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The effect of dietary oils and α-tocopherol on the n-3 fatty acid content and oxidative stability of broiler meat

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Introduction

The benefits to man of an increased consumption of n-3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and of maintaining an optimal ratio of n-6 : n-3 fatty acids in the diet on neural development of the foetus and neonate, incidence of coronary heart disease (CHD), death rate from CHD, inflammatory conditions e.g. psoriasis, rheumatoid arthritis, systemic lupus erythematosus, and suppression of cancer cell growth have recently been reviewed and recognized (British Nutrition Foundation (BNF), 1992). This report recommends a doubling in dietary intake of n-3 fatty acids to 1·5% of energy, primarily obtained by consumption of fish. However, not everyone would wish to eat the equivalent of a 100 to 120 g portion of salmon two to three times a week. Inclusion of fish oil in a broiler chicken diet will incorporate EPA and DHA into broiler meat and could make a significant contribution to the recommended intakes of these fatty acids by man (Hulan, Ackman, Ratnayake and Proudfoot, 1988). An enhanced intake of antioxidant vitamins (β-carotene, ascorbic acid and α-tocopherol) is also considered protective against CHD (Department of Health, 1991). In addition, feeding chickens a diet containing fish oil or α-tocopherol significantly increases antibody production and potentially increases their resistance to disease (Nockels, 1986; Fritsche, Cassity and Shu-Cai Huang, 1991). However, the use of fish oil in an animal diet is limited by its oxidative instability and the risk of causing taint in the meat (Opstvedt, 1984). The purpose of this experiment was to investigate the feasibility of increasing the content of EPA and DHA in broiler meat without compromising oxidative stability by feeding refined fish oil together with supra-nutritional amounts of α-tocopherol.

Material and methods

Twenty day-old ROSS cockerels were allocated to each of nine experimental diets, according to a factorial combination of three DL-α-tocopherol acetate levels (50, 250 and 450 i.u. per kg) with three fish oil (FO, MaxEPA) levels (0 g FO + 10 g soya oil + 40 g lard, 10 g FO + 40 g lard, 20 g FO + 30 g lard per kg diet). At 52 days, birds were commercially slaughtered. α-tocopherol and fatty acid profiles were analysed in breast and thigh muscles by high performance liquid chromatography (Ueda and Igarashi, 1990) and gas-liquid chromatography, respectively. Thiobarbituric acid reactive substances (TBARS) (Crackel, Gray, Booren and Buckley, 1988) were measured in uncooked meat 24 h *post mortem* and again after 6 days under refrigeration. Chickens were plain roasted and breast and thigh meat were assessed by a taste panel immediately after cooking and again after refrigerated storage at –3 to 0°C of the cooked half carcass for 3 days. TBARS were determined on freshly cooked breast and thigh meat and again after 3 and 8 days of refrigerated storage. Further chickens were stored for 6 months at –20 to –25°C, then cooked and subjected to the same taste panel and TBARS assessment immediately after cooking and after further refrigerated storage of the cooked meat.

Results

The first increment of FO substantially increased n-3 fatty acid content of meat lipids at the expense of n-6 acids and without change in the proportion of saturated or monounsaturated fatty acids (Table 1).

The change was greater with breast muscle than with thigh muscle. The second increment of FO further increased the n-3 content of thigh muscle lipids but brought about only a small further increment in breast muscle lipids.

Tissue α-tocopherol was highly correlated ($P < 0·01$) with dietary α-tocopherol concentration (breast muscle $r = 0917$; thigh muscle $r = 0·843$) and was reduced by FO ($P < 0·05$). Thigh muscle contained almost twice as much as breast muscle at each dietary level of α-tocopherol (Figure 1).

TBARS of all fresh or uncooked refrigerated meat were low and within an acceptable range (data not shown). Inclusion of FO without additional vitamin E increased TBARS development during cooking and subsequent refrigerated storage in a dose related

Table 1 *Fatty acids composition (% lipid) of breast and thigh muscles of broiler given different levels dietary fish oil*

Meat type	Fatty acids	Dietary fish oil (g/kg) 0 Mean	0 s.e.	10 Mean	10 s.e.	20 Mean	20 s.e.
Breast	Saturated†	35·7^{b}★	0·65	37·0^{ab}	0·78	39·6^{a}★	1·36
	n-3	2·4^{b}	0·47	9·2^{a}	1·07	10·9^{a}	0·58
	n-6	20·5^{b}	0·58	14·2^{a}	0·29	14·04^{a}	0·56
	Others[2]	35·3	1·51	33·8	1·88	34·2	2·632
Thigh	Saturated‡	33·5	0·58	34·9	0·49	34·8	0·62
	n-3	1·4^{c}	0·20	5·1^{b}	0·61	7·7^{a}	0·58
	n-6	20·2^{b}	0·74	15·7^{a}	0·33	15·5^{a}	0·50
	Others[2]	38·6	1·23	38·3	1·11	35·9	1·47

† 15 : 0 and shorter chain saturated fatty acids not included
‡ All other mono- or poly-unsaturated fatty acids exclusive of n-3 and n-6
$^{a, b, c}$ Tested by *t* test, without labels or labelled with the same letter in the same line means no significant difference; a, b and c: significant difference at 0·01 level; a★, b★, c★ at 0·05 level. (Mean of six).

manner. Additional α-tocopherol at 250 i.u. per kg reduced oxidation during cooking and subsequent storage of cooked breast and thigh meat from treatments both without and with added FO. After 3 days of refrigerated storage, cooked thigh meat had consistently greater TBARS than breast meat across all treatments (data not shown). When cooked after 6 months frozen storage, TBARS were only slightly, and not significantly, increased over those for freshly cooked meat. During subsequent refrigerated storage, TBARS increased in a similar pattern, but with slightly enhanced values, as with fresh meat and the changes were further exaggerated after 8 days refrigerated storage (Figures 2 and 3).

When tasted immediately after cooking, meat from all treatments was acceptable whether fresh or after 6

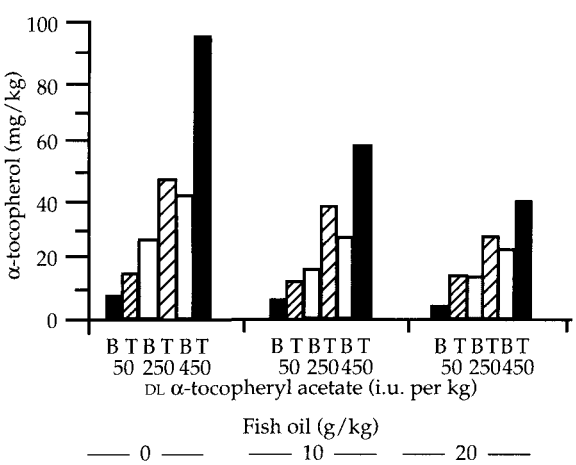

Figure 1 Alpha-tocopherol in fresh breast and thigh muscle.

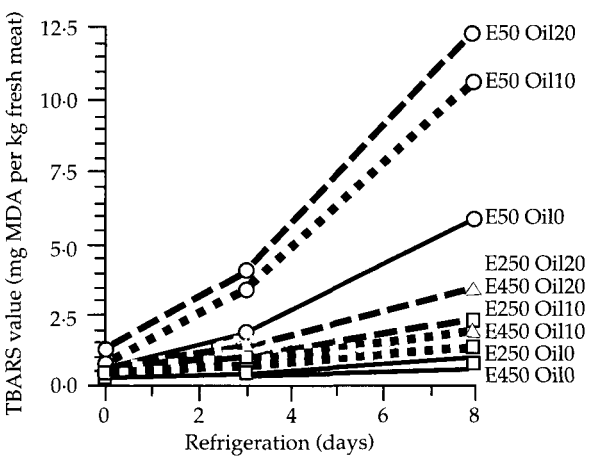

Figure 2 TBARS development of cooked breast muscle during refrigeration at –3 °C to 0 °C. E50 means dietary α-tocopherol 50 i.u. per kg. Oil20 means dietary fish oil 20 g/kg.

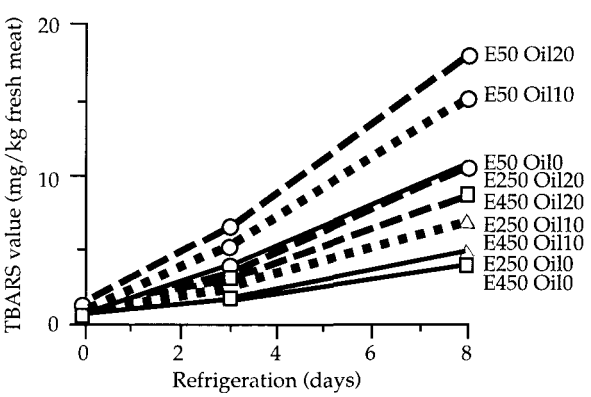

Figure 3 TBARS development of cooked thigh meat during refrigeration at –3 °C to 0 °C. E50 means dietary α-tocopherol 50 i.u. per kg. Oil20 means dietary fish oil 20 g/kg.

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Table 2 *The adjusted mean scores† of taste panel assessment on dark meat refrigerated for 3 days after cooking‡*

Treatment		Fresh§			Frozen§		
α-t (iu/kg)	FO (g/kg)	Odour	Taste	Score‖	Odour	Taste	Score‖
50	0	2·8	$2·9^{a}$	$3·8^{ab}$	$6·4^{a}$	$6·5^{ab}$	$6·6^{a}$
250	0	2·6	$3·0^{a}$	$4·0^{ab}$	$4·9^{dc}$	$5·3^{cbde}$	$5·5^{abc}$
450	0	2·6	$2·7^{a}$	$3·6^{ab}$	$5·8^{abc}$	$6·1^{abc}$	$6·4^{ab}$
50	10	2·5	$2·9^{a}$	$4·2^{a}$	$5·0^{dc}$	$5·5^{abcd}$	$5·6^{abc}$
250	10	2·7	$2·7^{a}$	$4·0^{ab}$	$6·0^{ab}$	$5·9^{abc}$	$6·3^{ab}$
450	10	2·3	$2·5^{a}$	$3·3^{bc}$	$6·0^{ab}$	$6·6^{a}$	$6·8^{a}$
50	20	2·3	$1·9^{b}$	$3·1^{c}$	$4·6^{d}$	$4·4^{e}$	$4·7^{c}$
250	20	2·5	$2·8^{a}$	$4·1^{a}$	$5·4^{bcd}$	$5·0^{cde}$	$4·7^{c}$
450	20	2·5	$2·6^{a}$	$3·8^{ab}$	$5·1^{bcd}$	$4·5^{de}$	$5·1^{abc}$

a, b, c, d The different letter at the same column means significant difference ($P < 0·05$), otherwise no significant difference.
† Treatment means adjusted for block effect.
‡ The scores of breast meat and thigh meat tasted immediately after cooking are not presented here.
§ Fresh meat: scored on a scale of 1 to 3 for odour and taste (2 = acceptable), 1 to 5 for overall acceptability (3 = acceptable); frozen meat: after 6 months freezing store, all scores are a scale of 1 to 10 (5 = acceptable).
‖ Score overall acceptability.

months frozen storage. No consistent effects of FO or α-tocopherol on FO flavour scores were observed (data not shown). After 3 days refrigerated storage of fresh cooked meat, thigh meat from 50 i.u. α-tocopherol with 20 g/kg FO was only marginally acceptable but additonal α-tocopherol, at 250 or 450 i.u. significantly improved acceptability ($P < 0·05$), (Table 2).

With the frozen meat, after 3 days refrigerated storage, thigh meat from 50 i.u. α-tocopherol with 20 g/kg FO was definitely not acceptable and additional α-tocopherol at 250 or 450 i.u. only increased two-thirds of the assessments to marginally acceptable. Breast meat from birds given 10 or 20 g/kg FO and thigh meat from those given 10 g/kg FO were still acceptable after 3 days refrigerated storage irrespective of dietary α-tocopherol.

Discussion

Replacement of 10 g/kg soya-bean oil with FO reduced the n-6 : n-3 ratio from 8·5 : 1 to 1·5 : 1 in breast meat and 14 : 1 to 1 : 1 in thigh meat. Further addition of FO at the expense of lard decreased the ratios to 1·3 : 1 and 2 : 1 respectively. Thus, inclusion of FO in the broiler diet substantially improves the n-6 : n-3 ratio of the meat towards the optimum of 4 : 1 recommended for the whole diet (BNF, 1992). Supplementation with 250 i.u. per kg or more α-tocopherol resulted in substantially greater tissue levels of α-tocopherol than have been reported previously, presumably due to the cumulative effect of feeding relatively high levels from day old. The greater deposition of α-tocopherol in thigh than breast muscle confirms earlier reports with chickens (Lin, Gray, Ashgar, Buckley, Booren and Flegel, 1989) and turkeys (Uebersax, Dawson and Uebersax, 1978, Sheldon, 1984) and appears to relate to anatomical (more lipid, more mitochondria and microsomes in thigh muscle) and physiological (greater oxidative metabolism in thigh muscle) differences. Replacing soya-bean oil with FO reduced tissue α-tocopherol suggesting increased utilization of α-tocopherol to stabilize the FO fatty acids. TBARS have previously been shown to increase during cooking and subsequent chill storage of chicken meat from birds given vegetable oils. Addition of α-tocopherol, at 200 i.u. per kg has minimized these changes (Lin *et al.*, 1989). These observations have now been extended to show that 250 i.u. per kg α-tocopherol or more will stabilize chicken meat containing high levels of the more reactive EPA and DHA as judged by TBARS and taste panel assessment.

Conclusion

Ten or 20 g/kg inclusion of fish oil in a broiler diet with supplementation of 250 i.u. per kg or more α-tocopherol can produce meat with a high n-3 fatty acid content with a significantly improved ratio of n-3 : n-6 and meat keeping quality without significantly reducing meat flavour.

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