Dietary Polyunsaturated Fat Reduces Skin Fat as Well as Abdominal Fat in Broiler Chickens

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ABSTRACT The aim of this study was to determine the effect of different dietary fatty acid profiles on the main fat depots of broiler chickens: skin including s.c. fat (SK) and abdominal fat pad (AF). One hundred forty-four female broiler chickens were fed a low-fat diet (B; 0.5% of added fat) or diets supplemented with 10% of tallow (T), sunflower oil rich in oleic acid (SOO), sunflower oil rich in linoleic acid (SOL), linseed oil rich in linolenic acid (LO), or a mix of fats (M: 55% of T + 35% of LO + 10% SOL) that contained one-third each of saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids. The animals were housed in 36 cages and were randomly distributed into 6 dietary treatments with 6 replicates each. Experimental diets were evaluated for apparent total fatty acid availability and AME. On d 42, birds were slaughtered to determine the weight of AF and SK and fatty acid profile. Regarding the diets containing 10% added fat, the highest saturated diet (T) resulted in the lowest values of apparent total fatty acid availability and percentage of AME. Animals fed the most polyunsaturated diet (LO) had a lower SK deposition than those fed the saturated diet, on both an absolute (LO: 145 vs. T: 159 and M: 168 g; $P < 0.001$) and a relative basis (LO: 6.94 vs. T: 7.39 and M: 7.52 g/100 g of BW; $P < 0.001$). Furthermore, the lowest AF depot was observed in the LO diet (LO: 26.3 g vs. T: 37.6 and M: 39.9 g; $P < 0.001$). The added fat treatments caused significant but similar changes in fatty acid profile of both studied tissues. In conclusion, feeding broiler chickens polyunsaturated fatty acids, in comparison to dietary saturated fatty acids, reduced the amount of both AF and SK by approximately 30 and 9%, respectively.

Key words: broiler, fatty acid profile, skin fat, abdominal fat pad

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INTRODUCTION

Many studies showed that the growth pattern of fat depots can be modified by dietary means. For example, Sanz et al. (1999), Crespo and Esteve-García (2001) and Villaverde et al. (2006) suggested that the reduction of lipid content of broiler chickens was strongly related to the dietary fatty acid (**FA**) profile. These authors reported less abdominal fat pad (**AF**) accumulation in broiler chickens fed diets containing high levels of polyunsaturated fatty acids (**PUFA**) compared with chickens fed diets containing high levels of saturated fatty acids (**SFA**) or monounsaturated fatty acids (**MUFA**). The reduction of total body fat and abdominal fat in chickens fed PUFA was accompanied by a reduction in other separable fat depots. Moreover, different growth patterns were observed for the different fats depots such as mesenteric fat and neck fat (Crespo and Esteve-García, 2002a). Skin fat, including s.c. fat (**SK**), represents approximately 11 to 15% of the carcass weight of chickens (Fereidoun et al., 2007) and, with AF, represents the main separable fat depots of the birds. However, few studies on the effect of dietary fats on the pattern of broiler SK deposition have been published. Thus, the objective of this study was to evaluate the effect of different dietary fatty acids on the weight and FA profiles of the skin, including s.c. fat, compared with the changes in the AF.

MATERIALS AND METHODS

Experiment Design

The animal facilities, working protocol, and slaughtering process were approved by the Universitat Autònoma de Barcelona Ethical Committee. One hundred forty-four 1-d-old female broiler chickens of Ross 308 strain were obtained from a commercial hatchery (Terra-Avant S.A., Girona, Spain). The chicks were randomly separated into 6 groups, and each group was fed 1 of 6 diets. Throughout the study, feed and water were provided for ad libitum

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Table 1. Ingredients and nutrient composition of experimental diets[1]

	Treatment[2]					
Ingredient (%)	B	T	SOO	SOL	LO	M
Wheat	68.8	55.3	55.3	55.3	55.3	55.3
Soybean meal (48%)	26.6	31.1	31.1	31.1	31.1	31.1
Tallow	—	10.0	—	—	—	5.5
Sunflower oil rich in oleic acid	—	—	10.0	—	—	—
Sunflower oil rich in linoleic acid	0.5	—	—	10.00	—	1.0
Linseed oil	—	—	—	—	10.0	3.5
DL-Met (99%)	0.25	0.25	0.25	0.25	0.25	0.25
L-Thr	0.03	0.00	0.00	0.00	0.00	0.00
L-Lys	0.23	0.13	0.13	0.13	0.13	0.13
Calcium carbonate	1.65	1.25	1.25	1.25	1.25	1.25
Dicalcium phosphate	1.14	1.25	1.25	1.25	1.25	1.25
Salt	0.40	0.32	0.32	0.32	0.32	0.32
Vitamin and mineral premix[3]	0.40	0.40	0.40	0.40	0.40	0.40
Nutrient composition analyzed (%)						
DM	90.1	90.9	90.9	90.9	90.9	91.3
Ash	5.1	5.3	5.0	5.1	5.3	5.0
CP	21.2	20.9	21.4	20.7	21.7	20.7
Ether extract	1.9	10.4	11.1	13.3	12.6	13.1
Crude fiber	4.1	4.5	4.2	4.1	4.3	4.4
Nutrient composition calculated (%)						
L-Lys	1.05	1.06	1.06	1.06	1.06	1.06
DL-Met	0.53	0.54	0.54	0.54	0.54	0.54
Met + Cys	0.86	0.86	0.86	0.86	0.86	0.86
L-Thr	0.64	0.64	0.64	0.64	0.64	0.64
Ca^{2+}	0.99	0.90	0.90	0.90	0.90	0.90
Available P	0.17	0.19	0.19	0.19	0.19	0.19
Na^{+}	0.17	0.13	0.13	0.13	0.13	0.13
Gross energy[4] (kcal/kg of feed)	4,394	4,761	4,833	4,810	4,832	4,887
AME[5](kcal/kg of feed)	2,826	3,300	3,300	3,300	3,300	3,300
AME[4] (kcal/kg of feed)	3,257	3,301	3,716	3,700	3,663	3,655

[1]Values are means of 3 determinations of samples taken on d 8, 22, and 42 of the experiment.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]Provided the following (per kg of diet): vitamin A, 12,000 IU; vitamin D_3, 2,400 IU; vitamin E, 30 mg; vitamin K_3, 3 mg; vitamin B_1, 2.2 mg; vitamin B_2, 8 mg; vitamin B_6, 5 mg; vitamin B_{12}, 11 μg; folic acid, 1.5 mg; biotin, 150 μg; calcium pantothenate, 25 mg; nicotinic acid, 65 mg; Mn, 60 mg; Zn, 40 mg; I, 0.33 mg; Fe, 80 mg; Cu, 8 mg; Se, 0.15 mg; and ethoxyquin, 150 mg.

[4]Analyzed.

[5]Calculated.

consumption. On 8 d of age, birds were weighed (135 ± 1.55g) and placed in 36 cages (4 birds per cage) until d 42. There were 6 replicates of 4 birds per treatment. The diets were formulated according to NRC requirements (1994) and were similar to those of Crespo and Esteve-García (2002a). The 6 diets were based on wheat and soybean meal (Table 1). Five of the diets were supplemented with 10% of different types of fat (the experimental fats were provided by Cailá-Parés S.A., Barcelona, Spain): tallow (T), sunflower oil rich in oleic acid (SOO), sunflower oil rich in linoleic acid (SOL), linseed oil rich in linolenic acid (LO), or a mix of fats (M: 55% of T + 35% of LO + 10% SOL). The M diet was formulated to have a similar percentage in the main classes of fatty acids (33% SFA + 33% MUFA + 33% PUFA). A sixth diet was supplemented with a low level of fat (0.5% sunflower oil rich in linoleic acid), and, consequently, it had a low energy content and was considered as negative control (B).

Food consumption and chicken weight were recorded at 8, 22, and 42 d of age. Feed samples taken on d 8, 22, and 42 were frozen at –20°C for analysis. A digestibility balance study was performed to calculate the percentage of AME and apparent total FA availability. Between 29 and 31 d of age, total excreta were collected from each replicate group for 48 h. The excreta were weighted, homogenized (model Blixer 3B, Robot Coupe, Vincennes, France), and a representative sample (10% of total excreta) was frozen at –20°C, lyophilized (condenser Dura-Dry, model FD2055D0T000, Kinetic Thermal System Inc., Stony Ridge, NY), and stored at –20°C until subsequent analyses were performed. Apparent digestibility values were calculated as the difference between intake and excretion and were expressed as a percentage of intake.

The 42-d-old broiler chickens were stunned, slaughtered, bled, plucked, and chilled at 4°C for 24 h in a local slaughterhouse. The carcasses (total BW excluding blood and feathers) were weighed and the AF (from the proventriculus surrounding the gizzard down to the cloaca), and SK were removed and also weighed. Total body lipid was estimated using linear regression analysis according to Crespo and Esteve-García (2002a). The percentages of

Table 2. Fatty acid composition (%) of experimental diets[1]

	Treatment[2]					
Fatty acid	B	T	SOO	SOL	LO	M
C14:0	0.21	2.86	0.07	0.11	0.08	1.58
C14:1 n-5	0.00	0.48	0.00	0.00	0.00	0.26
C15:0	0.12	0.98	0.00	0.04	0.02	0.56
C16:0	17.1	24.7	5.77	8.54	7.18	16.5
C16:1 n-7 *trans*	0.00	0.24	0.00	0.03	0.02	0.14
C16:1 n-7	0.16	2.28	0.10	0.13	0.04	1.29
C16:2 n-4	0.00	0.36	0.00	0.00	0.00	0.19
C17:0	0.18	1.76	0.00	0.07	0.04	0.99
C17:1 n-7	0.00	0.46	0.00	0.04	0.02	0.27
C18:0	2.59	19.8	13.5	3.81	3.27	12.20
C18:1 n-9[3]	16.5	32.1	70.3	28.1	16.7	26.3
C18:1 n-7	1.02	1.35	0.68	0.78	0.71	1.12
C18:2 n-6	57.5	10.5	17.9	59.8	22.1	19.5
C18:3 n-3	4.19	1.32	16.1	0.88	49.6	18.5
C18:4 n-3	0.00	0.35	0.00	0.00	0.04	0.18
C20:0	0.49	0.20	0.28	0.20	0.10	0.19
C20:1 n-9	0.00	0.05	0.31	0.00	0.00	0.06
C24:1 n-9	0.00	0.00	9.67	0.25	0.06	0.09
SFA[4]	20.7	50.3	9.70	12.4	10.7	32.0
MUFA[4]	17.6	36.9	71.4	28.5	17.5	29.6
PUFA[4]	61.7	12.8	18.9	59.1	71.8	38.4
PUFA:SFA rate	2.99	0.25	1.96	4.75	6.72	1.20

[1]Values are means of 3 determinations of samples taken on d 8, 22, and 42 of experiment.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]C18:1 n-9 includes sum of *cis* and *trans* isomers.

[4]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

SK and AF were expressed as percentage of final BW. One representative sample of each tissue (n = 6 samples per treatment) was freeze-dried, ground, and frozen at –20°C for the analysis of fatty acids.

Analytical Determinations

Chemical composition of feed and excreta were determined according to the following methods of the AOAC International (2000): DM content (934.01), ash content (942.05), CP (984.13), ether extract (920.39), and crude fiber (962.09). Gross energy was determined by the means of an adiabatic bomb calorimeter (IKA-Kalorimeter system C4000, Jankel-Kunkel, Staufen, Germany). Ingredient and nutrient composition of experimental diets are shown in Table 1.

FA Analysis

The FA content of experimental diets (Table 2) and excreta samples were determined according to the method of Sukhija and Palmquist (1988). The FA of SK and AF were determined by Carrapiso et al. (2000). In both cases, the FA techniques used in this study consist of a direct transesterification: lipid extraction and FA methylation is achieved in only 1 step. Samples were incubated at 70°C with methanolic chloride, and the organic layer was extracted with toluene. Nonadecanoic acid (C19; Sigma-Aldrich Chemical Co., St. Louis, MO) was added at the beginning of the procedure as an internal standard. The heptane extracts were injected in a gas chromatograph (HP6890, Agilent, Waldbronn, Germany) following the method conditions that were previously described by Cortinas et al. (2004). Peak areas were integrated and converted to concentration with comparison with the internal standard peak area. Concentration FAx = (area FAx/area C19) × [μg C19/(RC × simple weight)], where RC = the response coefficient. Identification of FA was made by comparison between retention times of the simple peaks with the retention time of the standards (Supelco 37 component FAME Mix, Sigma-Aldrich Bio-

Table 3. Effect of dietary fat type on broiler performance from 8 to 42 d of age[1]

Treatment[2]	Weight gain (g/d)	Feed intake (g/d)	Feed:gain ratio
B	40.1[d]	98.2[b]	1.97[a]
T	59.9[ab]	113[a]	1.87[b]
SOO	56.8[c]	97.6[b]	1.74[c]
SOL	57.5[bc]	98.1[b]	1.71[c]
LO	57.5[bc]	97.0[b]	1.69[c]
M	61.4[a]	106[b]	1.72[c]
Root MSE[3]	2.19	5.71	0.074

[a–d]Means within a column without a common superscript differ significantly ($P < 0.05$).

[1]Values are means of 6 replicates of 4 chickens/diet.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]MSE = pooled SD.

Table 4. Effect of dietary fat type on broiler energy and fatty acid (FA) digestibility balance from 29 to 31 d of age[1]

		Apparent digestibility[2] (%)			
Treatment[3]	AME (%)	Total FA	SFA	MUFA	PUFA
B	70.9[b]	61.5[c]	52.6[c]	58.1[d]	65.4[c]
T	66.4[c]	62.2[c]	47.1[c]	82.7[c]	62.2[c]
SOO	73.2[a]	88.4[a]	76.1[a]	93.0[a]	77.0[b]
SOL	73.8[a]	88.5[a]	80.5[a]	90.6[ab]	89.2[a]
LO	72.8[ab]	88.1[a]	72.5[a]	87.7[b]	89.9[a]
M	72.0[ab]	81.5[b]	68.5[b]	89.0[b]	86.6[a]
Root MSE[4]	1.88	2.43	4.17	2.18	2.31

[a–d]Means within a column without a common superscript differ significantly ($P < 0.05$).

[1]Values are means of 6 replicates of 4 chickens/diet.

[2]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

[3]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[4]MSE = pooled SD.

technology LP (St. Louis,MO) and Sigma-Aldrich Co.). The sum of total FA of each sample was used as an estimator of the total amount of fat (g of fat per kg of analyzed tissue) according to Villaverde et al. (2005).

Statistical Analysis

All values were analyzed by 1-way ANOVA using the GLM procedure of SAS for Windows version 9.1 (SAS Institute Inc., Cary, NC). When the *F*-test for treatments was significant at $P \leq 0.05$ in the ANOVA table, means were compared for significant differences using the Tukey test of SAS. The cage (4 animals) was the experimental unit for performance parameters and digestibility balance. For final BW and carcass and tissue weight, the experimental unit was the chicken (24 determinations/diet), whereas for the FA content analysis, it was the individual (6 determinations/diet). The relationship of skin and abdominal fat depot per treatment was assessed by linear regression analysis using the PROC REG of the same statistical package. The treatments not significantly correlated were not included in the prediction equation.

RESULTS AND DISCUSSION

Bird Performance

The feed-to-gain ratio of chickens fed negative diet control (B) was the highest in relation to the rest of the treatments (B: 1.97; $P < 0.001$) due to the lower weight gain recorded (Table 3, 8 to 42 d: 40.1 g; $P < 0.001$). Of all the treatments with 10% of added fat, the T diet resulted in the poorest feed-to-gain ratio value due to the higher feed intake of these chickens, which was in agreement with the results of Crespo and Esteve-García (2001) and Villaverde et al. (2004). Sanz et al. (1999) did not observe performance differences in chickens fed with different types of dietary added fat.

During the experimental period (from 8 to 42 d of age), the AME intake of chickens fed the negative control diet (B) was lower than energy intake of chickens fed the treatments with 10% of added fat (317 vs. 367 kcal of AME intake/animal per day, respectively; $P < 0.01$). This result paralleled to the lower performance parameter found in group B. The lowest percentage of AME was

Table 5. Final BW and carcass, abdominal fat, and skin contents of broiler chickens fed various dietary fat types[1]

				Abdominal fat		Skin	
Treatment[2]	Final BW (g)	Carcass weight[3] (g)	Carcass percentage (%)	(g)	(%)	(g)	(%)
B	1,828[c]	1,627[c]	88.9	15.9[d]	0.87[c]	111[d]	6.07[c]
T	2,153[ab]	1,924[ab]	89.1	37.6[a]	1.75[a]	159[ab]	7.39[a]
SOO	2,158[ab]	1,927[a]	88.3	32.0[b]	1.47[b]	164[a]	7.45[a]
SOL	2,069[b]	1,838[b]	88.9	26.7[bc]	1.29[b]	151[bc]	7.34[a]
LO	2,097[b]	1,865[b]	89.0	26.3[c]	1.24[b]	145[c]	6.94[b]
M	2,235[a]	2,001[a]	89.5	40.0[a]	1.79[a]	168[a]	7.52[a]
Root MSE[4]	153.4	141.4	0.97	9.28	0.418	21.2	0.726

[a–d]Means within a column without a common superscript differ significantly ($P < 0.05$).

[1]Values are means of 24 birds/diets.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]Carcass weight = total BW excluding blood and feather.

[4]MSE = pooled SD.

Table 6. Effect of dietary fatty acid on the fatty acid content of skin fat including subcutaneous fat[1]

Fatty acid	Treatment[2]						Root MSE[3]	*P*-value
	B	T	SOO	SOL	LO	M		
C8:0	0.09	0.10	0.09	0.10	0.08	0.08	0.001	NS
C10:0	0.00	0.00	0.00	0.00	0.10	0.00	0.009	***
C14:0	3.90^{c}	18.2^{a}	1.84^{d}	2.11^{cd}	1.80^{d}	9.61^{b}	1.295	***
C14:1 n-5	1.46^{cd}	4.57^{a}	0.33^{c}	0.28^{c}	0.26^{c}	1.03^{bc}	0.569	***
C15:0	0.74^{cd}	5.22^{a}	0.54^{cd}	0.85^{c}	0.42^{d}	1.99^{b}	0.720	***
C16:0	166^{a}	161^{a}	73.2^{cd}	87.6^{c}	71.5^{d}	125^{b}	13.17	***
C16:1 n-7 *trans*	3.85	5.54	4.50	3.64	2.32	4.07	1.395	NS
C16:1 n-7	49.1^{a}	41.8^{b}	12.6^{d}	9.81^{d}	9.77^{d}	24.1^{c}	4.599	***
C16:2 n-4	0.90^{b}	0.35^{c}	0.66^{bc}	2.80^{a}	0.99^{b}	0.75^{b}	0.261	***
C17:0	0.56^{c}	4.18^{a}	0.46^{c}	0.40^{c}	0.23^{c}	2.24^{b}	0.232	***
C17:1 n-7	1.20^{c}	9.78^{a}	1.22^{c}	1.78^{c}	1.33^{c}	6.25^{b}	0.451	***
C18:0	40.8^{c}	61.7^{a}	29.9^{e}	36.2^{cd}	33.7^{de}	53.9^{b}	4.19	***
C18:1 n-9 *trans*	0.00	1.94	0.00	0.00	0.00	3.24	1.719	NS
C18:1 n-9	278^{c}	361^{b}	489^{a}	223^{d}	152^{e}	251^{cd}	25.8	***
C18:1 n-7	20.4^{a}	17.9^{a}	7.78^{b}	5.52^{b}	5.65^{b}	8.09^{b}	2.266	***
C18:2 n-6	88.5^{c}	52.8^{d}	91.9^{c}	327^{a}	125^{b}	107^{bc}	14.14	***
C18:3 n-6	1.02^{b}	0.53^{c}	0.91^{b}	1.90^{a}	0.58^{c}	0.48^{c}	0.252	***
C18:3 n-3	5.42^{c}	7.35^{c}	5.54^{c}	4.43^{c}	279^{a}	100^{b}	12.22	***
C18:4 n-3	0.07^{d}	4.86^{a}	0.00	0.00	1.67^{b}	1.09^{c}	0.310	***
C20:0	3.10^{a}	2.79^{a}	3.41^{ab}	1.61^{b}	1.20^{c}	1.69^{b}	0.224	***
C20:1 n-9	0.00	0.36	0.00	0.00	0.00	0.00	0.014	***
C20:2 n-6	0.65^{b}	0.41^{c}	0.44^{c}	1.15^{a}	0.50^{c}	0.54^{bc}	0.107	***
C20:3 n-6	2.35	1.05	2.09	1.46	1.71	0.79	1.236	NS
C21:0	0.00	0.00	0.00	0.00	1.45^{a}	0.19^{b}	0.475	***
C20:4 n-6	0.00	0.00	0.00	0.00	0.59^{a}	0.27^{b}	0.112	***
C20:5 n-3	0.00	0.00	0.00	0.00	4.18^{a}	1.79^{b}	0.426	***
C22:6 n-3	0.00	0.00	0.00	0.95^{b}	1.90^{a}	2.06^{a}	0.672	***
C24:1 n-9	0.55^{b}	0.11^{b}	0.37^{b}	0.89^{ab}	1.62^{a}	0.65^{b}	0.597	**
Total FA[4]	668	764	728	714	699	708	62.1	NS
SFA[4]	215^{b}	253^{a}	109^{c}	129^{c}	110^{c}	195^{b}	18.3	***
MUFA[4]	355^{c}	443^{b}	516^{a}	245^{d}	173^{e}	299^{cd}	30.9	***
PUFA[4]	98.9^{d}	67.4^{d}	102^{d}	340^{b}	416^{a}	214^{c}	22.0	***
PUFA:SFA	0.46^{d}	0.27^{d}	0.93^{c}	2.64^{b}	3.77^{a}	1.10^{c}	0.175	***

$^{a-e}$Value in the same row with no common superscripts are significantly different ($P \leq 0.05$).

[1]Values are means of 6 determinations/diet expressed as grams per kilogram of tissue.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]MSE = pooled SD.

[4]FA = fatty acids; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

$^{**}P \leq 0.01$; $^{***}P \leq 0.001$.

recorded in the saturated rich diet (T) in accordance with the low values of total FA and, in particular, SFA availability observed (Table 4). The more unsaturated diets (SOO, SOL, and LO) presented higher mean values of total FA and SFA digestibility than the other treatments. These results agree with the established higher percentage of AME and fat availability of unsaturated oils in comparison to saturated fats reported by Blanch et al. (1995) and Wiseman and Salvador (1991). Compared with T, an improvement in the SFA availability of group M was observed. It has been established that the nutritive value of a SFA, defined in terms of the quantity of fat absorbed, increases in the presence of unsaturated fatty acids. In this synergism between FA, the PUFA improves the micellar solubilization and subsequent absorption of the SFA (Renner and Hill, 1961).

Skin and Abdominal Fat Depots

Chickens fed B had lower BW than those fed diets with 10% of added fat at 42 d of age (1,828 g, $P < 0.001$; Table 5). On the other hand, the BW was higher in chickens fed M compared with the birds fed SOL and LO polyunsaturated diets. The carcass weight paralleled the BW in all treatments, whereas carcass percentages were not affected by dietary treatment.

The AF and SK weights were lower in chickens fed the B diet compared with chickens fed supplemental fat diets (Table 5). Regarding the diets containing 10% added fat, broiler chickens fed dietary PUFA showed lower AF and SK weights than those chickens fed dietary SFA on both an absolute and a relative basis. The differences in AF depot in SOO, SOL, or LO chickens accounted for –4.78 ± 3.1, –10.1 ± 2.9, and –11.0 ± 3.1 g, respectively, compared with those fed the T diet. The amount of total body fat estimated (Crespo and Esteve-García, 2002a) from AF values was 273 ± 10.4 g for T, 246 ± 10.6 g for SOO, 228 ± 10.6 g for SOL, and 228 ± 10.2 g for LO. Thus, differences in AF depot represented approximately 19, 23, and 25% of the total reduction of body fat. The results are in agreement with Sanz et al. (2000a), Crespo and Esteve-

Table 7. Effect of dietary fatty acid on the fatty acid content of abdominal fat pad[1]

Fatty acid	Treatment[2]						Root MSE[3]	*P*-value
	B	T	SOO	SOL	LO	M		
C8:0	0.45^{a}	0.44^{ab}	0.29^{c}	0.38^{bc}	0.32^{c}	0.42^{ab}	0.068	**
C10:0	0.00	0.00	0.00	0.00	0.04	0.00	0.035	NS
C14:0	4.41^{c}	18.1^{a}	1.89^{d}	2.33^{d}	1.78^{d}	11.4^{b}	0.791	***
C14:1 n-5	1.60^{c}	4.72^{a}	0.34^{d}	0.34^{d}	0.15^{d}	2.46^{b}	0.297	***
C15:0	0.78^{cd}	6.04^{a}	0.57^{d}	1.03^{c}	0.69^{cd}	3.81^{b}	0.271	***
C16:0	183^{a}	162^{b}	80.2^{d}	104^{c}	74.1^{d}	146^{b}	12.6	***
C16:1 n-7 *trans*	3.88^{b}	5.79^{a}	6.71^{a}	3.93^{b}	2.41^{c}	4.74^{b}	0.701	***
C16:1 n-7	53.7^{a}	42.7^{b}	14.6^{d}	12.5^{d}	9.5^{d}	28.5^{c}	4.36	***
C16:2 n-4	1.13^{b}	0.99^{b}	0.82^{b}	3.37^{a}	1.16^{b}	1.19^{b}	0.456	***
C17:0	0.98^{c}	9.60^{a}	1.15^{c}	1.93^{c}	1.19^{c}	7.35^{b}	0.783	***
C17:1 n-7	0.37^{c}	4.42^{a}	0.43^{c}	0.36^{c}	0.40^{c}	2.72^{b}	0.269	***
C18:0	46.6^{b}	60.8^{a}	31.5^{d}	41.3^{bc}	36.5^{cd}	63.5^{a}	6.01	***
C18:1 n-9	306^{c}	378^{b}	552^{a}	260^{d}	164^{e}	300^{c}	20.8	***
C18:1 n-7	22.4^{a}	18.2^{b}	8.64^{d}	7.59^{d}	5.84^{e}	11.9^{c}	1.116	***
C18:2 n-6	95.9^{c}	53.5^{d}	98.9^{c}	366^{a}	138^{b}	126^{b}	12.99	***
C18:3 n-6	1.17^{b}	0.00	1.07^{b}	2.31^{a}	0.00	0.14^{c}	0.347	***
C18:3 n-3	4.89^{c}	7.15^{c}	4.25^{c}	4.11^{c}	319^{a}	118^{b}	7.923	***
C18:4 n-3	0.00	4.90^{a}	0.00	0.00	1.87^{b}	1.26^{c}	0.343	***
C20:0	3.70^{a}	2.92^{b}	3.87^{a}	1.94^{c}	1.41^{d}	2.02^{c}	0.354	***
C20:2 n-6	1.40^{ab}	0.00	1.86^{a}	1.15^{bc}	0.67^{c}	0.72^{c}	0.410	***
C20:3 n-6	0.00	0.00	0.00	4.79^{a}	0.00	0.00	0.576	***
C21:0	0.00	0.00	0.00	0.00	2.61^{a}	0.55^{b}	0.218	***
C20:4 n-6	0.00	0.00	0.00	0.00	0.14	0.00	0.124	NS
C20:5 n-3	0.00	0.00	0.00	0.00	4.16^{a}	1.44^{b}	0.575	***
C22:6 n-3	0.00	0.00	0.00	0.00	0.35	0.00	0.199	NS
C24:1 n-9	0.00	0.00	0.00	1.39^{b}	2.34^{a}	1.34^{b}	0.458	***
Total FA[4]	734^{c}	780^{abc}	806^{ab}	821^{ab}	769^{bc}	835^{a}	46.3	*
SFA[4]	239^{b}	260^{a}	116^{d}	152^{c}	118^{d}	235^{b}	18.3	***
MUFA[4]	388^{c}	454^{b}	583^{a}	286^{e}	184^{f}	352^{d}	23.3	***
PUFA[4]	104^{d}	66.6^{e}	107^{d}	382^{b}	466^{a}	248^{c}	18.6	***
PUFA:SFA	0.44^{d}	0.26^{d}	0.92^{c}	2.54^{b}	3.93^{a}	1.06^{c}	0.185	***

$^{a–f}$Value in the same row with no common superscripts are significantly different ($P \leq 0.05$).

[1]Values are means of 6 determinations/diet expressed as grams per kilogram of tissue.

[2]B = diet low in fat; T = diet with 10% of added tallow; SOO = diet with 10% of sunflower oil rich in oleic acid; SOL = diet with 10% of sunflower oil rich in linoleic acid; LO = diet with 10% of added linseed oil rich in linolenic acid; M = diet with 10% of mix of fats (55% of T + 35% of LO + 10% of SOL).

[3]MSE = pooled SD.

[4]FA = fatty acids; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

García (2001), and Villaverde et al. (2006), who have reported that AF decreases in birds fed diets rich in PUFA. In addition, the present results showed that dietary PUFA also lowered ($P < 0.001$) SK. The differences in SK depot of SOL and LO chickens accounted for –9.2 ± 7.1 and –12.7 ± 6.0 g, respectively, compared with those fed T (Table 5). These differences in SK depot represented approximately 21 and 29% of the total reduction of body fat and were slightly greater compared with the weight reductions found in AF. No differences in SK weight of SOO chickens compared with T were found. These results show that the main fat deposit of broiler chickens responded to the dietary FA profile and that SK represented approximately 60% of total body fat of broiler chickens, compared with 12% for the AF. Few studies have assessed the effect of dietary fats on SK of broiler chickens. Selverej and Purushothaman (2004) found that the skin weight decreases when the dietary level of sunflower seed rich in n-6 fatty acids is increased.

The following linear regression equation was calculated for all treatments relating to abdominal fat weight (AFW) and skin weight (SKW), in grams: SKW = 97.4 ± 5.18 ± 1.67 ± 0.18 × AFW ($r^2 = 0.50$; $P < 0.0001$). This result is in agreement with Zerehdaran et al. (2004), who found that abdominal fat weight had a high coefficient of determination with respect to the skin weight ($r^2 = 0.54$).

The observed reduction of fat deposition resulting from the dietary PUFA (LO) in contrast to saturated treatment (T) was not explained on the basis of lower ($P < 0.05$) apparent total FA availability (LO: 88.1 vs. T: 62.2%; Table 4) and AME intakes during the experimental period (LO and T: 367 kcal/animal per day). Thus, these changes in fat deposition most likely resulted from changes in lipid metabolism. Different rates of lipid synthesis or lipid oxidation according to the dietary FA profile have been reported by different authors (Sanz et al., 2000b, Crespo and Esteve-García, 2002b; Ferrini et al., 2005), who suggested that preferential oxidation of PUFA compared with SFA or MUFA could reduce FA available for deposition. Moreover, balance between energy intake and energy expenditure is known to play a fundamental role in accumulating energy storage as fat. In this sense, different

studies have shown that heat loss may be greater when a fat-rich diet is consumed, with PUFA contained playing a crucial role (Clarke, 2000; Newman et al., 2002; Ferrini et al., 2007).

FA Composition

Total FA content of SK was between 67 and 76% of tissue weight and did not differ ($P > 0.05$) among treatments (Table 6). Chickens fed M had higher ($P < 0.05$) FA content in AF compared with B and LO (M: 83% vs. B: 73% and LO: 77%, Table 7). The added fat treatments caused significant but similar changes in the FA profile of both tissues. At the same time, the proportion of FA classes found in the tissues paralleled the proportion of FA classes of the fat added to the diets. In contrast, a large portion of SFA and MUFA deposited in chickens fed the negative control diet (B) were derived mainly from de novo synthesis of FA due to the lower FA content in the diet (B: 1.9% vs. between 10.4 and 13.3% of ether extract; Table 1). The SK and AF SFA content was higher in T and M compared with the rest of treatments, and it was likely due to the higher concentration of palmitic acid (C16:0) and stearic acid (C18:0), derived mainly from the diet. The highest content of MUFA was in SOO chicken tissues, which was likely due to the high amount of oleic acid (C18:1 n-9) from the diet. Polyunsaturated FA, which are exclusively of exogenous origin, were higher in the tissues of chickens fed the SOL and LO diets compared with the rest of treatments. Furthermore, the main tissue PUFA were linoleic acid (C18:2 n-6) and linolenic acid (C18:3 n-3). The highest PUFA:SFA ratio was in the LO diet, with a similar ratio in the SK including s.c. fat (LO: 3.77 and SOL: 2.64 vs. M: 1.10, SOO: 0.93, and T: 0.27; $P < 0.001$) and AF (LO: 3.93 and SOL: 2.54 vs. M: 1.06, SOO: 0.92, and T: 0.26; $P < 0.001$), in agreement with the data previously reported by Blanch et al. (2000). The changes of profile of FA of SK caused by different dietary types of added fat could represent an important factor to investigate, because they could be related to the breaking strength. Christensen et al. (1994) found that the breaking strength of skin was not consistently associated with the different levels of dietary fat.

In conclusion, the results of this study suggest that SK and AF weights in broiler chickens can be attenuated by dietary FA and that fats rich in PUFA, as compared with SFA, produce smaller fat depots. However, this effect is greater in AF than SK.

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