ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 6 (11): 800-806, 2007
ISSN 1682-8356

Assessment of De-Novo Fatty Acid Synthesis in Broiler Chickens Fed Diets Containing Different Mixtures of Beef Tallow and Soybean Oil

Sasiphan Wongsuthavas[1], Chalermpon Yuangklang[1], Kraisit Vasupen[1],
Jamlong Mitchaothai[2], Paiwan Srenanual[1], Suntorn Wittayakun[3] and Anton C. Beynen[4]
[1]Department of Animal Science, Faculty of Natural Resources,
Rajamangala University of Technology, Isan, 47160 Sakon Nakhon, Thailand
[2]Department of Clinic for Swine, Faculty of Veterinary Medicine,
Mahanakorn University of Technology Bangkok, Thailand
[3]Rajamangala University of Technology Lanna, Lampang Campus, Lampang, Thailand
[4]Department of Nutrition, Faculty of Veterinary Medicine, Utrecht University, The Netherlands

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 inhibit whole-body de novo fatty acid synthesis. As indexes of de novo fatty acid synthesis, we used the concentration of plasma triacylglycerols and minimum fatty acid synthesis calculated as fatty deposition minus digestible fatty acid intake. 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 abdominal fat was reduced significantly 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. The decrease in abdominal fat was associated with a decrease in the level of plasma triacylglycerols, but it was not associated with minimum de novo fatty acid synthesis in the whole body.

Key words: Dietary fatty acids, broilers, abdominal fat, fatty acid deposition, fatty acid synthesis

Introduction

Numerous investigations have demonstrated that substitution of dietary polyunsaturated fatty acids (PUFA) for saturated fatty acids (SFA) reduces the amount of abdominal fat in broilers (Sanz *et al*., 1999, 2000a; Crespo and Esteve-Garcia, 2002; Newman *et al*., 2002; Pinchasov and Nir, 1992; Villaverde *et al*., 2005; Zollitsch *et al*., 1997; Wongsuthavas *et al*., 2007). The mechanism underlying the diminishing effect of PUFA on abdominal fat mass is not known (Crespo and Esteve-Garcia, 2002bc, 2003; Newman *et al*., 2002; Villaverde *et al*., 2006; Sanz *et al*., 2000b). We have put forward (Wongsuthavas *et al*., 2007a) the following possible mechanism. 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, 1994). As a consequence, the feeding of PUFA instead of SFA would not only lead to less deposition of abdominal fat, but be associated with more heat expenditure. However, we had to reject our hypothesis on the basis of a recent experiment in which energy expenditure was calculated for broilers fed on diets with different PUFA:SFA ratios (Wongsuthavas *et al*., 2007b).

An alternative hypothesis explaining the observed PUFA-induced reduction in abdominal fat in broiler chickens would be inhibition of de-novo fatty acid synthesis. There is evidence that the feeding of PUFA instead of SFA will inhibit de-novo fatty acid synthesis in the body (Zheng *et al*., 2006; Sanz *et al*., 2000b; Ide *et al*., 1996; Clarke *et al*., 1976). In this study, we tested whether a PUFA-mediated reduction in abdominal fat mass would be associated with a decrease in whole-body fatty acid synthesis. 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. Whole-body fatty acid synthesis was assessed indirectly by using two indicators. First, we measured the concentration of plasma triacylglycerols. Studies with isolated hepatocytes indicate that the concentration of plasma triacylglycerols is an index of de-novo fatty acid synthesis (Beynen *et al*., 1983). Secondly, we calculated minimum de-novo fatty acid synthesis as fatty deposition in whole carcass minus digestible fatty acid intake.

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.

Table 1: Ingredient and analyzed composition of the experimental diets

	Diet code				
Item	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	92.0	91.8	91.98	91.98	91.98
Crude Protein	18.0	18.0	18.1	18.1	18.0
Crude fat	3.4	3.5	3.4	3.3	3.3
Crude fiber	3.2	3.3	3.2	3.2	3.2
Ash	4.3	4.3	4.3	4.3	4.3

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: Fatty acid composition of the diets

Fatty acid composition,	Diet code				
%	1	2	3	4	5
C16:0	27.63	26.31	26.48	26.50	25.61
C18:0	32.47	23.45	16.26	11.55	7.95
C18:1 n-9	9.06	16.56	15.74	16.24	15.81
C18:1 n-7	2.69	2.79	2.09	1.68	1.45
C18:2 n-6 c	8.11	11.02	15.44	16.00	19.70
C18:3 n-6	0.40	0.26	0.00	0.00	0.00
C18:3 n-3	1.13	1.52	2.03	2.09	2.65
ΣSFA	68.31	55.38	48.09	45.50	41.33
ΣMUFA	15.93	26.47	28.92	32.04	31.91
ΣPUFA	9.64	12.80	17.47	18.09	22.35

ΣSFA= C8: 0+ C10: 0+ C12: 0+ C14: 0+ C15: 0+ C16: 0 + C17: 0+ C18:0+C20:0+C22:0+C24:0; ΣMUFA= C14: 1+ C15: 1+ C16: 1+C18:1n-9+C18:1n-7+C20:1n-9; ΣPUFA=C18:2 n-6+18:3 n-6+18:3 n-3

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. Fatty acid composition of the experimental diets is shown in Table 2. 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. The birds were killed at 08.00 am after a three-hour fasting period. Five birds per treatment were randomly chosen for weight measurement of abdominal adipose tissue (from the proventriculus surrounding the gizzard down to the cloaca) and blood sampling. The remaining 10 birds per dietary treatment were used to measure fatty acid composition of whole carcass.

Chemical analysis: The experimental diets were analyzed for dry matter, ash, crude fat, crude fiber and crude protein (AOAC, 1985). Total fat in dried excreta and carcass were extracted as described previously (Horwitz, 1975). Each sample was added to a flask and 2 ml of ethanol was added. Subsequently, 10 ml of HCl (8 mol/L) was added; the contents were gently mixed and the flask was placed in a water-bath of 80°C for 30-40 min. The tubes were cooled down, 10 ml of ethanol (96%, w/w) and 25 mL of petroleum ether (boiling point between 40 and 60°C) were added and the tube was shaken for one min. The fat-containing upper layer was decanted into a 150-mL round-bottom flask. The extraction procedure was repeated twice with 15 mL of diethyl ether and 15 mL of petroleum ether and the lipid extract was evaporated to dryness under N_2 in a water-bath of 40°C. The round-bottom flasks with the lipids were dried overnight at 60°C and the total lipids were measured gravimetrically. Total lipids were saponified and methylated according to the procedure of Metcalfe *et al.* (1966) followed by gas chromatography for determination of fatty acid composition. Concentrations of plasma triacylglycerols and cholesterol were analyzed according to the procedure of (Javadi, 2005).

Calculation of digestible fatty acid intake, fatty acid deposition and minimum de novo synthesis: The total digestible fatty acid intake was calculated as fatty acid intake (g/21 days) × apparent fatty acid digestibility (fraction of intake). The deposition of fatty acids was calculated with the following formula: Fatty acid deposition (g/21 days) = carcass content of fatty acid at the end of the study-carcass content of fatty acid at the start of the study. To determine baseline body fatty acid content, ten 7-day old chickens were used and their values were averaged. The ratio of fatty acid deposition and digestible fatty acid intake was calculated for selected individual fatty acids and groups of fatty acids. Minimum de novo fatty acid synthesis was calculated as fatty deposition minus digestible fatty acid intake.

Table 3: Effects of experimental diets on growth performance and weight of abdominal fat tissue

	Diet code					
Item	1	2	3	4	5	Pooled SE
Initial BW, g	184	176	182	187	182	4.10
Final BW, g	655	668	613	631	647	9.80
ADFI, g	45.4	47.2	44.8	42.4	41.8	3.00
ADG, g	22.4	23.4	21.0	21.8	22.1	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]Means in the same row with different letters are significantly different ($p<0.05$); Performance data are for 15 birds per dietary treatment. Abdominal fat data are for 5 birds per dietary treatment

Table 4: Influence of experimental diets on blood plasma lipid concentration

	Diet code					
Blood plasma lipid concentration	1	2	3	4	5	P value
Cholesterol, µmol/l	3,650	3,435	3,356	3,144	2,794	0.069
Triacylglycerols, µmol/l	2,751[a]	2,110[b]	2,092[b]	2,106[b]	1,985[b]	0.016

[a-b]Means in the same row with different letters are significantly different (n = 5)

Table 5: Influence of increasing levels of PUFA on fat and fatty acid deposition in whole carcass

	Diet code						
Item	1	2	3	4	5	P value	Pooled SE
Fat deposition in final whole carcass, %							
	27.97	27.48	26.13	26.63	25.74	0.6086	3.5541
Fatty acid composition, % of whole carcass							
C16:0	24.59[a]	23.49[ab]	23.15[b]	24.74[a]	22.90[b]	0.0080	1.3424
C18:0	20.53[a]	18.54[b]	17.19[b]	9.81[c]	7.72[d]	0.0001	1.7648
C18:1 n-9	37.93[b]	40.46[a]	40.79[a]	40.76[a]	31.90[c]	0.0001	1.2936
C18:2 n-6	8.06[c]	11.19[b]	11.66[b]	12.00[b]	13.73[a]	0.0001	1.2329
C18:3 n-3	0.39[d]	0.71[c]	0.72[c]	0.82[b]	0.88[a]	0.0001	0.0650
∑SFA	45.38[a]	42.29[b]	40.61[b]	34.81[c]	30.80[d]	0.0001	2.3043
∑MUFA	43.93[b]	46.80[a]	46.89[a]	46.64[a]	37.88[c]	0.0001	1.7093
∑PUFA	9.13[c]	12.21[b]	12.89[b]	13.01[b]	14.35[a]	0.0001	1.2886

[a-b-c-d]Means in the same row with different letters are significantly different (n = 10)

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 (Wongsuthavas *et al.*, 2007a), there were no significant diet effects on weight gain, feed intake and feed:gain ratio (Table 3). 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 (Wongsuthavas *et al.*, 2007a), 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.

The concentration of triacylglycerols in plasma was measured as an index of de-novo fatty acid synthesis. Table 5 illustrates that the replacement of beef tallow by soybean oil caused a significant reduction in plasma triacylglycerols ($p<0.05$). The reduction was already maximal when the diet with lowest inclusion level of soybean oil was fed. A decrease in plasma triacylglycerols after substitution of dietary PUFA for SFA has been observed earlier in broiler chickens (Crespo and Esteve-Garcia, 2001; Crespo and Esteve-Garcia, 2003). Thus, in this study the decrease in abdominal fat was associated with a lowering of plasma triacylglycerols. The implication could be that the diminished deposition of abdominal fat was caused by inhibition of de-novo fatty acid synthesis. The replacement of tallow by soybean oil produced a dose-dependent lowering of plasma cholesterol concentrations (Table 4). This observation confirms earlier work (Newman *et al.*, 2002).

Table 5 shows that the total SFA and PUFA content of whole carcass differed between the dietary groups. The replacement of SFA by PUFA lowered the SFA content of the whole body and increased that of PUFA. Other investigators have also reported that replacement of dietary SFA by PUFA had marked effects on total body

Table 6: Individual fatty acid digestibility, g/100g fatty acid intake

	Diet code					
Item	1	2	3	4	5	P value
Fatty acid composition						
C16:0	73.85^{b}	76.69^{b}	81.30^{a}	80.49^{a}	81.40^{a}	0.0001
C16:1	42.58^{b}	50.12^{b}	25.34^{b}	63.51^{a}	60.34^{a}	0.0001
C18:0	69.77	71.87	75.04	73.40	72.71	0.1852
C18:1 n-9	75.42^{b}	82.80^{a}	82.69^{a}	80.55^{a}	79.48^{a}	0.0001
C18:2 n-6	82.02^{b}	76.29^{c}	83.89^{ab}	82.09^{b}	85.46^{a}	0.0001
C18:3 n-3	79.72^{b}	73.94^{c}	85.67^{a}	81.24^{b}	85.79^{a}	0.0001
∑FA	73.77^{e}	75.90^{d}	80.18^{b}	79.26^{c}	80.44^{a}	0.0001
∑SFA	72.29^{b}	73.73^{b}	78.04^{a}	78.29^{a}	79.70^{a}	0.0005
∑MUFA	77.16^{b}	80.25^{a}	76.04^{b}	81.42^{a}	79.69^{a}	0.0001
∑PUFA	80.87^{b}	75.12^{c}	84.78^{a}	81.67^{b}	85.63^{a}	0.0001
∑UFA	76.96^{c}	79.81^{bc}	83.56^{a}	81.66^{ab}	82.55^{ab}	0.0004

$^{a\text{-}b\text{-}c\text{-}d\text{-}e}$Means within a row with different superscripts differ significantly; n = 15

fatty acid composition (Pinchasov and Nir, 1992; Crespo and Esteve-Garcia, 2002). The UFA were the predominant fatty acids in whole carcass for all of the treatments. However, for the diet with the highest PUFA level, PUFA deposition in the whole body was higher than for the other dietary groups (Table 5).

The dietary fat type had marked effects on the apparent digestibility of individual fatty acids. Palmitic, oleic, linoleic and alpha-linolenic acid were digested more efficiently when present in soybean oil than in beef tallow. A combination of different factors may be responsible for the observed diet-induced differences in apparent digestibility of identical fatty acids. As mentioned above, the total crude fat digestibility for soybean oil was greater than that for beef tallow, which may relate to enhanced micelle formation after feeding soybean oil. An improved micelle formation may favorably influence the digestion of all fatty acids in the diet. The position of a given fatty acid in the triacylglycerol molecule also plays a role. Fatty acids at the 2 position of glycerol in triacylglycerol molecules are better digested than those at the 1,3 position (Bracco, 1994; Innis and Dyer, 1997; Nelson and Innis, 1999). During digestion, the pancreatic lipase action specifically removes fatty acids at the 1,3 position while the resulting monoacylglycerol molecule is efficiently incorporated into micelles (Lien, 1994), leading to preferential absorption of fatty acids at the 2 position of the glycerol backbone of triacylglycerols. The intake level of a given individual fatty acid and its faecal excretion of endogenous origin will also affect the calculated apparent digestibility. A low intake level in combination with a high endogenous excretion will by itself lead to a low apparent digestibility. When comparing the digestibilities of palmitic and stearic acid for the diets with soybean oil and beef tallow, the values for the diets with soybean oil diet may biased to lower values because the intake levels were lower. On the other hand, the apparent digestibility for linoleic acid on the diets rich in soybean oil diet may be biased towards a higher value (Table 6).

The calculated intake of digestible fatty acids reflects the amount in the diet and feed intake, combined with the measured apparent digestibility. The deposition in the body of fatty acids was calculated as based on the fatty acid composition of the total body fat that was gained during the entire feeding period. As would be expected, the chickens fed the diets rich in soybean oil deposited more linoleic acid and those fed on diets rich in beef tallow had deposited more stearic acid in their whole body. Similar data have been shown for mice (Javadi *et al*., 2005) and goats (Yeom *et al*., 2005). The increased deposition of palmitic acid in the birds fed the diet rich in beef tallow did not reach statistical significance (Table 7).

To obtain clues as to preferential deposition of fatty acids, the ratio of deposition of a given fatty acid or group of fatty acids to the intake of digestible fatty acid or group of fatty acids was calculated. The deposition:intake ratio for fatty acid reflects the net amount synthesized and/or the proportion of the digested fatty acid not oxidized. A deposition:intake ratio>1 would point at net de novo synthesis, whereas a ratio<1 would indicate net oxidation. The low deposition:intake ratio for linoleic acid in the chickens fed the diets rich in soybean oil is consistent with the well-known preferential oxidation of linoleic acid (Slim *et al*., 1996; Sanz *et al*., 1999; Sanz *et al*., 2000b) and the fact that linoleic acid cannot be synthesized by chickens (Schafer *et al*., 2001). The deposition:intake ratio for the essential polyunsaturated fatty acids, linoleic and alpha-linolenic acid, cannot be higher than 1. Indeed, the ratios for alpha-linolenic acid were below and so was the ratio for linoleic acid in the broilers fed diets rich in soybean oil. The chickens fed diets high in beef tallow had a group mean deposition:intake ratio for linoleic acid that was just above 1, but was not significantly higher than 1. The extremely high deposition:intake ratio for stearic acid in chickens fed diets high in soybean oil is explained by a relatively low intake and high net synthesis of this fatty acid as shown in Table 7.

Table 7: Effect of dietary fat type on digestible fatty acid intake, fatty acid deposition, deposition:intake ratio and minimum de-novo fatty acid synthesis during the whole feeding period

	Diet code						
Fatty acids	1	2	3	4	5	P value	Pooled SE
Digestible intake, g/21 days							
C16:0	3.47^{a}	2.76^{b}	2.74^{b}	2.37^{c}	2.17^{c}	0.0001	0.2840
C18:0	6.62^{a}	3.35^{b}	2.18^{c}	1.18^{d}	0.61^{e}	0.0001	0.3135
C18:1 n-9	5.94^{a}	5.59^{b}	5.61^{b}	5.30^{c}	5.28^{c}	0.0001	0.1484
C18:2 n-6 c	2.02^{e}	8.27^{d}	11.24^{c}	12.40^{b}	13.70^{a}	0.0001	0.1821
C18:3 n-3	0.13^{e}	0.52^{d}	0.74^{c}	0.80^{b}	0.88^{a}	0.0001	0.0242
∑FA	23.87^{ab}	23.25^{b}	24.42^{a}	23.13^{b}	23.25^{b}	0.0491	1.0798
∑SFA	10.19^{a}	6.32^{b}	5.20^{c}	3.84^{d}	3.10^{e}	0.0001	0.5892
∑MUFA	6.25^{a}	5.87^{b}	5.90^{b}	5.56^{c}	5.53^{c}	0.0001	0.1645
∑PUFA	2.33^{e}	9.05^{d}	12.03^{c}	13.25^{b}	14.63^{a}	0.0001	0.2036
Deposition, g/21 days							
C16:0	5.96^{a}	5.83^{a}	4.15^{b}	5.09^{ab}	4.52^{a}	0.0159	1.3554
C18:0	6.09^{a}	5.91^{a}	4.24^{b}	1.99^{c}	1.28^{c}	0.0001	0.8604
C18:1 n-9	8.55^{ab}	10.04^{a}	7.44^{b}	8.15^{ab}	5.15^{c}	0.0001	2.0188
C18:2 n-6	1.99^{c}	3.31^{ab}	2.72^{b}	3.03^{b}	3.69^{a}	0.0001	0.6718
C18:3 n-3	0.06^{c}	0.20^{a}	0.15^{b}	0.20^{a}	0.22^{a}	0.0001	0.0447
∑FA	23.74^{ab}	24.93^{a}	18.30^{c}	20.04^{bc}	20.37^{bc}	0.0147	4.6774
∑SFA	12.11^{a}	11.81^{a}	8.44^{b}	7.14^{bc}	5.83^{c}	0.0001	2.1086
∑MUFA	9.89^{ab}	11.59^{a}	8.50^{b}	9.24^{b}	6.28^{c}	0.0003	2.3810
∑PUFA	2.27^{c}	3.57^{ab}	2.99^{b}	3.24^{ab}	3.78^{a}	0.0001	0.6825
Deposition : intake, g/21 days							
C16:0	1.72^{ab}	2.12^{a}	1.55^{b}	2.18^{a}	2.08^{a}	0.0417	0.5399
C18:0	0.92^{b}	1.77^{ab}	1.98^{a}	2.04^{a}	2.32^{a}	0.0458	1.0361
C18:1 n-9	1.44^{b}	1.80^{a}	1.33^{b}	1.54^{ab}	0.97^{c}	0.0003	0.3729
C18:2 n-6	0.99^{a}	0.40^{b}	0.24^{c}	0.24^{c}	0.27^{c}	0.0001	0.1238
C18:3 n-3	0.51^{a}	0.37^{b}	0.20^{c}	0.25^{c}	0.25^{c}	0.0001	0.1245
∑FA	0.99^{ab}	1.07^{a}	0.75^{c}	0.87^{bc}	0.87^{bc}	0.0070	0.1952
∑SFA	1.19^{b}	1.88^{a}	1.65^{a}	1.93^{a}	1.88^{a}	0.0129	0.5170
∑MUFA	1.58^{b}	1.98^{a}	1.45^{bc}	1.66^{ab}	1.13^{c}	0.0011	0.4201
∑PUFA	0.98^{a}	0.39^{b}	0.25^{c}	0.25^{c}	0.26^{c}	0.0001	0.1080
Minimum de novo fatty acid synthesis, g/21 days							
SFA	1.92^{b}	5.49^{a}	3.24^{b}	3.30^{b}	2.73^{b}	0.0087	2.0348
MUFA	3.64^{b}	5.72^{a}	2.60^{b}	3.68^{b}	0.75^{b}	0.0063	2.1975
SFA/(SFA+MUFA)	0.35^{b}	0.49^{a}	0.55^{a}	0.47^{ab}	0.78^{a}	0.0022	0.2275

$^{a\text{-}b\text{-}c\text{-}d\text{-}e}$Means within a row with different superscript differ significantly; n = 15

The birds fed soybean oil instead of beef tallow had a higher deposition:intake ratio for SFA, but lower ratios for MUFA and PUFA. The diet effect on the ratios for SFA and MUFA can be explained by the calculated minimum synthesis of these groups of fatty acids. Feeding the diet containing soybean oil stimulated the synthesis of SFA, but depressed that of MUFA. The higher synthesis ratio for SFA: (SFA+MUFA) in chickens fed the diets rich in soybean oil indicates that there was selective synthesis of SFA in these birds. This might point at de novo fatty acid synthesis being regulated to balance the amount of saturated and unsaturated fatty acids in the body because the intake of linoleic acid was very high in the birds fed the diets rich in soybean oil (Table 7).

In conclusion, the gradual replacement of beef tallow by soybean oil had no effect growth performance, but rather improved the digestibility of all individual fatty acids. Feeding the diets with increasing levels of soybean oil produced a markedly increased deposition of linoleic acid in the whole body. For groups of fatty acids, the ratio of deposition in the whole body to the intake of digestible fatty acids was calculated. It then became clear that the type of dietary had marked, specific effects on the synthesis and oxidation of fatty acids. The decrease in abdominal fat as induced by the feeding of soybean oil instead of beef tallow was associated with a decrease in plasma triacylglycerol concentrations, but not with a decrease in calculated minimum de novo fatty acid synthesis.

Acknowledgments

The authors thank the Department of Animal Science, Faculty of Natural Resources, Rajamangala University of Technology-Isan for providing financial support and research facilities. Thanks are due to Mr. Jakapol, Ms. Nataporn and Ms. Sikharin for taking care of the animals and the collection of samples.

References

AOAC, 1985. Official Methods of Analysis. Washington, DC: Association of Official Analysis Chemists.

Beynen, A.C. and M.B. Katan, 1985. Why do polyunsaturated fatty acids lower serum cholesterol?. Am. J. Clin. Nutr., 42: 560-563.

Beynen, A.C., G. Den Engelsman, K.E. Scholz, C.E. West, 1983. Casein-induced hypercholesterolemia in rabbits : distribution of cholesterol, triglycerides and phospholipids between serum and liver. Ann. Nutr. Metab., 27: 117-124.

Bracco, U., 1994. Effect of triglyceride structure on fat absorption. Am. J. Clin. Nutr., 60: 1002S-1009S.

Clarke, S.D., D.R. Romsos and G.A. Leveille, 1976. Specific inhibition of hepatic fatty acid synthesis exerted by dietary linoleate and linolenate in essential fatty acid adequate rats. Lipids, 11: 485-490.

Crespo, N. and E. Esteve-Garcia, 2001. Dietary fatty acid profile modifies abdominal fat deposition in broiler chickens. Poult. Sci., 80: 71-78.

Crespo, N. and E. Esteve-Garcia, 2002. Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. Poult. Sci., 81: 1533-1542.

Crespo, N. and E. Esteve-Garcia, 2003. Polyunsaturated fatty acids reduce insulin and very low density lipoprotein levels in broiler chickens. Poult. Sci., 82: 1134-1139.

Crespo, N. and E. Esteve-Garcia, 2002b. Dietary linseed oil produces lower abdominal fat deposition but higher de novo fatty acid synthesis in broiler chickens. Poult. Sci., 81: 1555-1562.

Crespo, N. and E. Esteve-Garcia, 2002c. Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. Poult. Sci., 81: 1533-1542.

Howitz, W., 1975. Official Methods of Analysis of Official Analytical Chemists, 12th Ed., Benjamin Franklin Station, DC: Association of Official Analytical Chemists, pp: 225.

Ide, T., M. Murata and M. Sugano, 1996. Stimulation of the activities of hepatic fatty acid oxidation enzymes by dietary fat rich in alpha-linolenic acid in rat. J. Lipid Res., 37: 448-463.

Innis, S.M. and R. Dyer, 1997. Dietary triacylglycerols with palmitic acid (16:0) in the 2-position increase 16:0 in the 2-position of plasma and chylomicron triacylglycerols, but reduce phospholipid arachidonic and docosahexaenoic acids and alter cholesteryl ester metabolism in formula-Fed piglets. J. Nutr., 127: 1311-1319.

Javadi, M., 2005. Fatty acid intake in relation to energy metabolism and body composition. Ph.D thesis. Utrecht University, The Netherlands.

Lien, E.L., 1994. The role of fatty acid composition and positional distribution in fat absorption in infants. J. Pediatr., 125: S62-S68.

Metcalfe, L.D., A.A. Schmitz and J.R. Pelka, 1966. Rapid preparation of fatty acid esters from lipids for gas chromatographic analysis. Anal. Chem., 38: 514-515.

Nelson, C.M. and S.M. Innis, 1999. Plasma lipoprotein fatty acids are altered by the positional distribution of fatty acids in infant formula triacylglycerols and human milk. Am. J. Clin. Nutr., 70: 62-69.

Newman, R.E., W.L. Bryden, E. Fleck, J.R. Ashes, W.A. Buttemer, L.H. Storlie and J.A. Downing, 2002. Dietary n-3 and n-6 fatty acids alter avian metabolism: metabolism and abdominal fat deposition. Br. J. Nutr., 88: 11-18.

Newsholme, E.A. and A. Leech, 1994. Biochemistry for the Medical Sciences. John Wiley and Sons, New York.

Pinchasov, Y. and I. Nir, 1992. Effect of dietary polyunsaturated fatty acid concentration on performance, fat deposition and carcass fatty acid composition in broiler chicken. Poult. Sci., 71: 1504-1512.

Sanz, M., A. Flores and C.J. Lopez-Bote, 1999. Effect of fatty acid saturation in broiler diets on abdominal fat and breast muscle fatty acid composition and susceptibility to lipid oxidation. Poult. Sci., 78: 378-382.

Sanz, M., A. Flores and C.J. Lopez-Bote, 2000a. The metabolic use of energy from dietary fat in broilers is affected by fatty acid saturation. Br. Poult. Sci., 41: 61-68.

Sanz, M., C.J. Lopez-Bote, D. Menoyo and J.M. Bautista, 2000b. Abdominal fat deposition and fatty acid synthesis are lower and beta-oxidation is higher in broiler chickens fed diets containing unsaturated rather than saturated fat. J. Nutr., 130: 3034-3037.

Schafer, K., K. Manner, A. Sagredos, K. Eder and O. Simon, 2001. Incorporation of dietary linoleic and conjugated linoleic acids and related effects on eggs of laying hens. Lipids, 36: 1217-1222.

Slim, R.M., M. Toborek, B.A. Watkins, G.A. Boissonneault and B. Hennig, 1996. Susceptibility to hepatic oxidative stress in rabbits fed different animal and plant fats. J. Am. Coll. Nutr., 15: 289-294.

Steel, R.G.D. and T.H. Torrie, 1980. Principles and Procedures of Statistics. McGraw Hill Book Company, New York.

Villaverde, C., M.D. Baucells, L. Cortinas, M. Hervera and A.C. Barroeta, 2005. Chemical composition and energy content of chickens in response to different levels of dietary polyunsaturated fatty acids. Arch. Anim. Nutr., 59: 281-292.

Villaverde, C., M.D. Baucells, L. Cortinas and A.C. Barroeta, 2006. Effects of dietary concentration and degree of polyunsaturation of dietary fat on endogenous synthesis and deposition of fatty acids in chickens. Br. Poult. Sci., 47: 173-179.

Wongsuthavas, S., S. Terapuntuwat, W. Wongsrikeaw, S. Katawatin, C. Yuangklang and A.C. Beynen, 2007a. Influence of amount and type of dietary fat on deposition, adipocyte count and iodine number of abdominal fat in broiler chickens. J. Anim. Physiol. Animal Nutr. (E-publication ahead of print).

Wongsuthavas, S., C. Yuangklang, K. Vasupen, J. Mitchaothai, P. Srenanual, A.C. Beynen, 2007b. Energy expenditure by broiler chickens fed diets containing various blends of beef tallow and soybean oil. Int. J. Poult. Sci., in press.

Yeom, K.H., J.T. Schonewille, H. Everts, K.-W. Lee, G. Van Trierum, A.C. Beynen, 2005. Growth performance and body composition of goat kids fed milk replacers with increasing levels of linoleic acid. J. Anim. Physiol. Anim. Nutr., 89: 29-34.

Zheng, C.T., H. Jorgensen, C.E. Hoy and K. Jakobsen, 2006. Effects of increasing dietary concentrations of specific structured triacylglycerides on performance and nitrogen and energy metabolism in broiler chickens. Br. Poult. Sci., 47: 180-189.

Zollitsch, W., W. Knaus, F. Aichinger and F. Lettner, 1997. Effects of different dietary fat sources on performance and carcass characteristics of broilers. Anim. Feed Sci. Technol., 66: 63-73.