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Energy Expenditure by Broiler Chickens Fed Diets Containing Various Blends of Beef Tallow and Soybean Oil

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Abstract: Replacement of dietary saturated fatty acids (SFA) by polyunsaturated fatty acids (PUFA) has been consistently shown to reduce the amount of abdominal fat in broiler chickens, but the metabolic basis for this effect is unknown. It was hypothesized that the feeding of PUFA instead of SFA would induce more heat expenditure, this effect being associated with less deposition of abdominal fat. Broiler chickens were given one of five diets in which the beef tallow component, which is rich in SFA, was replaced by increasing amounts of soybean oil, which is rich in PUFA. The variable fat content of the diets was 3% (w/w). There were neither significant nor systematic effects on weight gain and feed:gain ratio. The amount of body fat was reduced significantly ($p<0.05$) when about 75% of the tallow was replaced by soybean oil, but there was no further decrease after the incorporation of more soybean oil into the diet. Calculated energy expenditure, either expressed as absolute amount or percentage of intake, trended to enhance but was not significantly affected by the amount of soybean oil in the diet.

Key words: Broiler chickens, growth performance, energy expenditure

Introduction

Various studies have demonstrated that replacement of dietary Saturated Fatty Acids (SFA) by polyunsaturated fatty acids (PUFA) reduces the amount of abdominal fat in broiler chickens (Sanz *et al.*, 1999, 2000a; Crespo and Esteve-Garcia, 2002a; Newman *et al.*, 2002; Pinchasov and Nir, 1992; Villaverde *et al.*, 2005; Zollitsch *et al.*, 1997; Wongsuthavas *et al.*, 2007). The metabolic basis for the diminishing effect of PUFA on abdominal fat mass is poorly understood (Crespo and Esteve-Garcia, 2002bc, 2003; Newman *et al.*, 2002; Villaverde *et al.*, 2006; Sanz *et al.*, 2000b). One possible mechanism could be that PUFA versus SFA acids are preferentially oxidized (Beynen and Katan, 1985) and thereby yield ATP so that carbohydrates are shifted from the oxidative into the lipogenic pathway. The conversion of glucose into triglycerides is less efficient in terms of energy deposition than is the conversion of fatty acids into triglycerides (Newsholme and Leech, 1984). As a consequence, the feeding of PUFA instead of SFA would not only lead to less deposition of abdominal fat associated with more heat expenditure. This reasoning was tested in the present study. Broiler chickens were fed on diets in which the beef tallow component, which is rich in SFA, was replaced by increasing amounts of soybean oil, which is rich in PUFA.

Materials and Methods

Animals and experimental diets: Seven-day-old Arbor Acres broiler chicks were randomly allocated to five groups of 15 birds each and kept in individual cages. The five experimental diets were formulated to contain 3% of added fat. As indicated in Table 1, the amount of soybean oil was increased stepwise at the expense of beef tallow. The birds had free access to feed and water.

Data and sample collection: The chickens were weighed at 7 and 28 days of age. Feed consumption was recorded daily. The feed:gain ratio was calculated (g feed/g gain). Excreta were collected quantitatively during the entire experimental period. At the age of 28 days, the birds were stunned and killed. Five birds per treatment were randomly chosen for weight measurement of abdominal adipose tissue (from the proventriculus surrounding the gizzard down to the cloaca). The remaining 10 birds per dietary treatment were used to measure the energy content of whole carcass.

Chemical analysis: The experimental diets were analyzed for dry matter, ash, crude fat, crude fiber and crude protein (AOAC, 1975). Bomb calorimetry analysis was done to determine gross energy in diets,

Table 1: Ingredient and analyzed composition of the experimental diets

Item	Diet code 1	2	3	4	5
Ingredients (g/100 g diet)					
Tallow	2.87	1.45	0.72	0.28	-
Soybean oil	0.13	1.56	2.28	2.72	3.00
Constant components	97.00	97.00	97.00	97.00	97.00
Macronutrients (g/100 g diet)					
Dry matter	92.00	92.00	92.00	92.00	92.00
Crude Protein	18.00	18.00	18.10	18.10	18.00
Crude fat	3.36	3.49	3.42	3.26	3.33
Crude fiber	3.23	3.25	3.21	3.23	3.24
Ash	4.28	4.30	4.30	4.31	4.33
Gross energy (kJ/100 g diet)	1,613.00	1,619.00	1,612.00	1,632.00	1,636.00

The constant components consisted of (g/100 g diet): tapioca starch, 46.02; soybean meal, 41.05; rice bran hulls, 4; dicalcium phosphate, 3.87; D,L-methionine, 0.3; L-lysine, 0.25; sodium chloride, 0.51; premix, 1. The premix supplied per kg of diet: vitamin A, 1,650 IU; vitamin D, 330 IU; vitamin E, 11 IU; vitamin K, 0.55 mg; thiamine, 198 mg; riboflavin, 3.96 mg; niacin, 3.30 mg; pyridoxine, 3.85 mg; vitamin B_{12}, 0.01 mg; calcium pantothenic acid, 10 mg; folacin, 0.61 mg; biotin, 0.17 mg; choline, 1,430 mg; manganese, 65.99 mg; iodine, 0.39 mg; potassium, 330 mg; zinc, 43.97 mg; copper, 8.80 mg; ferrous, 87.59 mg; selenium, 0.17 mg

Table 2: Effects of experimental diets on growth performance and weight of abdominal fat tissue

Item	Diet code 1	2	3	4	5	Pooled SE
Initial BW, g	184.00	176.00	182.00	187.00	182.00	4.10
Final BW, g	655.00	668.00	613.00	631.00	647.00	9.80
ADFI, g	45.40	47.20	44.80	42.40	41.80	3.00
ADG, g	22.40	23.40	21.00	21.80	22.10	2.38
Feed : gain	2.07	2.02	2.18	2.04	1.80	0.63
Abdominal fat, % of final BW	1.19^{a}	1.07^{a}	0.81^{b}	0.88^{b}	0.94^{b}	0.27

$^{a-b}$Values in the same row with the different superscripts differ significantly (p<0.05); Performance data are for 15 birds per dietary treatment. Abdominal fat data are for 5 birds per dietary treatment

homogenized whole carcass and excreta. Carcass and excreta were dried prior to energy measurement at 60°C for 72 h in a forced-hot air oven. An adiabatic bomb calorimeter was used with benzoic acid as thermochemical standard. The total amount of energy that was lost as heat (energy expenditure) was calculated with the formula: energy lost as heat = energy intake-energy in excreta-energy stored in body. Energy stored in the body was determined as energy in whole carcass at the end of the 21-days feeding period minus the baseline energy content in the whole body. To determine baseline body energy content, 10 seven-day old chickens were used and their values were averaged.

Statistical analysis: Data were subjected to Duncan's multiple range test (Steel and Torrie, 1980) using the program of Microsoft Excel (Windows XP®). The level of statistical significance was preset at p<0.05.

Results and Discussion

In keeping with our previous investigation (Wongsutthavas *et al*., 2007), there were no significant diet effects on weight gain, feed intake and feed:gain ratio (Table 2). Moreover, the gradual replacement of tallow by soybean oil did not induce systematic trends on weight gain and feed:gain ratio. When feed intake was not expressed in grams but gross energy, the inclusion of extra soybean oil into the diet was associated with significantly less energy intake. The lower energy intake by the birds fed soybean oil at the expense of tallow may be explained by the higher digestibility of soybean oil (Preston *et al*., 2001; Mossab *et al*., 2000; Leeson and Atteh, 1995), implying a higher dietary content of metabolizable energy and thus gross energy needed to meet the energy requirement. In fact, feed intake expressed as grams did show a tendency towards lower intakes with increasing dietary inclusion levels of soybean oil, although feed intake for the second inclusion level would appear to be aberrant.

The amount of abdominal fat was reduced significantly (p<0.05) when about 75% of the tallow was replaced by soybean oil. Contrary to our earlier work (Wongsutthavas *et al*., 2007), there was no further decrease after the incorporation of more soybean oil into the diet. The lowering of abdominal fat was in the order of 20-30%. Thus, this study confirms the well-known effect that substitution of PUFA for SFA in the diet of broiler chickens diminishes the deposition of abdominal fat.

As would be expected on the basis of the growth performance data, there was no significant diet effect on the amount of energy stored in the carcass. The energy balance data did show that increasing intakes of soybean oil were associated with decreasing amounts of energy in the fat fraction of excreta. This effect can be explained by the fact that soybean oil is digested more efficiently by broilers than is tallow (Preston *et al*., 2001; Mossab *et al*., 2000; Leeson and Atteh, 1995) and substantiates the lower energy intakes with increasing inclusion levels of soybean oil.

Table 3: Influence of experimental diets on energy balance

Items	Diet code 1	2	3	4	5	Pooled SE
Energy balance (kJ/21 days)						
Intake	13,996	14,627	13,620	13,237	13,039	88.66
Stored in the body	5,112	5,323	4,691	4,540	4,641	52.92
Expenditure	5,853	5,750	5,942	5,741	5,665	57.69
Total excreta	3,010	3,548	2,986	2,956	2,721	41.88
Excreta as fat	368[a]	306[b]	258[c]	256[c]	252[c]	17.17
Fat-free excreta	2,642	3,241	2,728	2,700	2,469	39.87
Energy in whole body (kJ)						
Final	7,929	8,140	7,508	7,357	7,458	793.35
Energy balance (% of intake)						
Stored in the body	36.6	36.4	34.4	34.3	35.6	4.52
Expenditure	41.9	39.3	43.6	43.3	43.5	4.93
Total excreta	21.5	24.3	21.9	22.3	20.9	3.57
Excreta as fat	2.6[a]	2.1[a]	1.9[b]	1.9[b]	1.9[b]	1.46
Fat-free excreta	18.9	22.2	20.0	20.4	19.0	3.40

[a-b-c-d-e]Values in the same row with the different superscripts differ significantly (p<0.01); Initial energy content of whole body was 2,817 kJ (SEM = 45.51 kJ, n =10); Data are for 10 birds per dietary treatment

The hypothesis tested in this study was that replacement of dietary tallow by soybean oil would increase energy expenditure. Table 3 shows that calculated energy expenditure, either expressed as absolute amount or as percentage of intake, trended to enhance energy expenditure was systematically related to the amount of soybean oil in the diet. It should be around that different dietary fatty acids may differently affect energy expenditure, at least in mice (Javadi *et al.*, 2004). Studies in humans have shown that diets with a high PUFA:SFA ratio may increase energy expenditure. The diet with a high PUFA : SFA ration trended to increase the thermogenic effect food compared with a diet with a low PUFA:SFA ratio. Furthermore, the results of these studies suggest that with a high intake of PUFA there is an increased contribution of fat oxidation to the thermogenic effect of food whereas the contribution of carbohydrates is decreased. BMR was not affected by the fat type (Jones and Schoeller, 1988), but in another study polyunsaturated fat increased BMR (Van Marken Lichtenbelt *et al.*, 1997). In any event, it appears that the lowering of abdominal fat in broiler chickens as caused by consumption of soybean oil is associated with increased energy expenditure. Abdominal fat only is a small portion of total body fat in broiler chickens, whereas the effect of intake of PUFA instead of SFA had consistent effect on whole body fat was decreased (Crespo and Esteve-Garcia, 2002bc, 2003; Newman *et al.*, 2002; Villaverde *et al.*, 2006; Sanz *et al.*, 2000b). Alternatively, another mechanism, such as inhibition of de-novo fatty acid synthesis induced by high intakes of PUFA (Zheng *et al.*, 2006; Ide *et al.*, 1996; Clarke *et al.*, 1976), is responsible for the observed reduction of abdominal fat in the chickens fed the diets rich in soybean oil.

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