ω3 ENRICHMENT OF CHICKEN MEAT: USE OF FISH, RAPESEED AND LINSEED OILS.

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Summary

Two successive experiments have been carried out to assess the influence of three oils rich in ω3 fatty acids on the nutritional and organoleptic qualities of broiler chicken meat. A basal diet enriched with 8.2% Fish Oil (FO) was fed to one group of birds throughout the whole growth period (T1); this basal diet was replaced by another supplemented with 8.2% Linseed Oil (LO) instead of FO (exp I), and Rapeseed Oil (RO, exp II) for three different periods: the last week (T2), the last two weeks (T3) and the whole experiment (T4). The experimental diets were formulated to be isonitrogenous (25% CP) and isocaloric (3200 Kcal EM / kg) and were fed *ad libitum* to birds until slaughtering at the age of 35 days. Performance parameters and processing yields were reported at the time. Moreover, the sensory evaluation of chicken meat quality was conducted and the other meat quality traits were determined. After processing, lyophilizing and storing at -20°C, the fatty acid profile of meat samples from both experiments was conducted.

Thigh samples provided the most accurate reflection of the fatty acid profile of diets. Removing FO resulted in progressively lower values of SATurated fatty acids and higher total w6 fatty acid content, because of the rise in linoleic acid (LA, C18:2ω6) in both experiments. Treatments including larger amounts of LA for longer periods (T4) showed minimal decrease in tissue concentration of desaturation and elongation products of this acid (C20 series). The amounts of most ω3 fatty acids (C18:4, C20;5, C22;5, C22:6) were significantly reduced with the suppression of Fish oil. However, replacing FO by LO resulted in minimal effects on total ω3 fatty acids, mainly due to the rise of C18:3 (linolenic acid, LNA). Nevertheless, replacing FO by RO resulted in the fall of the total ω3 fatty acid content of meat samples, since the minor increase in LNA could not compensate for the depression of the other ω3 fatty acids, present in considerable amounts in fish oil diets. On the other hand, in the second experiment, levels of monounsaturated fatty acids (MUFA) were increased, due to the larger amounts of oleic acid (C18:1ω9).

Grades for organoleptic quality awarded the meat from treatments without fish oil (T4) by sensory panelists were significantly higher in both experiments.

Introduction

Recent findings concerning the benefits of the fatty acids (FA) EPA and DHA for human health indicate that we should make an effort to increase their presence in diet. A ω6/ω3 balance in the diet close to that provided by seafood would seem to be beneficial for human health, but its acceptance among consumers is limited (Hargis and Van Elswyck, 1993). Enriching products such as eggs and chicken meat with these FA may prove to be a viable alternative. Numerous studies (Hargis et al., 1991; Scaife et al., 1994) have set out to increase the ω3 content of eggs or broiler meat by way of the addition of such ingredients as fish oil to the chickens' diet. The use of this one is however limited, by the appearance of undesirable flavours in the resulting product, which make it unattractive for the consumer. On the other hand various studies have investigated the use of vegetable sources of ω3 such as rapeseed and linseed (Chanmugam et al., 1992; Ajuyah et al., 1993), which are rich in LNA. However, their use has led to a lower deposition of EPA and DHA.

With the objective of achieving a balance between, on the one hand, the benefits of higher quality nutritional features through the inclusion of fish oil in the chicken diets and, on the other, the avoidance of a deterioration in flavour, different time-spans were set out for the replacement of a diet supplemented with fish oil by one with rapeseed or linseed oil at the same level.

Materials and methods

In two experiments (I and II), 64 one-day old Cobb chickens were distributed into 32 cages (two per cage) and four different treatments were randomly set. All the chickens had *ad libitum* access to water and to the diets designed to cover all the nutritional requirements in growth (N.R.C., 1994), consisting of extruded soybean (36%), wheat (35.8%), starch (10%) and oat flour (5%) (CP: 25%; ME: 3200 kcal/kg). The FO diet (supplemented with 8.2% Fish Oil) fed the whole experimental period (TI) was replaced by the same basic diet supplemented with Linseed Oil (LO, exp I) or with Rapeseed Oil (RO, exp II) in three different periods: the last week (T2), the last two weeks (T3) or throughout the entire period (T4). The FA profile of the diets is shown in Table 1.

After slaughter at 35 days, the quality of the meat was assessed. The criteria for assessing quality were juiciness (Grau and Hamm, 1953), cooking losses (electric grill of up to 85°C of internal temperature) and tenderness of the 1cm thick

cooked samples when cooled, this one determined by an Instron apparatus. The breast and thigh samples destined to FA analysis were lyophilized and frozen at -20°C before analysis. The total fat content of diets and meat tissue was extracted as described by Folch et al. (1957) and then methylated with boron trifluoride methanol (Morrison and Smith, 1964). Their FA profile was determined by gas chromatography as described by Hwang et al. (1980). The evaluation of the samples, cooked at 180°C, was carried out by a panel of six experienced persons, who judged the meat in a triangulated test (Seemann, 1981). The panel evaluated taste and general impression and graded the meat according to the following scale: Traditional taste of poultry (5); Acceptable (4); Mediocre (3); Bad (2) and Very bad (1).

Results

The quality parameters of broiler meat are set out in table 2. Statistically significant differences between treatments were not observed in either of the two experiments. The FA composition of the tissue samples and the results of the triangulated test carried out in both experiments are set out in tables 3 and 4 respectively.

We shall now examine each experiment separately. In exp I, it can be seen that the SATurated fat content diminished ($p<0.001$) when FO (T1) was replaced by LO (T4). When the LO was incorporated into the diet, the percentage of MUFA in the samples did not change. However, their PUFA content did increase ($p<0.001$), basically due to the increased LNA. The proportion of ω3 totals did not vary in the breast samples, although it increased in the thigh samples due to the increased level of LNA (T1: 2.04%; T4: 23.76%), which compensated for the fall in the levels of EPA and DHA. Regarding the results of the six-person tasting panel, the only breast meat samples identified as being different from the others were those of T4. In addition, among the thigh meat samples differences were so small that only when comparing samples from non-contiguous treatments significant differences could be observed. The use of FO throughout the entire experimental period (T1) had a negative effect on the flavour of the meat (data not shown). The breast meat samples scored lower than the thigh samples. The thigh samples scored highly - except T1 - and exceeded 3 (T2) -Mediocre- and 4 (T3, T4) -Acceptable-, while the only breast samples to score above 4 were those from T4 (without FO). Breast samples from the other treatments, with the exception of T1 (unanimously assessed as 1 or 2) were only awarded 3 points.

In exp II, a drop in SAT was noted ($p<0.001$), due to the drop in ω3 totals, this was accompanied by a moderate increase in ω6 due to the increase in LA. Unlike exp I, the drop in EPA, DPA and DHA was not palliated by a slight increase in LNA, which led to a marked drop in ω3 totals. Instead there was a notable increase in MUFA content, as an oleic acid (thigh T1: 20.8%; T4: 49.0%). The tasting panel in exp II identified the breast samples from non-contiguous treatments as different, while all thigh samples were identified when treatments were compared 2 to 2, with the exception of T3 and T4. The thigh samples, except those from T1, once again scored higher than the breast samples. The use of fish oil throughout the entire experiment had once again a negative effect on the flavour: in this case, 40% of the panelists awarded a score of 1 or 2 to the T1 samples. Scores awarded to other treatment samples were in excess of 3 (T2) and 4 (T3, T4). The longer the period of withdrawal of fish oil from the diet, the less differences were noted between the two types of tissue.

Discussion and conclusions

In our conditions, the animals fed on a diet of 8.2% FO throughout the entire experiment (T1, I and II) registered levels of ω3 in keeping with the findings of Scaife et al. (1994) with a diet of 5% fish oil. The T1 meat samples have a lower quality flavour than those from treatments where diets did not include fish oil (T4, I and II) as had already been demonstrated by, among others, Edwards and May (1965). The withdrawal of fish oil improved the flavour of the meat but led to a fall in ω3 levels. Miller et al. (1969) withdrew menhaden oil four weeks prior to slaughter at 56 days, which led to an improvement in flavour but ω3 levels which were similar to those of his control group.

Establishing intermediate-length periods of withdrawal of FO in the diet (T2, T3, I and II), not only did not lead to a deterioration in the flavour but also enabled us to achieve a nutritional improvement of the meat, given that its EPA and DHA contents are higher than those obtained in the treatment which did not have fish oil. The use of LO (exp I) has enabled us to maintain ω3 at higher levels than with RO (exp II), even if the ω3 mainly takes the form of LNA, a rather poor substrate of the 5-lipooxigenase in the synthesis of the leukotrien series (Chanmugam et al., 1992).

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Table 1. Fatty acid composition of experimental diets.

Fatty Acid	Experiment I		Experiment II	
	FO[1]	LO	FO	RO
	(% of total methyl esters of fatty acids)			
18:1 ω 9	16.87	22.85	16.94	57.25
18:2 ω 6	12.77	24.05	12.45	25.03
18:2 ω 3	2.38	38.99	1.90	6.11
18:4 ω 3	1.64	0.24	1.68	0.06
20:5 ω 3	15.48	0.35	15.80	0.30
22:5 ω 3	1.96	0.08	2.03	0.50
22:6 ω 3	8.77	0.24	9.08	0.21
Total SAT	31.23	12.63	30.97	9.43
Total MUFA	24.25	23.25	24.58	58.25
Total PUFA	44.52	64.12	44.45	32.31
Total ω 6	14.29	24.22	13.96	25.13
Total ω 3	30.23	39.90	30.49	7.19
rel ω 6/ω3	0.47	0.61	0.49	3.50

[1] Diets FO:8.2% Fish Oil; LO:8.2% Linseed oil; RO:8.2% Rapeseed oil

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20:5 ω 3	15.48	0.35	15.80	0.30
22:5 ω 3	1.96	0.08	2.03	0.50
22:6 ω 3	8.77	0.24	9.08	0.21
Total SAT	31.23	12.63	30.97	9.43
Total MUFA	24.25	23.25	24.58	58.25
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Table2. Quality parameters of broiler meat.

Variable		T1	T2	T3	T4		
		5 w FO[1]	4 w FO 1 w LO/RO	3 w FO 2 w LO/RO	5 w LO/RO	Std Err.	Sig.
Cooking losses (%)	exp I	23.67	23.46	24.39	24.48	0.856	N. S.
	exp II	18.76	19.10	21.84	18.53	1.088	N. S.
Juiciness	exp I	0.60	0.66	0.61	0.58	0.022	N. S.
	exp II	0.64	0.68	0.62	0.65	0.024	N. S.
Tenderness Maximal Thoughness (N)	exp I	9.60	10.73	10.83	9.37	1.049	N. S.
	exp II	9.12	12.57	8.72	8.44	1.849	N. S.
Total Energy (J)	exp I	162.30	178.12	201.94	177.68	15.813	N. S.
	exp II	164.72	209.53	176.43	146.91	28.485	N. S.

[a,b] Values in the same row and variable with no common superscript are significantly different
[1] FO: Diet 8.2% Fish oil; LO: Diet 8.2% Linseed oil (exp I); RO: Diet 8.2% Rapeseed oil (exp II)

Table 3. Fatty acid composition of meat.

Fatty Acid	Meat	T1	T2	T3	T4	Std Err.	Sig.
		5 w FO	4 w FO 1 w LO/RO	3 w FO 2 w LO/RO	5 w LO/RO		
		(% of total methyl esters of fatty acids)					
		Experiment I (FO/LO)					
18:2 ω 6	white	10.24[d]	12.76[c]	14.97[b]	17.55[a]	0.348	p < 0.01
	dark	10.64[a]	12.74[c]	15.47[b]	17.94[a]	0.444	p < 0.01
18:3 ω 3	white	3.25[d]	8.60[c]	14.08[b]	19.09[a]	0.971	p < 0.01
	dark	2.04[d]	9.02[c]	16.45[b]	23.76[a]	0.856	p < 0.01
20:5 ω 3	white	6.43[a]	5.10[b]	2.78[c]	1.24[d]	0.278	p < 0.01
	dark	8.19[a]	4.41[b]	1.72[c]	0.54[d]	0.206	p < 0.01
22:5 ω 3	white	3.09[a]	2.75[a]	2.11[ab]	1.47[b]	0.245	p < 0.01
	dark	2.90[a]	1.56[b]	0.74[c]	0.54[c]	0.079	p < 0.01
22;6 ω 3	white	7.78[a]	6.45[a]	3.31[b]	0.86[c]	0.587	p < 0.01
	dark	6.45[a]	2.80[b]	0.97[c]	0.34[d]	0.165	p < 0.01
Total SAT	white	35.63[a]	32.06[b]	30.07[bc]	27.23[c]	0.738	p < 0.01
	dark	32.45[a]	32.69[a]	29.45[b]	22.98[c]	0.709	p < 0.01
Total MUFA	white	30.30	29.03	30.14	30.24	0.748	N. S.
	dark	33.75	34.46	33.74	32.56	0.650	N. S.
Total PUFA	white	34.01[b]	38.92[a]	39.69[a]	42.50[a]	1.084	p < 0.01
	dark	33.80[b]	32.77[b]	36.81[b]	44.45[a]	1.243	p < 0.01
Total ω 6	white	12.40[d]	14.91[c]	16.45[b]	18.94[a]	0.382	p < 0.01
	dark	12.49[c]	13.79[c]	16.12[b]	18.71[a]	0.486	p < 0.01
Total ω 3	white	21.61	24.01	23.24	23.56	1.020	N. S.
	dark	21.31[b]	18.99[b]	20.69[b]	25.74[a]	0.892	p < 0.01
w 6/ω3	white	0.58[b]	0.62b	0.72[ab]	0.81[a]	0.037	p < 0.01
		Experiment II (FO/LO)					
18:2 ω 6	white	12.99[c]	14.64[b]	16.54[b]	18.84[a]	0.452	p < 0.01
	dark	13.00[d]	16.27[c]	18.22[b]	20.21[a]	0.362	p < 0.01
18:3 ω 3	white	2.44[b]	2.48[b]	2.88[ab]	3.84[a]	0.336	p < 0.05
	dark	1.60[d]	2.84[c]	3.91[b]	4.52[a]	0.128	p < 0.01
20:5 ω 3	white	6.44[a]	4.28[b]	1.82[c]	0.96[d]	0.226	p < 0.01
	dark	7.63[a]	5.50[b]	3.08[c]	0.50[d]	0.162	p < 0.01
22:5 ω 3	white	2.53[a]	2.38[a]	0.96[b]	0.70[b]	0.127	p < 0.01
	dark	2.29[a]	1.74[b]	1.09[c]	0.18[d]	0.101	p < 0.01
22:6 ω 3	white	7.10[a]	6.13[a]	1.84[b]	1.21[b]	0.303	p < 0.01
	dark	5.59[a]	4.11[b]	2.32[c]	0.48[d]	0.158	p < 0.01
Total SAT	white	31.95[a]	28.08[a]	27.94[a]	20.88[b]	1.146	p < 0.01
	dark	33.70[a]	26.31[b]	23.57[b]	19.19[c]	0.944	p < 0.01
Total MUFA	white	33.25[c]	39.28[b]	45.98[a]	51.12[a]	1.295	p < 0.01
	dark	32.64[d]	40.20[c]	45.63[b]	53.50[a]	0.766	p < 0.01
Total PUFA	white	34.81[a]	32.64[a]	26.08[b]	28.00[b]	0.575	p < 0.01
	dark	33.67[a]	33.49[a]	30.79[b]	27.31[c]	0.500	p < 0.01
Total ω6	white	15.11[c]	16.53[b]	18.04[b]	20.91[a]	0.483	p < 0.01
	dark	14.88[a]	18.04[b]	19.63[b]	21.47[a]	0.386	p < 0.01
Total ω 3	white	19.70[a]	16.11[b]	8.04[c]	7.09[c]	0.492	p < 0.01
	dark	18.79[a]	15.44[b]	11.16[c]	5.85[d]	0.348	p < 0.01
ω 6/ω3	white	0.77[c]	1.04[c]	2.25[b]	2.97[a]	0.102	p < 0.01
	dark	0.79[d]	1.17[c]	1.76[b]	3.68[a]	0.073	p < 0.01

[a,b] Values in the same row and variable with no common superscript are significantly different
[1] FO: Diet 8.2% Fish oil; LO: Diet 8.2% Linseed oil (exp I): RO: Diet 8.2% Rapeseed oil (exp II)

Table 4. Sensory pannel: contrasts among treatments.

Exp I — Breast

		T1	T2	T3	T4
Thigh	T1		N. S.	N. S.	0.01
	T2	N. S.		N. S.	0.05
	T3	0.01	N. S.		0.01
	T4	0.01	0.01	N. S.	

Exp II — Breast

		T1	T2	T3	T4
Thigh	T1		N. S.	0.05	0.05
	T2	0.05		N. S.	0.05
	T3	0.05	0.01		N. S.
	T4	0.01	0.05	N. S.	