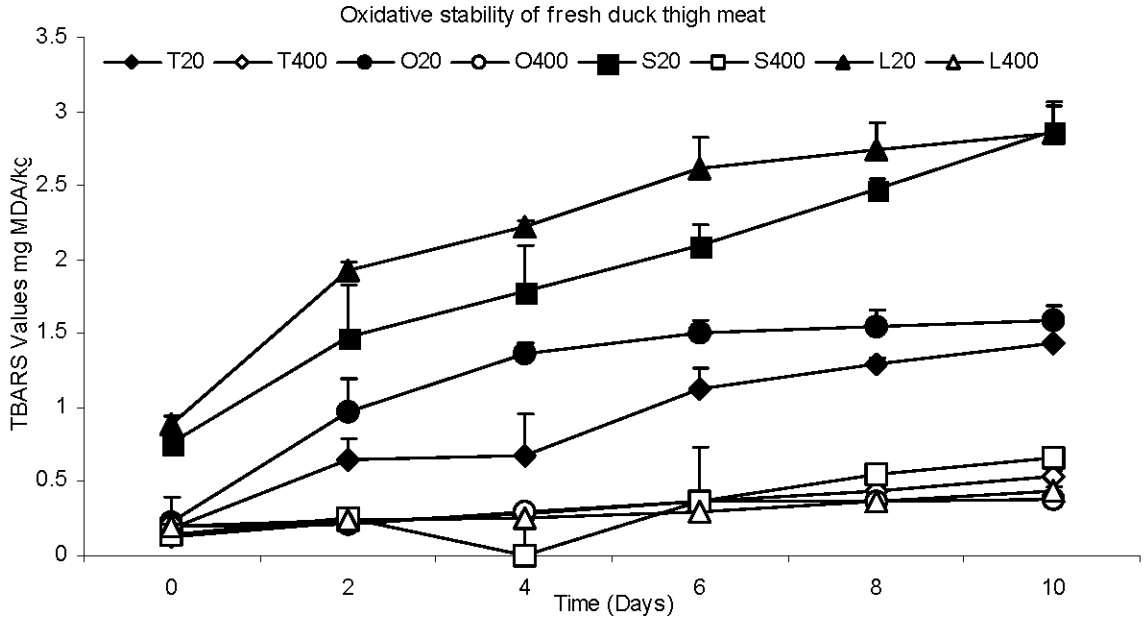

Fig. 2: Oxidative stability of duck thigh meat stored under refrigerated display conditions for 10 days

corresponding control group, while the opposite trend occurred in the group fed olive oil. Dietary supplementation with α-TA did not significantly affect the proportion of PUFA in thigh meat.

Assessment of Lipid Oxidation in Fresh, Previously Frozen and Cooked Duck Breast and Thigh Patties: TBARS values in breast meat from control groups decreased in the order: L20 > O20 > T20 > S20 (Fig. 1). TBARS values in S20 were lower ($p < 0.05$) than in all other control dietary groups. TBARS values in L20 were higher ($p < 0.05$) than T20, O20 and S20 from days 2 to 10. TBARS values for T400, O400, S400 and L400 were lower ($p < 0.05$) than O20 and L20 groups on days 2 to 10. No significant differences were observed between S400 and S20 over the entire storage period. TBARS values for α-TA supplemented meat samples were lower compared to those from the corresponding control

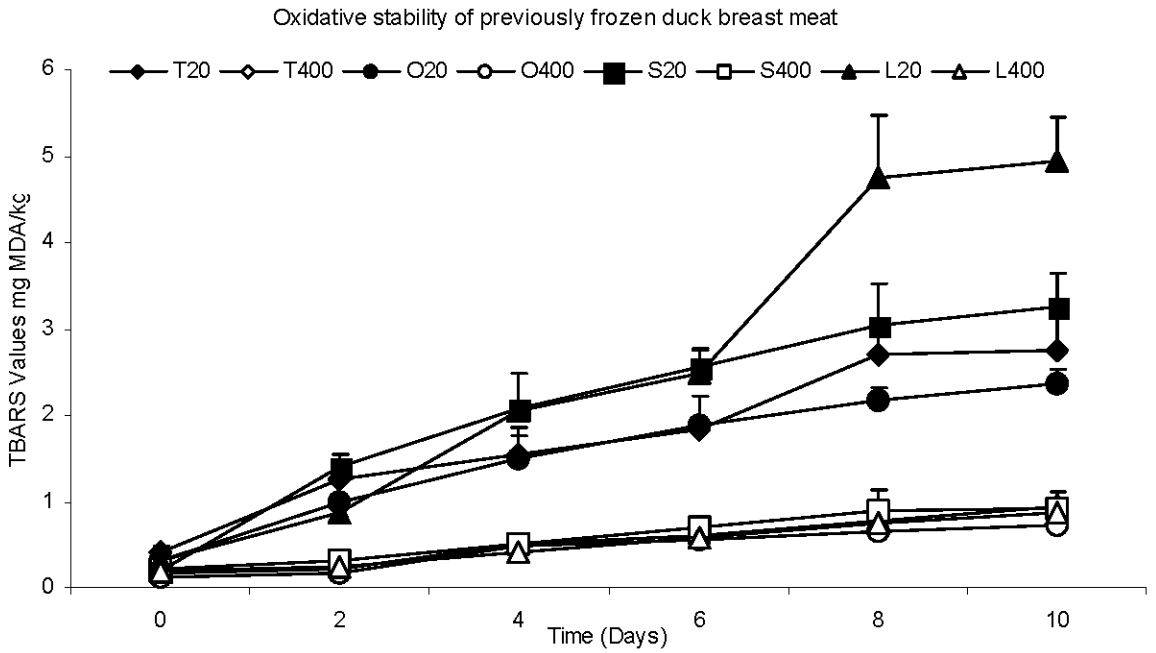

Fig. 3: Oxidative stability of previously frozen duck breast meat stored under refrigerated display conditions for 10 days

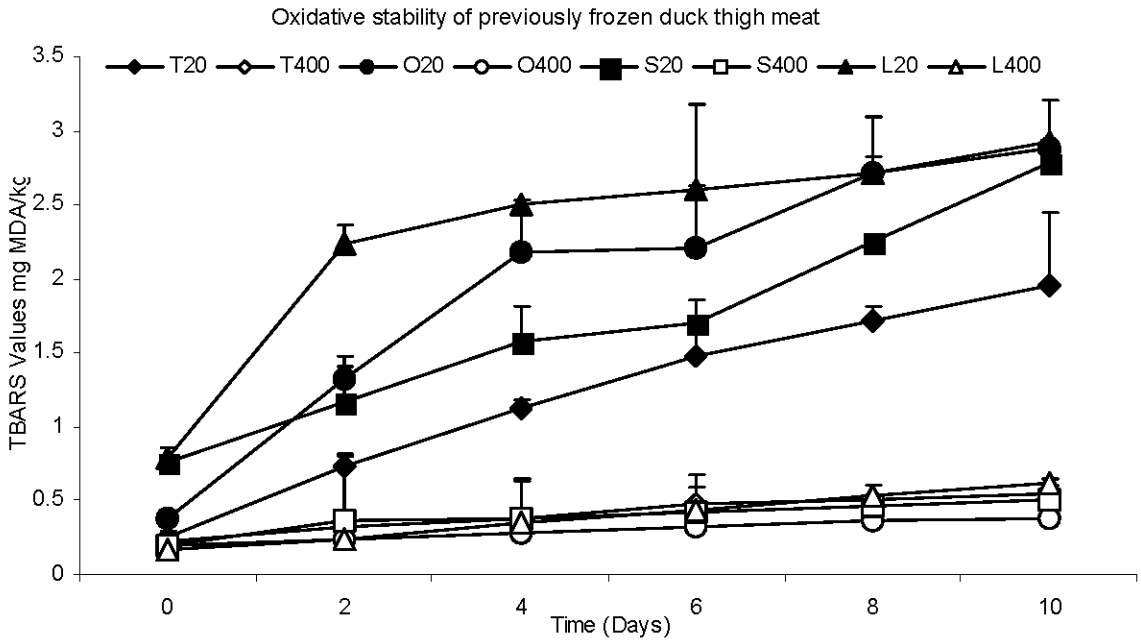

Fig. 4: Oxidative stability of previously frozen duck thigh meat stored under refrigerated display conditions for 10 days

diet and significantly ($P < 0.05$) lower for ducks fed linseed and olive oils.

TBARS values in thigh meat patties increased during storage for all dietary treatments (Fig. 2). Overall, TBARS values in control groups decreased in the order: L20 > S20 > O20 > T20. T20 and O20 had lower ($p < 0.05$) TBARS values than L20 or S20 from days 2 to 10. Supplemented groups had lower ($p < 0.05$) TBARS values than control groups on days 2 to 10, irrespective of the dietary fat source fed. Within control groups, TBARS values for group S20 were higher compared to T20. In the present study, dietary fat source fed did not have a significant effect on TBARS values when 400 mg α-TA/kg feed was fed to ducks. On day 10, TBARS values for meat from all dietary treatments decreased in the order: S400 > T400 > L400 > O400.

Previously frozen (-20 °C for 2 months) breast and thigh meat was displayed in refrigerated storage and assessed for oxidative stability. TBARS values were similar in breast meat from all groups on day 0 (Fig. 3). Supplemented groups had lower ($p < 0.05$) TBARS values than control groups on days 2 to 10, irrespective of dietary fat source fed. TBARS values in breast patties of control groups decreased in the order: L20 > S20 > T20 > O20 and in the order: T400 > S400 > L400 > O400 for breast patties of supplemented groups. No significant differences were observed in TBARS values for breast meat from supplemented ducks fed different dietary fats. Duck fed olive oil was the most stable of the groups fed the control level of α-TA. Thigh meat from supplemented groups had significantly ($p < 0.05$) lower TBARS values compared to control groups on days 2 to 10 after two months frozen storage, irrespective of dietary fat source fed (Fig. 4). Dietary oil fed did not have a significant effect on TBARS values when 400 mg α-TA/kg feed was fed to the ducks, but patties from ducks fed olive oil tended to have lower TBARS values. Overall, oxidative changes were much more extensive in breast muscle compared to corresponding thigh meat for all dietary treatments for frozen patties.

The oxidative stability of refrigerated, cooked, over-wrapped breast and thigh duck patties was also examined. As expected, TBARS values increased after cooking. There was an 8-fold difference between the initial level of oxidation in raw and cooked breast meat patties (Fig. 5) and a 12-fold difference between the initial level of oxidation in raw and cooked thigh meat patties (Fig. 6). TBARS values in cooked breast meat control groups decreased in the order: S20 > T20 > O20 > L20. TBARS values in supplemented groups decreased in the order: T400 > S400 > O400 > L400. TBARS values were lower ($p < 0.05$) in L400 compared to all other treatments. Addition of α-TA at 400 mg/kg feed significantly ($p < 0.05$) reduced oxidation during cooking and subsequent storage of cooked thigh meat compared to meat from ducks fed 20 mg α-TA/kg feed, irrespective of the dietary oil fed (Fig. 6). TBARS values in cooked thigh meat control groups decreased in the order: L20 > S20 > O20 > T20. L20 had significantly ($p < 0.05$) higher TBARS values compared to O20, S20 and T20 on days 6 to 10. TBARS values in supplemented groups decreased in the order: T400 > O400 > L400 > S400. T400 and O400 had significantly ($p < 0.05$) higher TBARS values than L400 and S400 throughout the storage period. α-TA supplementation resulted in a large decrease in the concentration of TBARS, compared to controls, irrespective of the dietary fat source.

Discussion

Effect of α-Tocopheryl Acetate Supplementation on α-Tocopherol Content of Duck Muscle: α-Tocopherol concentrations observed in duck breast and thigh meat in this study (Table 2) were from 2- to 10-fold higher than those previously reported by Russell *et al.* (2003) who found α-tocopherol contents of 0.2 to 0.4 mg/kg meat (control groups) and 3.8 to 4.2 mg/kg meat (supplemented groups) in duck breast meat and 0.5 to 0.6 mg/kg meat (control groups) and 3.8 to 6.2 mg/kg meat (supplemented groups) in duck thigh meat. In general, α-tocopherol levels in duck muscle showed no definite accumulation trend between breast or thigh meat. This finding is in contrast to Russell *et al.* (2003) who reported that α-tocopherol accumulated to a much greater degree in breast meat than thigh meat. It is not clear why α-tocopherol levels detected in meat between this study and that of Russell *et al.* (2003) should be so different (seeing as feed α-tocopherol levels were similar, data not shown) or why α-tocopherol accumulation levels between breast and thigh meat in this study and that of Russell *et al.* (2003) do not correlate. However, both this study and that of Russell *et al.* (2003) still show that α-tocopherol accumulation in duck muscle does not occur in the same way as in other poultry species. Jensen *et al.* (1998) reported that skeletal muscles with the highest oxidative capacity also possessed the greatest storage capacity for α-tocopherol. Taking both this study and Russell *et al.* (2003) together, this apparent anomaly may be explained by the fact that the breast muscles of ducks are used for flight and therefore have a similar or greater oxidative capacity than the breast muscle of chickens or turkeys. α-Tocopherol levels in duck breast and thigh from the supplemented tallow group were higher than those reported in turkeys by Mercier *et al.* (1998) for the same dietary level of α-tocopheryl acetate (400 mg/kg feed) and the same fat source (tallow) fed for 16 weeks. Therefore, ducks behaved differently to turkeys in both the extent and the rate at which α-tocopherol was absorbed. O'Neill *et al.* (1998) reported that α-tocopherol levels in broiler thigh meat were higher than those in breast meat after feeding chickens with either control (30 mg/kg feed) or supplemental (200 mg/kg feed) levels of α-TA. In this study, α-tocopherol levels were generally higher in breast meat for the control diets (except O20) and higher in thigh meat for the supplemental diets (except T400). Therefore, the uptake of α-tocopherol by breast and thigh muscle in ducks and broilers is very different.

Effect of Dietary Fat on the Fatty Acid Composition of Duck Meat: Overall, duck breast muscle contained 27-41% SFA, 35-50% MUFA and 20-28% PUFA and duck thigh muscle contained 27-33% SFA, 46-57% MUFA and 16-25% PUFA Salichon *et al.* (1997) reported broadly similar proportions for breast meat of Muscovy ducks which contained 38.7% SFA, 30.8% MUFA and 30.5% PUFA. The fatty acid profile of duck breast and thigh meat was influenced by the type of fat included in the diet. From an extensive review of the scientific literature, no reports were detected on the influence of fat in the diet of ducks on the fatty acid profile of duck meat.

However, our findings are in agreement with previous studies for chickens. Scaife *et al.* (1994) found that PUFA (C18:2, C20:2 and C22:4) were higher in breast muscle from broilers fed diets rich in these fatty acids compared to diets rich in saturated fats. Nam *et al.* (1997) found that linseed supplementation reduced the concentration of total SFA in both broiler breast and thigh meat, whereas total PUFA increased in both muscles. MUFA levels were not affected. In this study, the highest levels of SFA occurred in thigh meat from ducks fed tallow, the highest levels of MUFA in duck breast and thigh meat occurred in ducks fed olive oil, while the highest levels of PUFA was found in breast meat from ducks fed sunflower oil and thigh meat from ducks fed sunflower oil and linseed oil. Farrell (1991) reported that oils rich in α-linolenic acid (linseed oil) and precursors of the longer chain n-3 PUFA such as EPA and DHA (fish oil) can be used successfully to produce these long chain PUFA in duck meat. Ahn *et al.* (1995) reported that dietary α-linolenic acid (flax seed) increased the proportions of n-3 (PUFA) and n-6 diunsaturated fatty acids (DUFA) in lipids of leg meat from chickens, thereby replacing MUFA and SFA. Similarly, in this study, breast and thigh n-3 fatty acids were highest in linseed oil-fed groups, while n-6 were highest in sunflower oil-fed groups. Sanz *et al.* (1999) fed broiler chicks diets containing different fat sources 8% (tallow, lard or sunflower oil). Broilers fed diets containing sunflower oil had a higher concentration of PUFA (n-6) fatty acids in the intramuscular neutral lipids compared to lipids from the other diets. This result is similar to the findings in this study for the lipid composition of duck thigh meat.

From an extensive review of the scientific literature, no reports were found on the effect of dietary fat source on the fatty acid composition of duck meat. In this study, ducks fed tallow had, in general higher levels of C14:0, C16;0 and C18:0 in both breast and thigh meat. Breast meat from duck fed control or supplemented α-TA and thigh meat from duck fed control α-TA had the highest levels of C16:1 and C18:1. This finding is in agreement with O'Neill *et al.* (1998) who reported that feeding olive oil to broilers resulted in a higher proportion of C18:1 in breast and thigh meat. The highest level of C18:2n-6 occurred in breast and thigh meat from ducks fed sunflower oil and the highest level of C18:3n-3 occurred in breast and thigh meat from ducks fed linseed oil.

From an extensive review of the scientific literature, no reports were found on the fatty acid profile of duck breast and thigh meat. Lauridsen *et al.* (1997) fed broilers a diet containing either tallow or olive oil and either control (20mg α-TA/kg) or supplemented (200mg α-TA/Kg) levels of α-TA. The levels of C14:0 and C18:0 in breast meat from ducks fed tallow or olive oil in this study were broadly similar to those reported by Lauridsen *et al.* (1997) for breast meat from chickens. However, the levels of C16:0 in this study were significantly ($P < 0.05$) higher than those reported by Lauridsen *et al.* (1997) for chickens. The levels of C16:1 in this study were significantly ($p < 0.05$) higher in duck than chicken, while the levels of C18:1 were broadly similar (Lauridsen *et al.*, 1997). The levels of C18:2 in chicken breast meat were significantly higher ($p < 0.05$) than those found in this study for duck, while the levels of C18:3 were broadly similar for chicken and duck breast meat. In thigh meat, the levels of C14:0 in this study were significantly ($p < 0.05$) lower than those in chicken thigh meat. The levels of C16:0 in duck thigh meat were higher but not significantly so ($P > 0.05$) and the levels of C18:0 were significantly higher in ducks than in chickens when supplemental levels of α-TA were added to the diets. The levels of C16: 1 and C18: 1 were significantly ($p < 0.05$) higher and the level of C18:2 was significantly ($p < 0.05$) lower in ducks than chickens. The levels of C18:3 in duck thigh meat in this study were broadly similar to those reported for chickens (Lauridsen *et al.*, 1997). From an extensive review of the scientific literature, no reports were found on the individual fatty acid profile of turkeys, so a comparison between the fatty acid profiles of ducks and turkeys could not be made.

Assessment of Lipid Oxidation in Duck Breast and Thigh Patties: TBARS values decreased in the order: L20 > O20 > T20 > S20 and in the order: T400 > L400 > O400 > S400 for breast muscle from control and α-TA supplemented groups, respectively. TBARS values for thigh muscle decreased in the order: L20 > S20 > O20 > T20 (control) and in the order: S400 > T400 > L400 > O400 (supplemented). From an extensive review of the scientific literature, no reports on the oxidative stability of duck meat were found. TBARS values for duck breast and thigh meat recorded in this study were higher than those reported for chickens (Sheehy *et al.*, 1993; Morrissey *et al.*, 1997) and laying hens (Cherian *et al.*, 1996) and similar to those reported by Higgins *et al.* (1998) for turkeys. Galvin *et al.* (1997) and Higgins *et al.* (1998) reported that the lipid stability of chicken and turkey meat, respectively, was improved by the dietary supplementation of α-TA. This is in agreement with the present study which found that the α-TA supplemented ducks had lower TBARS values for both breast and thigh meat, irrespective of dietary fat source. Breast meat from ducks fed sunflower oil was the most oxidatively stable for both control and supplemental α-TA groups. However, in thigh meat, ducks fed sunflower oil had higher TBARS values than all other dietary groups with the exception of L20.

Previously frozen duck breast and thigh meat from the control α-TA groups had higher ($p < 0.05$) TBARS values than supplemental α-TA groups on days 2 to 10. From an extensive review of the scientific literature, no reports were detected for studies of the oxidative stability of previously frozen duck meat. The results in this study for duck do however, agree with Higgins *et al.* (1998) who found that previously frozen turkey breast and thigh patties from E600 (600 mg α-TA/kg feed) had

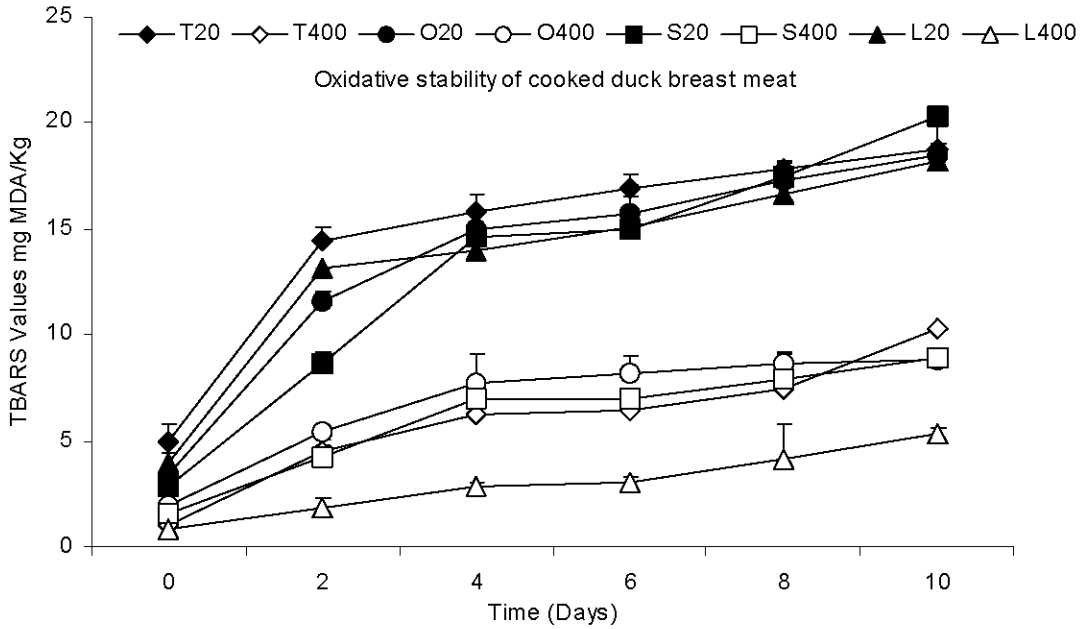

Fig. 5: Oxidative stability of cooked duck breast meat stored under refrigerated display conditions for 10 days.

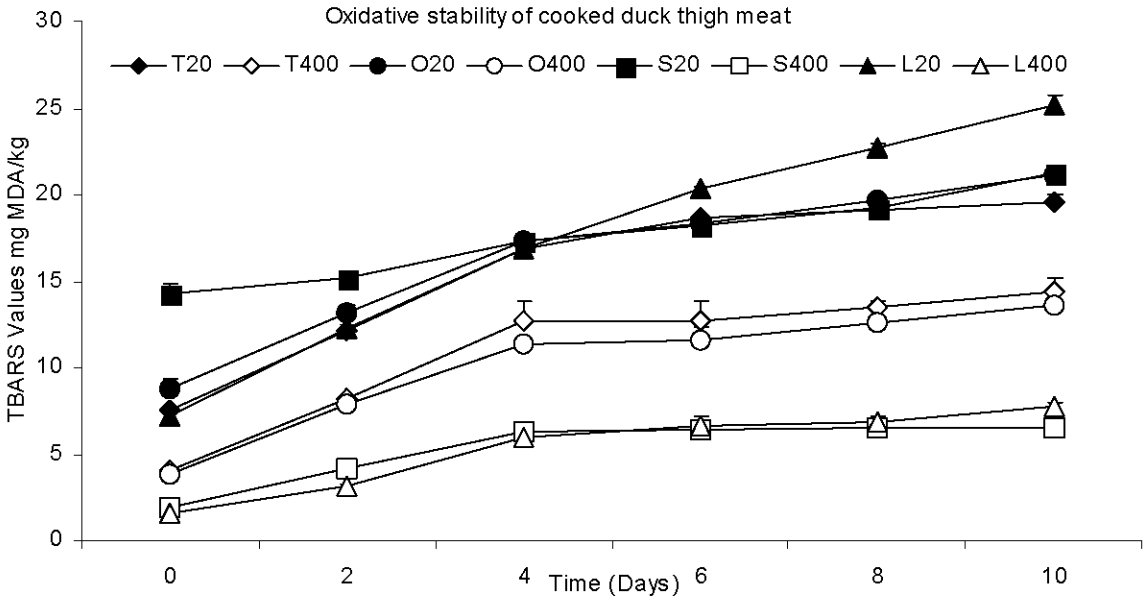

Fig. 6: Oxidative stability of cooked duck thigh meat stored under refrigerated display conditions for 10 days

significantly lower TBARS values compared to E20 (20 mg α-TA/kg feed). Previously frozen duck thigh meat from α-TA supplemented groups had lower ($p < 0.05$) TBARS values than control α-TA groups on days 2 to 10 after two months frozen storage, irrespective of the dietary oil fat source. Thigh meat from the T20 dietary group had lower TBARS values than the other control α-TA groups on days 2 to 10. TBARS values in S20 and L20 were higher ($p < 0.05$) than in T20 and O20 on day 0. These higher TBARS values reflect the higher PUFA concentration in thigh meat from ducks fed sunflower and linseed oils. However, thigh meat from ducks fed the O400 diet had the lowest TBARS values within the supplemental α-TA groups. From an extensive review of the scientific literature, no reports were found on the effect of dietary fat on the oxidative stability of previously frozen duck thigh meat. However, these results for duck meat agree with Lauridsen *et al.* (1997) who reported that TBARS values from chicken meat were lower in the olive oil fed groups than the tallow fed groups.

TBARS values for cooked duck breast and thigh meat were higher ($p < 0.05$) than those for fresh and previously frozen breast and thigh meat, irrespective of α-TA supplementation and dietary fat source.

Supplementation with α-TA resulted in lower TBARS values for both breast and thigh meat, irrespective of dietary fat source. From an extensive search of the scientific literature, no reports were found on the oxidative stability of cooked duck breast and thigh meat. However, our results agree with Wen *et al.* (1996) who observed that cooked burgers produced from turkey thigh meat offered 300 or 600 mg α-TA/kg feed were more stable than meat from control turkeys. In agreement, Galvin *et al.* (1997) reported that dietary α-TA supplementation improved the stability of cooked chicken thigh meat, with stability increasing as muscle α-tocopherol concentrations increased.

Many researchers have shown that the rate and extent of lipid oxidation are dependent on the α-tocopherol concentration in the tissues. In contrast to our findings for duck meat, which have shown that breast meat accumulated more α-tocopherol than thigh meat, previous studies have found that chicken and turkey thigh meat had higher amounts of endogenous α-tocopherol than breast meat, but oxidized faster than breast meat (Lin *et al.*, 1989; Higgins *et al.*, 1999). These findings demonstrate the differences that exist in the physiology and composition of duck meat (waterfowl) compared to chicken and turkey meat. Muscle α-tocopherol is one important factor influencing the level of lipid oxidation, but the influence of the fatty acid composition and the content of pro-oxidants, such as iron, must be taken into consideration as well. In chicken and turkey meat the higher susceptibility of thigh meat to oxidation is readily explained by the higher absolute content of PUFA in thigh meat compared to breast meat. Asghar *et al.* (1990) claimed that the higher total lipid contents in thigh meat of broilers might contribute to the higher TBARS values. Another factor may also be the faster rate of lipolysis in thigh muscle. Thigh meat has been shown to take up more α-tocopherol than breast meat in other poultry species (Wen *et al.*, 1996; Higgins *et al.*, 1998). The level of iron reported in duck thigh meat by Russell *et al.* (2003) was higher than that contained in duck breast meat. Therefore, one might expect higher TBARS values for duck thigh meat than duck breast meat. However, in this study, duck thigh meat had lower TBARS values than breast meat for fresh and previously frozen patties and similar TBARS values were found in duck breast and thigh meat for cooked patties.

In conclusion, α-TA supplementation of duck diets increased tissue α-tocopherol concentration irrespective of the dietary oil used. The level of α-tocopherol accumulated in duck breast meat was higher than that in duck thigh meat. This trend is the opposite to that reported for chickens and turkeys. Ducks fed tallow had a higher percentage saturated fats, while ducks fed olive oil had a higher percentage monounsaturated fats than other dietary groups. Duck meat contained significantly more C16:0 and C16:1 and significantly less C18:2 than chicken meat while the levels of C14:0, C18:0, C18:1 and C18:3 were broadly similar in duck and chicken meat. α-TA supplementation resulted in lower TBARS values in fresh, previously frozen and cooked breast and thigh meat. Breast and thigh meat from α-TA supplemented groups receiving olive oil had the lowest TBARS values for both fresh and previously frozen patties. The lowest TBARS values in cooked patties occurred in α-TA supplemented groups receiving linseed oil (breast) and sunflower oil (thigh). TBARS values in breast meat were higher than the corresponding thigh meat for both fresh and previously frozen patties while TBARS values were not significantly different for cooked breast and thigh patties. Therefore, duck breast and thigh meat was very different form chicken and turkey meat as TBARS values for chicken and turkey breast meat are widely reported to be lower than those for chicken and turkey thigh meat.

α-TA supplementation improved the overall quality of duck breast and thigh meat. Further work needs to be carried out to evaluate the effectiveness of α-tocopherol under large commercial situations and assess its full potential and cost effectiveness.

Acknowledgements

We would like to thank the staff of Teagasc Moorepark Research Centre for providing facilities and resources during these trials. This study was funded entirely from resources within the Department of Food and Nutritional Sciences, University College Cork.

References

Ahn, D.U., F.H. Wolfe and J.S. Sim, 1995. Dietary α-linoleic acid and mixed tocopherols and packaging influences on lipid stability in broiler chicken breast and leg muscle. J. Food Sci., 60: 1013-1018.

Asghar, A., C.F. Lin, J.I. Gray, D.J. Buckley, A.M. Booren and C.J. Flegal, 1990. Effects of dietary oils and α-tocopherol supplementation on membranal lipid oxidation in broiler meat. J. Food Sci., 55: 46-52.

Boberg, M., B. Vessby and I. Selinus, 1986. Effects of dietary supplementation with n-6 and n-3 long chain polyunsaturated fatty acids on serum lipoproteins and platelet function in hypertriglyceridaemic patients. Acta Medical Scandinavia, 220: 153-160.

Buttriss, J.L. and A.T. Diplock, 1984. High pressure liquid chromatography methods for vitamin E in tissues. Methods in Enzymol., 105: 131-138.

Cherian, G., F.W. Wolfe and J.S. Sim, 1996. Dietary oils with added tocopherols effects on egg or tissue tocopherols, fatty acids, and oxidative stability. Poult. Sci., 75: 423-432.

Department of Health, UK., 1994. Nutritional aspects of cardiovascular disease. Report on health and social subjects No. 46, HMSO, London.

Farrell, D.J., 1991. Manipulation of growth, carcass composition and fatty acid content of meat-type ducks using short-term feed restriction and dietary addition. J. Anim. Physiol. and Nutr., 65: 146-153.

Folch, J., M. Lees and G.H.S. Sloane-Stanley, 1957. A simple method for isolation and purification of total lipids from animal tissues. J. Biol. Chem., 266: 497-509.

Galvin, K., P.A. Morrissey and D.J. Buckley, 1997. Influence of dietary vitamin E and oxidized sunflower oil on the storage stability of cooked chicken muscle. Br. Poult. Sci., 38: 499-504.

Harris, W.S., W.E. Connor, N. Alam and D.R. Illingworth, 1988. Reduction of postprandial triglyceridemia in humans by dietary n-3 fatty acids. J. Lipid Res., 29: 1451-1460.

Higgins, F.M., J.P. Kerry, D.J. Buckley and P.A. Morrissey, 1998. Assessment of α-tocopheryl acetate supplementation, addition of salt and packaging on the oxidative stability of raw turkey meat. Br. Poult. Sci., 39: 596-600.

Higgins, F.M., J.P. Kerry, D.J. Buckley and P.A. Morrissey, 1999. Effects of α-tocopheryl acetate supplementation and salt addition on the oxidative stability (TBARS) and warmed-over flavour (WOF) of cooked turkey meat. Br. Poult. Sci., 40: 59-64.

Huang, Y.X. and E.L. Miller, 1993. The effect of dietary oils and α-tocopherol on the n-3 fatty acid content and oxidative stability of broiler meat, In: Wood, J.D., Lawrence, T.L.J. (Eds.), Safety and Quality of Food from Farm Animals. BAPS, Edinburgh, UK, pp: 108-111.

Jensen, C., C. Lauridsen and G. Bertelsen, 1998. Dietary vitamin E: Quality and storage stability of pork and poultry. Trends in Fd. Sci. Tec., 9: 62-72.

Kanner, J., 1994. Oxidative processes in meat and meat products: quality implications. Meat Sci., 36: 169-189.

Ke, P.J., R.G. Ackman, B.A. Linke and D.M. Nash, 1977. Differential lipid oxidation in various parts of frozen mackerel. J. Fd. Tec., 12: 37-47.

Kinsella, J.E., B. Lokesh and R.A. Stone, 1990. Dietary n-3 polyunsaturated fatty acid and amelioration of cardiovascular disease: possible mechanisms. J. Fd. Sci. Tec., 52: 1-28.

Lauridsen, C., D.J. Buckley and P.A. Morrissey, 1997. Influence of dietary fat and vitamin E supplementation on α-tocopherol levels and fatty acid profiles in chicken muscle membranal fractions and on susceptibility to lipid per oxidation. Meat Sci., 46: 9-22.

Lin, C.F., J.I. Gray, A. Asghar, D.J. Buckley, A.M. Boreen and C.J. Flegal, 1989. Effects of dietary oils and α-tocopherol supplementation on lipid composition and stability of broiler meat. J. Fd. Sci., 54: 1457-1462.

Lopez-Bote, C.J., A.I. Rey, M. Sanz, J.I. Gray and D.J. Buckley, 1997. Dietary vegetable oils and α-Tocopherol reduce lipid oxidation in rabbit muscle. J. Nutr., 127: 1176-1182.

Mercier, Y., P. Gatellier, M. Viau, H. Remignon and M. Renerre, 1998. Effect of dietary fat and Vitamin E on colour stability and on lipid and protein oxidation in turkey meat during storage. Meat Sci., 48: 301-318.

Morrissey, P.A., S. Brandon, D.J. Buckley, P.J.A. Sheehy and M. Frigg, 1997. Tissue content of α-tocopherol and oxidative stability in broilers receiving dietary α-tocopheryl acetate supplementation for various periods pre-slaughter. Br. Poult. Sci., 38: 84-88.

Nam, K.T., H.A. Leea, B.S. Minb and C.W. Kanga, 1997. Influence of dietary supplementation with linseed and vitamin E on fatty acids, tocopherol and lipid per oxidation in muscles of broiler chicks. Anim. Feed Sci. Tec., 66: 149-158.

Neter, J., W. Wasserman and M.H. Kutner, 1990 In: Neter, J., Wasserman. W. and Kutner, M.H. (Eds.), Applied Linear Statistical Models; Regression, Analysis of Variance and Experimental Design. Homewood, Irwin, Boston, pp: 1035-1066.

O'Neill, L.M., K. Galvin, P.A. Morrissey and D.J. Buckley, 1998. Comparison of effects of dietary olive oil, tallow and vitamin E on the quality of broiler meat and meat products. Br. Poult. Sci., 39: 365-371.

Russell, E.A., P.B. Lynch and J.P. Kerry, 2003. Dietary supplementation of α-tocopheryl acetate on α-tocopherol levels in duck tissues and its influence on meat storage stability (In Press).

Salichon, M.R, E. Baeza and B. Leclercq, 1997. Biochemical characteristics of Muscovy duck breast. Sciences des Aliments, 17: 227-233.

Sanz, M., A. Flores and C.J. Lopez-Bote, 1999. Effect of fatty acid saturation in broiler diets on abdominal fat and breast muscle fatty acid composition and susceptibility to lipid oxidation. Poult. Sci., 78: 378-382.

Scaife, J., J. Moyo, H. Galbraith, W. Mitchie and V. Campbell, 1994. Effect of different dietary supplemental fats and oils on the tissue fatty acid composition and growth of female broilers. Br. Poult. Sci., 35: 107-118.

Sheehy, P.J.A, P.A. Morrissey and A. Flynn, 1993. Influence of heated vegetable oils and α-tocopheryl acetate supplementation on α-tocopherol, fatty acids and lipid per oxidation in chicken muscle. Br. Poult. Sci., 34: 367-381.

Slover, H.T. and E. Lanza, 1979. Quantitative analysis of food fatty acids by capillary gas chromatography. J. A. O. C. S., 56: 933-943.

Tarladgis, B.G., B.M. Watts, M.T. Younathan and L.R. Dungan Jr., 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. A. O. C. S., 37: 44-48.

Wen, J., S.N. McCarthy, F.M.J. Higgins, P.A. Morrisey, D.J. Buckley and P.J.A. Sheehy, 1996. Effect of dietary α-tocopheryl acetate on the uptake and distribution of α-tocopherol in turkey tissues and lipid stability. Ir. J. Agri. Fd. Res., 36: 65-74.

Wood, J.D. and M. Enser, 1997. Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. Br. J. Nutr., 78: S49-S60.