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Effects of Different Dietary Lipids on the Fatty Acid Composition of Broiler Abdominal Fat

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■ Keywords

Abdominal fatty acids, carcass composition, PUFA.

ABSTRACT

The effect of three different lipid sources (soybean oil, chicken oil or bovine fat) on the abdominal fat fatty acid composition in 50 day-old broiler chickens was evaluated. A completely randomized design was used, with 4 treatments, 8 repetitions and 40 Arbor Acres broiler chicks of each sex. The four treatments were isocaloric and isoproteic with the following characteristics: T1 Control (Soybean-corn); T2 Control + 3% soybean oil; T3 Control + 3% chicken oil; and T4 Control + 3% bovine fat. The lipids from the diets had significantly statistical effects ($p<0,05$) on the fatty acid composition of broiler abdominal fat. Multivariate techniques also showed differences in fatty acid composition within treatments due to sex. The studied dietary lipids affected the polyunsaturated/saturated fatty acid ratio (P/S) but had only small effects on the n-6: n-3 fatty acid ratio.

INTRODUCTION

An increasing supplementation of diets with lipids from oilseeds for intensive poultry production has been observed. These contain predominantly n-6 PUFAs and, consequently, poultry lipids have comprised higher levels of such fatty acids and lower levels of n-3 PUFAs. With the generally very high n-6: n-3 ratios seen in these diets, chain elongation of any existing small amounts of linolenic acid would be unlikely. Current evidences point to an n-6:n-3 fatty acid ratio of around 5:1 as being optimal. Linolenic acid (18:3 n-3) is important, but long chain EPA (20:5 n-3) and DHA (22:6 n-3) are the most effective. When the ratio n-6:n-3 is above 5:1, the effectiveness of linolenic acid is further reduced (British Nutrition Foundation, 1992).

In recent years, besides the technological aspects related to the susceptibility of meats to oxidation, the effects of dietary fat sources with different degrees of unsaturation and double bond positioning on the lipid composition of meat are specially considered.

Chicken lipids are a good source of essential n-6 fatty acids for humans but generally have high n-6/n-3 fatty acid ratio. Decreasing this ratio could be one desirable aspect in poultry lipids. Ruminant fats are one of the few lipid sources poor in n-6 and their inclusion in poultry diets could contribute to lower the concentrations of n-6 in poultry lipids.

Fat inclusion in broiler diets affects carcass fat quality because dietary fatty acids are incorporated with little change into the bird body fats (Scaife *et al.*, 1994). Thus, the type of fat used in the feed influence the composition of broiler body lipids. Abdominal fat is a good indicator of chicken body fats because it is very sensitive to changes in dietary fatty acid composition (Yau *et al.*, 1991; Pinchasov & Nir, 1992; Saenz *et al.*, 1999).

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The purpose of this experiment was to analyse the effect of three different dietary fat sources, soybean oil, chicken oil or bovine fat, on the abdominal fat fatty acid composition of male and female broiler chickens.

MATERIALS AND METHODS

A total of 2,000 birds aged four weeks were used as experimental animals. The tails were discarded according to a live weight curve of normal distribution. A completely randomized design of 4 treatments, with 8 repetitions and 40 Arbor Acres broiler chicks of each sex was used. The four treatments were isocaloric and isoproteic with the following characteristics:

T1 Control (Soybean-corn);
T2 Control + 3% soybean oil;
T3 Control + 3% chicken oil; and
T4 Control+ 3% bovine fat.

The composition of the diets and the fatty acid composition of supplemented lipids are shown in Tables 1 (A&B) and 2, respectively. When the birds were 50 days old, two males and two females were taken at random from each repetition for abdominal fat analysis, resulting in a total of 16 birds per treatment. To assess carcass composition, two males from each repetition were randomly chosen. Total abdominal fat was weighed, carefully minced, and aliquot samples were extracted with chloroform. Crude lipids were purified using TLC (hexane:ethyl ether:acetic acid 80:20:1 v/v/v) and the triglyceride fraction converted to methyl-esters and analysed by GLC (gas liquid chromatography). Fatty acid composition was determined using a 50 m CP Sil 88 capillary column with an inner diameter of 0.25 mm and 0.20 µm film thickness. (Chrompack, Middelburg, the Netherlands).

Data were statistically analysed using one-way ANOVA, and means with significant F ratio were compared by Tukey's multiple range test. Multivariate techniques such as factor analysis and linear discriminant analysis were performed by means of the statistical software SYSTAT version 6.1 (1996).

RESULTS AND DISCUSSION

No differences ($p>0.05$) were detected in carcass composition and abdominal fat weight due to treatment (Table 3). These results were as expected and similar to the reported by other authors (Hrdinka *et al.*, 1996).

Concentrations of all fatty acids were significantly different ($p<0.05$) among treatments, showing the importance of dietary lipids in poultry lipid composition (Table 4). The differences were important, and for some fatty acids the changes were higher than 50%.

Table 1 A – Composition of diets (22 to 35 days).

Ingredients (g/kg)	T1	T2	T3	T4
Maize grain	593.2	430.0	418.9	413.8
Soybean meal	199.4	69.1	120.1	118.0
Soybean grain	114.0	226.9	227.8	229.0
Fat		3.0	3.0	3.0
Gluten meal		26.9	3.0	4.4
Wheat starch	60.0	60.0	60.0	60.0
Meat meal	20.0	20.0	20.0	20.0
DL-methionine	1.9	6.4	2.0	2.0
Sodium chloride	3.0	3.0	3.0	3.0
Dicalcium phosphate		1.2	1.7	1.7
Vitamin*				
Calculated composition (per kg)				
Protein, g	196.0	196.0	196.0	196.0
Fat, g	50.0	64.0	64.0	64.0
Lysine, g	11.4	11.0	11.0	10.5
Methionine, g	5.1	5.1	5.1	5.1
Methionine plus cystine, g	8.3	8.3	8.3	8.3
Metabolizable energy (MJ)	12.7	12.7	12.7	12.7

* Vitamin and mineral mixture supplying (mg/kg): 3.3 retinol, 0.13 cholecalciferol, 50 dl-tocopheryl acetate, 3 menadione, 2 thiamine, 6 riboflavin, 3 pyridoxine, 0.01 cyanocobalamin, 1.75 folic acid, 0.2 biotin, 1000 choline chloride, 70 niacin, 20 calcium pantothenate, 100 Mn, 80 Zn, 80 Fe, 8 Cu, 15 Se, 160 Na, 400 K, 160-220 choride, 100 Mn, 1 Mo.

Table 1 B – Composition of diets (36 to 49 days).

Ingredients (g/kg)	T1	T2	T3	T4
Maize grain	554.1	491.8	488.1	481.9
Soybean meal	85.0	74.4	74.9	75.7
Soybean grain	189.1	200.2	201.1	202.4
Fat		3.0	3.0	3.0
Wheat starch	108.3	130.0	130.0	130.0
Meat meal	20.0			
Bone ash	16.9			
DL-methionine	2.0	2.3	2.3	2.3
Sodium chloride	3.0	3.0	3.0	3.0
Dicalcium phosphate	16.9	38.3	38.3	38.3
Vitamin*	3.5	3.5	3.5	3.5
Calculated composition (per kg)				
Protein, g	185.0	185.0	185.0	185.0
Fat, g	64.0	64.0	64.0	64.0
Lysine, g	9.8	9.8	9.8	9.8
Methionine, g	5.0	5.0	5.0	5.0
Methionine plus cystine, g	8.0	8.0	8.0	8.0
Metabolizable energy (MJ)	13.0	13.0	13.0	13.0

* Vitamin and mineral mixture supplying (mg/kg): 3.3 retinol, 0.1 cholecalciferol, 50 dl-tocopheryl acetate, 2 menadione, 2 thiamine, 5 riboflavin, 2 pyridoxine, 0.01 cyanocobalamin, 1.5 folic acid, 0.05 biotin, 1000 choline chloride, 40 niacin, 20 calcium pantothenate, 100 Mn, 60 Zn, 80 Fe, 8 Cu, 15 Se, 160 Na, 400 K, 160-220 choride, 100 Mn, 1 Mo.

Sex has not significantly affected ($p>0.05$) the fatty acid composition of abdominal fats (Table 4). In spite of this, the application of a multivariate analysis

Table 2 – Fatty acid composition of the three lipid sources.

Fatty acid %	Soybean oil	Chicken oil	Bovine fat
14:0	0.1	0.7	2.2
16:0	11.9	25.1	29.2
16:1	0.1	6.1	5.3
18:0	4.6	4.8	12.2
18:1	21.5	41.8	36.2
18:2	54.7	19.4	7.4
18:3	7.2	1.6	5.3
SFA[1]	16.6	30.6	43.6
MUFA[2]	21.6	47.9	41.5
PUFA[3]	61.9	21.0	12.7
(MUFA+PUFA)/SFA	5.0	2.3	1.2
PUFA/SFA	3.7	0.7	0.3
n-6/n-3	7.6	12.1	1.4

1 - SFA saturated fatty acids. 2 - MUFA monounsaturated fatty acids. 3 - PUFA polyunsaturated fatty acids.

showed differences due to sex. Classification based on fatty acid composition was performed and the factor loading matrix obtained for the three factors and the variance explained by each of them are presented in Table 6. These three factors accounted for 92% of the total variability. Linear discriminant analysis showed a percentage correctly classified between 75 and 100% (Table 7) These results differ from the results of a previous study that has reported no effect of chicken sex on abdominal fat fatty acid patterns (Olumo & Baracos, 1991).

The incorporation of soybean oil produced the smallest changes in fatty acid composition (Table 4). Dietary soybean oil decreases the percentages of

Table 3 – Carcass composition. Values represent mean±SD.

	T1	T2	T3	T4
Carcass, g	3215±147[a]	3198±121[a]	3230±172[a]	3224±194[a]
Carcass, % live-weight	67.0±2.54[a]	67.0±1.96[a]	66.9±3.96[a]	66.5±2.13[a]
Breast without bones % live-weight	14.7±0.78[a]	15.3±1.23[a]	15.0±1.07[a]	14.9±0.82[a]
Leg and thigh, % live-weight	20.4±1.75[a]	20.1±0.68[a]	20.9±1.23[a]	20.9±0.57[a]
Abdominal fat, % live-weight	2.3±0.29[a]	2.1±0.40[a]	2.2±0.47[a]	2.2±0.30[a]

a Similar superscripts in the row indicate non-significant differences (p >0.05).

Table 4 – Fatty acid composition of abdominal fat (% total fatty acids). Male (M), female (F). Values represent mean ± SD.

Fatty acid		T1	T2	T 3	T 4
14:0	M	0.4±0.04[a]	0.4±0.09[a]	0.6±0.07[b]	1.1±0.09[c]
	F	0.5±0.07[a]	0.5±0.03[a]	0.6±0.06[b]	1.0±0.06[c]
15:0	M	0.2±0.03[a]	0.2±0.06[a]	0.2±0.05[a]	0.5±0.05[b]
	F	0.2±0.01[a]	0.2±0.07[a]	0.3±0.04[b]	0.4±0.05[c]
16:0	M	21.8±1.01[a]	22.5±0.74[a,b]	23.3±1.15[b]	23.4±0.86[b]
	F	21.8±1.60[a]	21.7±0.79[a]	22.8±1.35[a,b]	23.2±0.56[b]
16:1	M	3.8±0.77[a]	5.9±0.91[b]	5.1±0.29[b]	5.2±0.76[b]
	F	4.3±0.59[a]	6.5±0.93[b]	5.9±0.61[b,d]	5.5±0.56[c,d]
18:0	M	6.0±0.65[a]	5.9±0.91[a]	5.9±0.61[a]	6.9±0.98[b]
	F	5.8±0.47[a]	6.5±0.93[a,c]	5.9±0.74[a]	6.9±0.58[b,c]
18:1	M	38.4±0.93[a]	40.6±1.81[b]	42.7±1.14[c]	45.0±1.01[d]
	F	37.8±0.93[c]	40.9±1.68[c]	42.8±1.34[c]	45.9±1.09[d]
18:2	M	26.8±1.88[a]	23.8±2.03[b]	20.7±0.93[c]	16.4±1.10[d]
	F	26.2±1.93[a]	24.7±2.28[b]	20.8±1.30[c]	15.91.23[d]
18:3	M	2.4±0.22[a]	2.1±0.18[b]	1.6±0.14[c]	1.4±0.13[d]
	F	2.3±0.15a	2.1±0.21b	1.6±0.13c	1.3±0.15d

a b c d - Similar superscripts in the row indicate non-significant differences (p > 0.05).

Table 5 – Abdominal fat data of nutritional and technological interest.

		T1	T2	T3	T4
14:0+16:0	M	22.3±1.04[a]	22.9±0.77[a,c]	23.9±1.18[b,c]	24.4±0.82[b]
	F	22.3±1.66[a]	22.2±0.78[a,c]	23.4±1.34[c,d]	24.2±0.53[d]
14:0+16:0+18:0	M	28.3±1.06[a]	28.8±1.30[a,c]	29.8±1.51[a,b]	31.3±1.50[b]
	F	28.1±1.52[a]	28.7±1.30[a]	29.3±1.61[a,b]	31.0±0.98[b]
18:2:18:3	M	11.4±0.65[a]	11.2±0.35[a]	13.3±1.23[b]	12.1±0.85[a,b]
	F	11.3±0.57[a]	12.0±0.72[a,c]	12.8±0.57[b]	12.2±0.56[b,c]
P/S	M	1.03±0.10[a]	0.91±0.09[b]	0.75±0.06[c]	0.57±0.05[d]
	F	1.02±0.12[a]	0.93±0.11[b]	0.77±0.08[c]	0.56±0.04[d]
MUFA	M	42.3±1.63	44.9±2.23	47.8±1.19	50.2±1.55
	F	43.0±1.19	44.8±2.00	48.0±1.44	51.4±1.16
(MUFA+PUFA) / SFA		2.52±0.13	2.49±0.15	2.35±0.16	2.17±0.15
	F	2.55±0.19	2.49±0.16	2.40±0.19	2.21±0.10

a b c d - Similar superscripts in the row indicate non-significant differences (p > 0.05).

Table 6 – Factor loading, and explained and cumulative variance[1].

Fatty acids	Factor 1	Factor 2	Factor 3
14:0	0.886	0.246	0.189
15:0	0.858	0.189	0.282
16:0	0.640	-0.237	-0.711
16:1	0.754	-0.61	0.079
18:0	0.351	0.895	-0.236
18:1	0.897	-0.52	0.221
18:2	-0.983	0.029	0.054
18:3	-0.944	0.008	0.081
Variance explained for components	5.285	1.329	0.741
Cumulative % of total variance explained	66.0	82.7	91.9

1 - The variance explained by each factor is the eigenvalue.

Table 7 – Classification matrix of samples from linear discriminant analysis of abdominal fat fatty acids. Male (M), Female (F).

	T1 M	T1 F	T2 M	T2 F	T3 M	T3 F	T4 M	T4 F	% correct
T1 M	7	1	0	0	0	0	0	0	88
T1 F	1	7	0	0	0	0	0	0	88
T2 M	2	1	4	1	0	0	0	0	50
T2 F	2	0	0	5	0	1	0	0	79
T3 M	0	0	0	0	8	0	0	0	100
T3 F	0	0	0	0	1	7	0	0	88
T4 M	0	0	0	0	0	0	6	2	75
T4 F	0	0	0	0	0	0	1	7	88
Total	12	9	4	6	9	8	7	9	80

18:2 and 18:3 and increases the percentages of 16:1 and 18:1 when compared with the control treatment.

Changes due to dietary chicken oil were lower but quite similar to the bovine fat. Dietary chicken oil increased the percentages of 14:0, 16:0, 16:1 and 18:1 and decreased the percentages of 18:2 and 18:3 % compared with the control treatment.

Bovine fat had the most important effects and increased significantly 14:0, 15:0, 16:0, 16:1, 18:0 and 18:1, while 18:2 and 18:3 decreased compared with the control, T2 and T3.

Table 5 shows some data of nutritional and technological interest. The three dietary fats significantly decreased ($p<0.05$) the P/S ratio, but effects on the n-6/n-3 ratio were small. N-6/n-3 ratios were lower in T1 and T2 compared with T3 and T4. P/S ratios were statistically different among the four treatments. Major nutritional recommendations have indicated to decrease fat intake to a mean level of 30% and to decrease the intake of saturated fatty acids to 10% or less. The ratio of polyunsaturated to saturated fatty acids (P/S) should be between 0.4 and 1.0, and the n-6:n-3 ratio should be less than 4. (Department of Health and Social Security, 1994).

From a technological point of view, the differences in total SFA and (MUFA+PUFA)/SFA were very important (Table 5). Several researchers consider that they represent the best estimation of both the slip point and the clarification point for poultry adipose tissues (Hrdinka *et al.*, 1996).

The present paper shows that the two animal fats used were effective in decreasing linoleic acid, but it is necessary to increase linolenic acid through other dietary components to fulfil present nutritional requirements.

The human diet and that of intensively reared animals have become unbalanced in terms of the make-up of fat. The intake of n-6 polyunsaturated fatty acids (n-6 PUFAs) must be decreased, whereas n-3 intake must be increased. Bovine fats, with naturally low levels of linoleic acid, can effectively decrease the concentrations of this fatty acid in poultry lipids, but it is necessary to supplement with a good source of linolenic acid to reduce the n-6: n-3 ratio in broiler lipids.

CONCLUSIONS

Dietary fat composition affected significantly $p<0.05$) the concentrations of all fatty acids in broiler abdominal fat. Such differences were important, and the changes were higher than 50% for some fatty acids. The application of a multivariate analysis also showed differences due to sex.

Bovine fat had the most important effects and increased significantly ($p<0.05$) 14:0, 15:0, 16:0, 16:1, 18:0 and 18:1 and decreased 18:2 and 18:3 fatty acids. The incorporation of soybean oil produced the smallest changes in fatty acid composition, whereas chicken

oil changes were lower but quite similar to bovine fat changes.

The three dietary fats significantly decreased ($p<0.05$) the P/S ratio compared with the control. Effects on the n-6/n-3 ratio were small in spite of the big differences in 18:3 and 18:2 fatty acid concentrations between diets and abdominal fats.

The present study shows that the two animal fats used were effective in decreasing percentages of linoleic acid, but it is necessary to increase linolenic acid through other dietary components to fulfil present nutritional requirements for the n-6/n-3 fatty acid ratio.

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