Effect of the Inclusion Time of Dietary Saturated and Unsaturated Fats Before Slaughter on the Accumulation and Composition of Abdominal Fat in Female Broiler Chickens

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ABSTRACT The aim of this experiment was to assess the effects of four different feeding programs designed to include tallow, a saturated fat at 0, 8, 12, and 28 d prior to slaughter on female broiler performance and the deposition, fatty acid profile, and melting point of abdominal fat. The following treatment groups were established according to dietary inclusion—from 21 to 49 d of age—of: sunflower oil (SUN), sunflower oil followed by tallow during the last 8 d (SUN + 8TALL), sunflower oil followed by tallow during the last 12 d (SUN + 12TALL), and tallow (TALL). The diets were designed to be isoenergetic and isonitrogenous. Abdominal fat deposition increased linearly with increasing number of days in which birds were fed the tallow-enriched diet. However, linear and quadratic response patterns were found between days before slaughter in which the birds were fed the tallow-enriched diet and abdominal fat melting points. This result suggested an exponential response in which 85% of the maximum level was already attained when the dietary fat type changed from an unsaturated to a saturated condition during the last 8 d of the feeding period. The use of an unsaturated fat source during the first stages of growth, and the substitution of a saturated fat for a few days before slaughter, may offer the advantage of lower abdominal fat deposition and an acceptable fat fluidity compared with the use of a saturated fat source during the whole growing and finishing period.

(*Key words*: dietary fat, broiler, fat deposition, melting point)

2000 Poultry Science 79:1320–1325

INTRODUCTION

The control of lipid deposition in broilers aimed at efficient lean-meat poultry production is of current interest (Fisher, 1984; Hermier, 1997). It has been previously reported that broilers fed isoenergetic diets rich in polyunsaturated fatty acids show lower abdominal fat deposition compared with those fed diets containing saturated fat (Barroeta, 1989; Sanz et al., 1999b). This concept is of particular interest for the rearing of female broilers, because the amount of abdominal fat at slaughter age (49 d) may represent more than 3% of the live weight (Sanz et al., 1999b). Any reduction in the amount of abdominal fat is considered to be positive by both producers and consumers, because it is lost during carcass cut-up, it contributes little to meat quality, and there is an increasing consumer resistance to eating fatty foods (Fisher, 1984; Hermier, 1997).

However, the use of an unsaturated fat source to reduce lipid accumulation could negatively affect carcass quality characteristics due to the excessively low melting point of the deposited fat (Hrdinka et al., 1996). It is widely known that the melting point of chicken fat is dependent upon its fatty acid profile (Hrdinka et al., 1996) and that it is possible to customize this fatty acid composition by dietary intervention (Yau et al., 1991).

Several reports suggest the possibility of increasing fatty acid saturation in broiler chicken tissue by introducing a saturated fat into the diet during the late growing period (Scaife et al., 1994; Hrdinka et al., 1996; Zollitsch et al., 1997). However, there is presently little data regarding the effects of the time of the switch from an unsaturated to a saturated dietary fat source on fat accumulation.

The aim of this experiment was to assess the effects of four different feeding programs designed to include tallow, a saturated fat, at 0, 8, 12, and 28 d prior to slaughter on female broiler performance and the deposition, fatty acid profile, and melting point of abdominal fat.

MATERIALS AND METHODS

Animals and Housing

Five-hundred 1-d-old Hybro G female broiler chicks were raised in 20 wood-floor pens and were fed standard

Received for publication November 23, 1999.
Accepted for publication April 3, 2000.
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Abbreviation Key: SUN = sunflower oil; TALL = tallow.

growing diet until the start of the experiment (Table 1). At 21 d, the number of birds per pen (20) and the average live weight per pen were balanced. Five pens were assigned to each of four experimental treatments. Feed and water were provided ad libitum. A light:dark cycle of 23:1 h and a room temperature of 22 to 26 C were maintained throughout the experiment.

Diets and Experimental Design

Pre-experimental and experimental diets are shown in Table 1. The experimental diets were formulated to be isoenergetic and isonitrogenous. The fat energy values on which the experimental diets were based (tallow AME_a = 7,100 kcal/kg; sunflower oil, AME_a = 8,824 kcal/kg) were calculated in a preliminary experiment (Sanz et al., unpublished data) by estimation of the difference in fat availability between a basal diet with no added fat and an experimental diet including 8% of the test fat, as described by Blanch et al. (1995). Celite was used in the sunflower oil diet as an inert filler. Four treatment groups were established according to the feeding program for the period corresponding to 21 to 49 d of age: Sunflower oil (SUN; n = 100) birds were fed a sunflower oil-enriched diet throughout the feeding period; birds were fed a sunflower oil-enriched diet from 21 to 40 d of age and a tallow enriched diet from 41 to 49 d of age (SUN + 8TALL; n = 100); SUN + 12TALL (n = 100), birds were fed a sunflower oil-enriched diet from 21 to 36 d of age and a tallow-enriched diet from 37 to 49 d of age; and TALL (n = 100), birds were fed a tallow-enriched diet throughout the experimental period. An outline of the experimental design is shown in Table 2. Throughout the experiment, chickens were handled according to the principles for the care of animals in experimentation (NRC, 1985).

Controls and Sampling

Feed intake and weight gain per pen were recorded at the end of the experimental period. On Day 49, a total of 120 birds (30 per treatment; six per pen) was randomly selected, individually weighed, stunned, slaughtered,

TABLE 1. Ingredients, nutrient content, and major fatty acid composition of pre-experimental and experimental diets enriched with tallow or sunflower oil

Item	Pre-experimental diet	Tallow diet	Sunflower oil diet
Raw material composition (g/kg diet)			
Wheat	110.00	105.96	105.96
Corn	374.72	447.71	399.43
Soybean meal (47% CP)	300.00	298.38	306.59
Sunflower meal (33% CP)	50.00	. . .	. . .
Full-fat soybean	67.33	30.00	30.00
Tallow	30.00	80.00	. . .
Sunflower oil	29.15	. . .	80.00
Sodium chloride	3.00	3.00	3.00
CO_3Ca	5.97	6.20	6.20
Dicalcium phosphate	21.36	21.99	21.99
Celite	. . .	. . .	39.94
L-Lysine	0.98	. . .	. . .
DL-Methionine	2.48	1.76	1.73
Mineral-vitamin premix[1]	5.00	5.00	5.00
Calculated nutrient composition (per kg of diet)			
AME_n (kcal)	3,100	3,200	3,200
Crude protein (g)	226.9	200.0	200.0
Ether extract (g)	92.6	107.1	105.0
Digestible Methionine (g)	5.6	4.5	4.5
Digestible Lysine (g)	11.9	10.0	10.0
Ca (g)	9.0	9.0	9.0
Available Phosphorus (g)	4.5	4.5	4.5
Analyzed nutrient composition (per kg of diet)			
Crude protein (g)	219	196	191
Ether extract (g)	87	100	101
Fatty acid profile (g/kg fatty acids)			
C16:0	161	214	88
C16:1(n-7)	15	26	3
C18:0	117	162	46
C18:1(n-9)	327	359	282
C18:2(n-6)	341	184	563
C20:4(n-6)	10	10	12
Σ Saturated	278	376	134
Σ Monounsaturated	342	385	285
Σ Polyunsaturated	351	194	575
Unsaturated-to-saturated ratio	2.49	1.54	6.42

[1]Vitamin mineral premix provided (per kg of diet) = vitamin A, 7,500 IU; cholecalciferol, 1,500 IU; vitamin E (dl-α-tocopheryl acetate), 7.52 IU; vitamin B_2, 5.28 mg; pantothenic acid, 8 mg; vitamin B_6, 1.84 mg; folic acid, 0.5 mg; vitamin B_{12}, 12.5 mg; choline, 350 mg; Se, 0.15 mg; I, 1.9 mg; Co, 0.2 mg; Cu, 6 mg; Fe, 30.8 mg; Zn, 50 mg; Mn, 80 mg; and S, 232 mg.

TABLE 2. Outline of the experimental design

	Dietary fat type		
Treatment	21 to 36 d of age	37 to 40 d of age	41 to 49 d of age
SUN	Sunflower oil	Sunflower oil	Sunflower oil
SUN + 8TALL	Sunflower oil	Sunflower oil	Tallow
SUN + 12TALL	Sunflower oil	Tallow	Tallow
TALL	Tallow	Tallow	Tallow

bled, and plucked in a local slaughterhouse. Carcasses were chilled to 4 C without evisceration, and the abdominal fat pad (from the proventriculus surrounding the gizzard to the cloaca) was removed and weighed (Cahaner et al., 1986). Twenty-eight randomly selected subsamples of abdominal fat (seven per treatment) were individually identified, packed in plastic bags, and stored at –20 C until further analysis.

Chemical Analysis

Samples of each diet were analyzed for nitrogen content (Kjeldahl method; AOAC, 1990), crude protein (N × 6.25), dry matter (by drying in an oven at 103 C for 4 h), and lipid content (6 h Soxhlet extraction). The fatty acid determination of the feeds and abdominal fat pads was performed by extracting the fat in chloroform and methanol (Bligh and Dyer, 1959). Fatty acids were converted into methyl esters and separated by gas chromatography, as described elsewhere (Lopez-Bote et al., 1997), using a 5890 Hewlett Packard gas chromatograph[2] and a 30 m × 0.32 mm × 0.25 μm cross-linked polyethylene glycol capillary column.[2] External standards of fatty acid methyl esters were purchased from Sigma-Aldrich.[3] Pentadecanoic acid[3] methyl ester was used as the internal standard in all analyses to control extraction losses. Analyses were performed using a temperature program of 170 to 245 C. The injector and detector were maintained at 250 C. The carrier gas (helium) flow rate was 3 mL/min. The melting point of the abdominal fat samples was determined by the capillary tube method according to an AOAC procedure (1990; reference 920.157).

Statistical Analysis

We used the general linear models (GLM) procedure (SAS Institute, 1988) for the statistical analysis of data. Means were separated using Duncan's multiple-range test. Individual pens were the experimental unit for performance data, whereas individual animals were used as the experimental unit for all other variables. Linear and quadratic patterns of change of abdominal fat deposition and melting point with the number of days before slaughter in which the birds were fed the tallow-enriched diet were estimated using the SAS-GLM procedure.

A nonlinear regression (NLIN) procedure (SAS Institute, 1988) was used to fit an exponential response curve between the tallow-enriched diet administration time and the abdominal fat melting point.

RESULTS AND DISCUSSION

The dietary fatty acid composition reflected the fatty acid profile of the added dietary fat (Table 1). The treatments showed no effect on feed intake, daily weight gain, or final weight (Table 3). However, despite the isoenergetic and isonitrogenous nature of the diets, the feed conversion ratios of birds fed the tallow-enriched diet throughout the feeding period were significantly higher than those of birds fed the SUN or SUN + 8TALL diets (2.02 vs. 1.98, 1.97, respectively). Pinchasov and Nir (1992) also reported a significant linear increase in the gain-to-feed ratio of broiler chickens fed isoenergetic and isonitrogenous diets with increased levels of polyunsaturated fatty acids. Such an effect may reflect actual differences in metabolizable energy content among the experimental diets due to differences in dietary fat digestibility (Wiseman et al., 1991) higher than that already considered in diet formulation. However, the increase in the gain-to-feed ratio may also be the result of the different metabolic use of energy from sunflower oil or tallow. A previous report showed that the efficiency of ingested metabolizable energy used for weight gain (MJ AME intake per 100 g weight gain) was greater in animals fed diets containing sunflower oil than those fed diets containing tallow (Sanz et al., 2000). In that study, improved use of ingested metabolizable energy for growth led to an improved feed-to-gain ratio in birds fed diets containing unsaturated fats.

Although analysis of variance revealed no significant differences among treatments ($P = 0.0949$), abdominal fat pad weight values increased in a linear fashion as the number of days before slaughter in which the animals were fed the tallow-enriched diets increased ($P = 0.0326$) (Table 3). In a recent experiment, broilers fed diets containing a blend of animal fats or tallow during the whole fattening period had higher abdominal fat pad weights than those fed diets containing sunflower oil ($P < 0.001$) (Sanz et al., 1999b). These results are consistent with eariler reports (Barroeta, 1989, Vila and Esteve-Garcia, 1996); however, no information on the evolution of abdominal fat weight with administration time of saturated fat before slaughter has been reported. The linear effect and the lack of quadratic response indicate a constant pattern of change in abdominal fat accumulation throughout the experimental period (0.32-g increase of abdominal fat weight per extra day on the saturated fat diet) (Figure 1).

The use of an unsaturated dietary fat source instead of saturated fats to produce lower abdominal fat deposition is obviously of interest, but in practice, a drawback related to the fluidity of the carcass fat arises. Fat firmness and melting point are dependent upon the fatty acid profile, which, in turn, can be modified by dietary means (Hulan et al., 1984; Sklan and Ayal, 1989; Hrdinka et al., 1996; Sanz et al., 1999a). As expected, the different fatty acid

[2]Hewlett-Packard Española S. A., Las Rozas, 20230 Madrid, Spain.
[3]Sigma-Aldrich Quimica, Alcobendas, 28100 Madrid, Spain.

TABLE 3. Performances of female broiler chickens assigned to four different feeding programs between 21 and 49 d of age

Item	Feeding program[1]					
	SUN	SUN + 8TALL	SUN + 12TALL	TALL	Pooled SD	$P > F$
Intial weight (g)	692.7	691.5	691.5	692.5	1.605	NS[2]
Final weight (g)	2,738.8	2,779.3	2,721.6	2,699.3	61.575	NS
Average daily gain (g)	73.1	74.6	72.5	71.7	4.105	NS
Daily feed intake (g)	144.0	147.9	144.7	145.1	2.180	NS
Feed conversion ratio	1.97[b]	1.98[b]	1.99[ab]	2.02[a]	0.024	0.0227
Abdominal fat pad weight (g)[3]	69.88	76.44	79.17	80.20	16.304	0.0949

[a,b]Means within rows bearing different superscripts differ significantly ($P < 0.05$).

[1]SUN = sunflower oil-enriched diet from 21 to 49 d of age; SUN + 8TALL = sunflower oil-enriched diet from 21 to 40 d of age and tallow-enriched diet from 41 to 49 d of age; SUN + 12TALL = sunflower oil-enriched diet from 21 to 36 d of age and tallow-enriched diet from 37 to 49 d of age; and TALL = tallow-enriched diet from 21 to 49 d of age.

[2]$P > 0.1$.

[3]Linear response to the number of days before slaughter in which the animals were fed the tallow-enriched diets ($P = 0.0326$); quadratic response to the number of days before slaughter in which the animals were fed the tallow-enriched diets ($P = 0.1715$).

profile of the dietary fat gave rise to typical differences in the profile of the abdominal fat of birds receiving the SUN or TALL treatments (Table 4). Saturated and monounsaturated fatty acid levels were higher in birds fed the tallow-enriched diet, whereas the levels of polyunsaturated fatty acids were higher in birds fed the diet containing sunflower oil throughout the whole growing period. The change in dietary fat type from sunflower oil to tallow on the last 8 or 12 d of the feeding period (SUN + 8TALL, SUN + 12TALL treatments, respectively) led to a considerable change in the abdominal fat fatty acid profile with respect to the corresponding SUN group (Table 4). Similar results were reported by Nam et al. (1997), who fed 5-wk-old broiler chickens on the following programs: a control diet for 4 wk, a control diet for 3 wk followed by a linseed-enriched diet for the last week, and a control diet for 2 wk followed by a linseed-enriched diet for the last 2 wk. The results showed that the linseed-enriched diet administered during the last week was sufficient to significantly increase the n-3 concentration of breast meat lipids, although maximum n-3 concentration was only attained after the birds had been fed the linseed-enriched diet for 4 wk. Lipstein and Bornstein (1973) reported that at least 3 wk of feeding was required for tissue fatty acid composition to approach dietary fatty acid composition. Wiseman (1988) concluded that 80% of changes in fatty acid profile of abdominal fat occurred about 14 d after diet changeover.

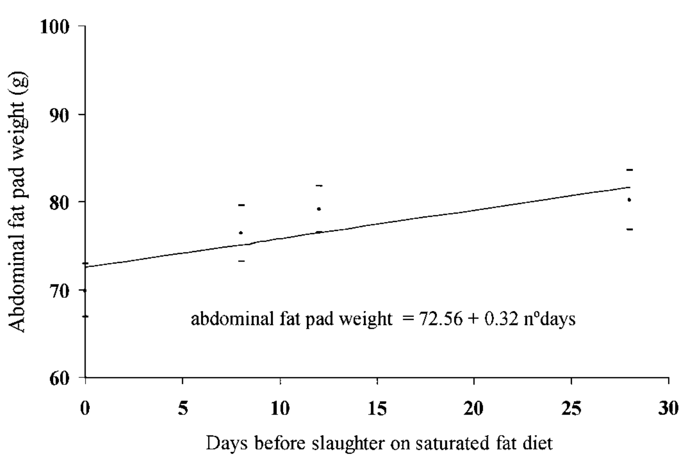

FIGURE 1. Influence of the number of days prior to slaughter in which female broiler chickens were switched from unsaturated to saturated dietary fat on abdominal fat pad deposition at 49 d of age. Each point represents the mean ± SE (horizontal lines). The solid line represents the fitted linear regression equation.

The abdominal fat melting point of birds fed sunflower oil-enriched diets over the entire trial was 52% lower than that of birds fed tallow-enriched diets during the whole feeding period (12.07 C vs. 25.34 C) (Table 4). It is of interest that the abdominal fat melting points of broilers assigned to either the SUN + 8TALL or the SUN + 12TALL treatments were only 15 and 13% lower, respectively, than that of the birds assigned to the TALL treatment (21.60, 22.01 C vs. 25.34 C), which indicates a particularly fast rate of change during the few days following the dietary change (Table 4). The linear and quadratic response patterns found between days before slaughter, in which animals were fed the tallow-enriched diet, and the abdominal fat melting points suggested an exponential response (Figure 1), which was fitted using the following equation:

$$y = a + b\ (1 - e^{-cx})$$

where y = melting point of abdominal fat; a = intercept, b = difference between abdominal fat melting point of animals fed the SUN diet and those fed the TALL diet, a + b = asymptote, c = curvature steepness, and x = number of days before slaughter in which the birds were fed tallow-enriched diet.

In contrast to abdominal fat deposition (Figure 1), the rate of change of abdominal fat melting point follows the law of diminishing returns (Figure 2), being faster during the first weeks prior to slaughter. Thus, for example, when the dietary fat type changes from unsaturated to saturated during the last 8 d of the feeding period, abdominal fat

TABLE 4. Abdominal fat fatty acid profile and melting point of female broiler chickens assigned to four different feeding programs[1]

Item	Feeding program[1]				Pooled SD	$P > F$
	SUN	SUN + 8TALL	SUN + 12TALL	TALL		
Fatty acid (g/100 g total fatty acids)						
C16:0	15.76[b]	18.77[a]	20.05[a]	22.4[a]	1.288	0.0001
C16:1 (n-7)	1.61[c]	2.65[b]	3.19[b]	3.84[a]	0.547	0.0001
C18:0	6.11[b]	7.54[a]	7.54[a]	8.51[a]	1.081	0.0041
C18:1 (n-9)	33.36[c]	38.59[b]	40.09[b]	46.96[a]	1.731	0.0001
C18:2 (n-6)	39.03[a]	28.68[b]	25.01[c]	14.58[d]	2.789	0.0001
C18:3 (n-3)	0.79[bc]	0.77[c]	0.85[ab]	0.87[a]	0.055	0.0110
C20:4 (n-6)	0.43[a]	0.25[bc]	0.27[b]	0.15[c]	0.094	0.0002
Σ Saturated	21.87[c]	26.32[b]	27.60[b]	30.92[a]	1.933	0.0001
Σ Monounsaturated	34.97[c]	41.24[b]	43.29[b]	50.81[a]	2.083	0.0001
Σ Polyunsaturated	40.25[a]	29.71[b]	26.13[c]	15.61[d]	2.844	0.0001
Unsaturated-to-saturated ratio	3.44[a]	2.70[b]	2.54[b]	2.15[c]	0.248	0.0001
Melting point (C)[2]	12.07[c]	21.60[b]	22.01[b]	25.34[a]	1.428	0.0001

[a–c]Means within rows bearing different superscripts differ significantly ($P < 0.05$).

[1]SUN = sunflower oil-enriched diet from 21 to 49 d of age; SUN + 8TALL = sunflower oil-enriched diet from 21 to 40 d of age and tallow-enriched diet from 41 to 49 d of age; SUN + 12TALL = sunflower oil-enriched diet from 21 to 36 d of age and tallow-enriched diet from 37 to 49 d of age; and TALL = tallow-enriched diet from 21 to 49 d of age.

[2]Linear response to the number of days before slaughter in which the animals were fed the tallow-enriched diets ($P = 0.0001$); quadratic response to the number of days before slaughter in which the animals were fed the tallow-enriched diets ($P = 0.0001$).

melting points attain 72% of the maximum possible differences (maximum possible difference = 13.27 C), whereas abdominal fat weight attains only 63% (maximum possible difference = 10.32 g).

In conclusion, the use of an unsaturated fat source during the first stages of growth and the substitution of a saturated fat for a few days before slaughter may offer the advantage of lower abdominal fat deposition and an acceptable fat fluidity compared with the use of a saturated fat source during the whole growing and finishing period. Further research is needed to estimate the optimal date for the change.

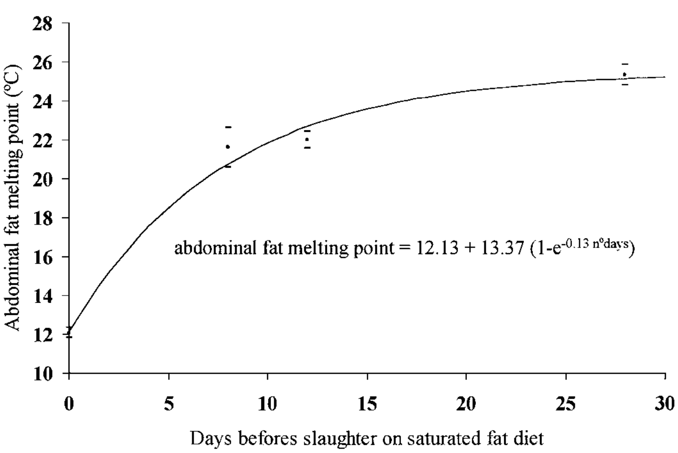

FIGURE 2. Influence of the number of days prior to slaughter in which female broiler chickens were switched from unsaturated to saturated dietary fat on abdominal fat melting point at 49 d of age. Each point represents the mean ± SE (horizontal lines). The solid line represents the fitted linear regression equation.

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