Utilization of Fat Sources in Pigs Weaned at 21 Days of Age[a]

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ABSTRACT : A total of 80 pigs (5.68±0.61 kg BW; 21 d of age) were used to evaluate the effect of fat sources in weaned pigs. Pigs were allotted into five treatments based on body weight, in a completely randomized block design. Treatments consisted of diets representing different ratio between soy oil or corn oil and tallow; 1) S100 (soy oil 100%), 2) S75 (soy oil:tallow=75:25), 3) S50 (soy oil:tallow=50:50), 4) C75 (corn oil:tallow=75:25), 5) C50 (corn oil:tallow=50:50). During d 0 to 14, pigs were fed diets containing 3,400 kcal ME, 23% crude protein, 1.65 % lysine and for the period of d 15 to 28, pigs were fed diets supplying 3,400 kcal ME, 20.5% crude protein, 1.355% lysine. For d 0 to 14, a significant differences in ADG and ADFI were observed among treatments, pigs fed animal-vegetable fat blends gained more than pigs fed the S100. As tallow addition was increased from 25% to 50% replacing soy or corn oil, ADG was improved from 6.32% to 28.38%. In phase II (d 15 to 28) period, ADG, ADFI and FCR were not significantly different among treatments. For overall period (d 0 to 28), pigs fed 50% animal:50% vegetable fat blends diets consumed more feed and grew faster than pigs fed control diet and 75% vegetable oil:25% tallow groups, but the differences was not significant among treatments. Apparent DM, CP and fat digestibility were increased with time postweaning for each treatment. There were no differences in digestibilities of total amino acid during overall period. The combination of soy oil or corn oil with tallow produced slightly higher serum triglycerides (TG) and total cholesterol (TC) combination compared with the soy oil alone. In conclusion, tallow:soy (or corn) oil blends diets improved growth rate and the ratio of 50% tallow plus 50% soy (or corn) oil blends diets were favorable for growth and nutrient digestibilities of weaned pigs. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 9 : 1255-1262*)

Key Words : Soy Oil, Corn Oil, Tallow, Growth, Blood, Weaned Pigs

INTRODUCTION

The newborn piglet, like the premature infant, has very small body energy resources for maintenance and rapid growth. This lack of energy reserves renders the neonatal pig susceptible to environmental stress and the associated risk of death (Pettigrew, 1981; Bruegger and Conrad, 1972). Animal fat and soybean oil are the most common fat sources used in swine diets. Nutritional intervention, such as energy supplementation, appears to improve neonatal survival, but the benefit of fat as an energy supplement for neonatal pigs is equivocal (Bruegger and Conrad, 1972; Pettigrew, 1981).

Several studies have shown that dietary fat enhances ADG and feed/gain (F/G) of early weaned pigs (Atteh and Leeson, 1983; Lawrence and Maxwell, 1983; Allee et al., 1971; Crampton and Ness, 1954) and improves digestibility of fatty acids (Frobish et al., 1970). The ability of the weanling pig to digest fat may be related to dietary fat source (Cera et al., 1990) and improves with age (Frobish et al., 1970; Leibbrandt et al., 1975; Atteh and Leeson, 1983; Cera et al., 1988a, 1989). Contrary to these results, in some studies, added fat did not improve either growth or feed efficiency in weanling pigs (Lawrence and Maxwell, 1983; Peo et al., 1957; Cera et al., 1988c). These differences may be a result of several factors such as absorption of fatty acids in the diet (Bayley and Lewis. 1965), melting point (Calloway et al., 1956), energy:amino acid ratio (Allee et al., 1971), age of pigs (Cera et al., 1988b; Lindemann et al., 1986), addition of Cu (Luo and Dove, 1996; Dove, 1995; Dove and Haydon, 1991, 1992) and dietary fat source or concentration (Li et al., 1990; Hamilton and McDonald, 1969; Frobish et al., 1970; Cera et al., 1988a). It was suggested that chain length, degree of saturation of fatty acids and their arrangement within the triglyceride molecule are important factors in determining the degree of fat digestibility in chicks (Calloway et al., 1956) and pigs (Eusebio et al., 1965). Pigs performed better on diets containing either soybean oil, choice white grease, or coconut oil than on diets containing tallow (Turlington, 1988). While Tokach et al. (1995) reported that adding 6% soy oil, corn oil or tallow to the diet had no influence on ADG of pigs.

Therefore, the objective of this study was to investigate the effect of soybean oil or corn oil and tallow combinations on pig performance, apparent digestibility and serum traits of pigs weaned at 21

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days of age.

MATERIALS AND METHODS

A total of 80 pigs (5.68±0.61 kg BW; 21 d of age) were used to evaluate the effect of fat sources in weaned pigs. Pigs were allotted into five treatments based on body weight, in a completely randomized block design. Each treatment has 4 replicates of 4 heads. Treatments consisted of diets representing different ratio between soy oil or corn oil and tallow; 1) S100 (soy oil 100%), 2) S75 (soy oil:tallow=75:25), 3) S50 (soy oil:tallow=50:50), 4) C75 (corn oil:tallow=75:25), 5) C50 (corn oil:tallow=50:50). During phase I (d 0 to 14), pigs were fed diets containing 3,400 kcal ME, 23% crude protein, 1.65% lysine, 0.9% Ca and 0.8% P. For the period of d 15 to 28 postweaning (phase II), pigs were fed diets supplying 3,400 kcal ME, 20.5% crude protein, 1.35% lysine, 0.9% Ca and 0.8% P (table 1, 2). The tallow used in our study were thawed at 70℃ temperature and were blended with vegetable oil before mixing the feed. The experimental diets were fed as mash form. Chromic oxide (Cr_2O_3, 0.20%) were used as an indigestible marker to allow digestibility determination. Fecal samples were collected by rectal massage with two pigs in each pen. Collected samples were pooled for each pen and dried in an air-forced drying oven then ground with 1 mm Wiley mill for chemical analysis. Digestibility was determined at 2 week and 4 week, respectively. Also on d 0, d 14 and d 28, blood samples were collected from one pig of each pen. The blood samples were centrifuged (3,000×g) at 5℃ for 15 minuets. The serum was stored at -20℃ until the analyses for blood urea nitrogen, triglycerides and total cholesterol.

Table 1. Formula and chemical composition of experimental diets (d 0 to 14)

Treatment	S100*	S75	S50	C75	C50
Corn	26.07	26.07	26.07	26.07	26.07
Dried skim milk	10.00	10.00	10.00	10.00	10.00
Milk replacer	15.00	15.00	15.00	15.00	15.00
Soybean meal	13.56	13.56	13.56	13.56	13.56
Lactose	14.00	14.00	14.00	14.00	14.00
Soy oil	6.00	4.50	3.00	0.00	0.00
Corn oil	0.00	0.00	0.00	4.50	3.00
Tallow	0.00	1.50	3.00	1.50	3.00
Fish meal	2.50	2.50	2.50	2.50	2.50
Spray dried plasma protein	7.50	7.50	7.50	7.50	7.50
Spray dried blood meal	2.50	2.50	2.50	2.50	2.50
Monocalcium phosphate	1.00	1.00	1.00	1.00	1.00
Limestone	0.79	0.79	0.79	0.79	0.79
Salt	0.20	0.20	0.20	0.20	0.20
Vit. min. mix.[1]	0.50	0.50	0.50	0.50	0.50
Avilamycine	0.05	0.05	0.05	0.05	0.05
DL-Methionine (98%)	0.13	0.13	0.13	0.13	0.13
Cr_2O_3	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition (%)[2]					
Gross energy (kcal/kg)	4,211	4,261	4,264	4,291	4,210
Metabolic energy (kcal/kg)	3,465	3,465	3,465	3,465	3,465
Crude protein	23.21	23.76	23.08	23.06	23.70
Lysine	1.67	1.66	1.66	1.66	1.66
Methionine	0.44	0.46	0.45	0.47	0.47
Calcium	0.87	0.86	0.89	0.90	0.90
Phosphorus	0.77	0.75	0.75	0.76	0.75

* Abbreviations: S100:100% of soybean oil; S75:75% of soybean oil with 25% of tallow; S50:50% of soybean oil with 50% of tallow; C75:75% of corn oil with 25% of tallow; C50:50% of corn oil with 50% of tallow.

[1] Vit.-Min. mixture contains per kg : Vitamin A, 2,000,000 IU; vitamin D_3, 400,000 IU vitamin E, 250 IU; vitamin K_3, 200 mg; vitamin B_1, 20 mg; vitamin B_2, 700 mg; riboflavin 10,000 mg; pantothenic calcium, 3,000 mg; choline chloride, 30,000 mg; niacin, 8,000 mg; folacin, 200 mg; vitamin B_{12}, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Analyzed value.

Table 2. Formula and chemical compositon of experimental diet (d 15 to 28)

Treatment	S100*	S75	S50	C75	C50
Corn	23.71	23.71	23.71	23.71	23.71
Milk replacer	19.00	19.00	19.00	19.00	19.00
Soybean meal	20.00	20.00	20.00	20.00	20.00
Lactose	19.00	19.00	19.00	19.00	19.00
Soy oil	6.00	4.50	3.00	0.00	0.00
Corn oil	0.00	0.00	0.00	4.50	3.00
Tallow	0.00	1.50	3.00	1.50	3.00
Fish meal	1.80	1.80	1.80	1.80	1.80
Spray dried plasma protein	5.00	5.00	5.00	5.00	5.00
Spray dried blood meal	1.80	1.80	1.80	1.80	1.80
Monocalcium phosphorus	1.45	1.45	1.45	1.45	1.45
Limestone	0.90	0.90	0.90	0.90	0.90
Salt	0.20	0.20	0.20	0.20	0.20
Vit. min. mix.[1]	0.50	0.50	0.50	0.50	0.50
Avilamycine	0.04	0.04	0.04	0.04	0.04
L-Lysine · HCl (78%)	0.23	0.23	0.23	0.23	0.23
DL-Methionine (98%)	0.17	0.17	0.17	0.17	0.17
Cr_2O_3	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition (%)[2]					
Gross energy (kcal/kg)	4,274	4,207	4,186	4,192	4,144
Metabolic energy (kcal/kg)	3,450	3,450	3,450	3,450	3,450
Crude protein	20.49	20.68	20.66	20.41	20.22
Lysine	1.31	1.34	1.32	1.30	1.33
Methionine	0.42	0.43	0.43	0.42	0.42
Calcium	0.89	0.87	0.89	0.90	0.89
Phosphorus	0.82	0.80	0.81	0.80	0.81

* Abbreviations: See table 1.

[1] Vit.-Min. mixture contains per kg : Vitamin A, 2,000,000 IU; vitamin D_3, 400,000 IU; vitamin E, 250 IU; vitamin K_3, 200 mg; vitamin B_1, 20 mg; vitamin B_2, 700 mg; riboflavin 10,000 mg; pantothenic calcium, 3,000 mg; choline chloride, 30,000 mg; niacin, 8,000 mg; folacin, 200 mg; vitamin B_{12}, 13 mg; Mn 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Analyzed value.

Pigs were housed in an environmentally controlled feeding room (1×1.5 m) in which temperature was maintained at 31℃ during the first week and decreased by 1~2℃ each week. Each pen was equipped with a nipple waterer and a feeder to provide pigs an ad libitum access to the experimental diets. Weight gain and feed intake were recorded weekly and the wasted feed was collected, dried and weighted for accurate calculation of feed intake.

Analyses of proximate nutrients composition of experimental diets and excreta was conducted according to the methods of AOAC (1990), and amino acids composition was measured using an automatic amino acid analyzer (Pharmacia Biotech, Biochrom 20, England) after 24 hours of acid hydrolysis in 6 N HCl. Phosphorus content were measured using the UV-visible spectrophotometer (Hitachi, U-1000, Japan) and gross energy content of feeds and excreta were measured using an Bomb Calorimeter (Parr Instrument Co., Model 1241, USA). Chromium was measured using atomic absorption spectrophotometer (Shimadzu, AA6145F, Japan). The fatty acid composition of the experimental diets measured using a gas chromatography (HP 5890, Hewlett-Packard Co., USA) according to the method of Lepage and Roy (1986). Serum urea nitrogen (BUN), total triglycerides (TG) and total cholesterol (TC) were analyzed using commercially available kits (ChungIl Chem., Korea).

Statistical analysis for the present data was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) procedure of SAS (1985) package program. Pen means were used as an experimental unit.

RESULTS AND DISCUSSION

Fatty acid profiles of fat sources used in this

experiment were given in table 3. All of fat sources predominantly composed of long-chain fatty acids with chain lengths of 14 or more carbons (LCFA>99%), soybean oil and corn oil were relatively high in proportion of unsaturated fatty acids (USFA>85%), while the tallow was relatively high in proportion of saturated fatty acids (SFA>57%). Also, soy oil and corn oil were almost ten times higher in USFA/SFA ratio (5.84 and 6.89) than tallow (0.73). The USFA and SFA concentrations of the soy oil, corn oil and tallow were similar with those listed by NRC (1998).

For d 0 to 14, a significant differences were observed in average daily gain (ADG) and average daily feed intake (ADFI) among the fat sources and levels of fat. Pigs fed animal-vegetable fat blends gained more than did pigs fed the control diet (S100, vegetable oil) during the first 2 weeks after weaning (table 4). Between soy oil-tallow blends and corn oil-tallow blends, pigs fed soy oil-tallow blends had greater ADG ($p<0.001$), ADFI ($p<0.01$) and better FCR ($p<0.05$) compared to pigs fed corn oil-tallow blends diets during the first 2 weeks.

Between tallow addition levels, 50% tallow diets showed improved ADG ($p<0.01$) and ADFI ($p<0.05$) compared to 25% tallow diet. As tallow addition was increased from 25% to 50% replacing soy or corn oil, improvement of ADG was increased from 6.32% to 28.38%. The results were surprising because usually tallow has been recognized as an inferior fat source for weaned pigs even with emulsifier (Turlington, 1988; Jones et al., 1992; Jin et al., 1998). However, Cera et al. (1988a) observed an improved performance of pigs fed tallow compared to pigs fed corn oil during the first 2 weeks after weaning. Cera et al. (1989) also reported an improved performance of pigs during the first 2 weeks when pigs fed either 50% tallow:50% corn oil blended diets. ADG and ADFI during first 2 weeks after weaning were improved by 28.13% and 8.60%, respectively, which showed similar result with ours. Also, it has been suggested that the primary response to fat additions to postweaning diets

Table 3. Fatty acid composition of fat sources used in this experiment

Item	Soy oil	Corn oil	Tallow
Fatty acids, % of total fatty acids*			
Saturated			
C14:0	-	-	0.29
C16:0	10.56	10.19	27.57
C18:0	4.06	2.49	29.91
Submean	14.62	12.68	57.77
Monounsaturated			
C16:1	0.08	0.08	0.24
C18:1	24.18	27.67	41.20
Submean	24.26	27.75	41.44
Polyunsaturated			
C18:2	60.44	59.57	0.55
C18:3	0.68	-	0.06
C20:4	-	-	0.08
C22:6	-	-	0.10
Submean	61.12	59.57	0.79
Saturated (SFA)	14.62	12.68	57.78
Unsaturated (USFA)	85.38	87.32	42.23
USFA/SFA	5.84	6.89	0.73

* Analyzed value.

Table 4. Effects of dietary oil source and level on the growing performance of piglet*

Treatment	S100	S75	S50	C75	C50	SE[1]	Contrast[2]		
							A	B	C
D 0~14									
ADG (g)	340^{c}	376^{bc}	459^{a}	347^{c}	414^{ab}	11.87	0.0543	0.0002	0.0078
ADFI (g)	401^{bc}	400^{bc}	491^{a}	388^{c}	463^{ab}	12.27	0.0291	0.0066	0.0262
FCR	1.18^{a}	1.06^{b}	1.07^{b}	1.12^{ab}	1.12^{ab}	0.02	NS	0.0286	NS
D 15~28									
ADG (g)	559	566	540	565	536	7.38	NS	NS	NS
ADFI (g)	933	913	899	907	933	13.85	NS[3]	NS	NS
FCR	1.67	1.61	1.66	1.61	1.74	0.02	0.0515	NS	NS
D 0~28									
ADG (g)	450^{b}	471^{ab}	499^{a}	457^{ab}	475^{ab}	6.82	NS	0.0140	mNS
ADFI (g)	667	656	695	647	698	10.42	NS	NS	NS
FCR	1.48	1.40	1.39	1.42	1.47	0.02	NS	0.0758	NS

* Average initial and final body weight were 5.68±0.61 kg.

[1] Pooled standard error.

[a,b,c] Means with different superscript in the row differ ($p<0.05$).

[2] A: Soy oil vs other, B: Soy oil & Tallow vs corn oil & Tallow, C: 25% tallow vs 50 % tallow.

[3] Not significant, $p>0.05$, respectively.

Table 5. Effect of dietary oil source and level on apparent fecal digestibility of nutrients for weaned pigs

Treatment	S100	S75	S50	C75	C50	SE[1]	Contrast[2]		
							A	B	C
Day 14									
Dry matter	82.92[a]	80.21[ab]	79.69[ab]	78.80[b]	79.89[ab]	0.51	NS[3]	NS	NS
Crude ash	62.54	61.96	60.68	55.67	57.31	1.18	NS	NS	0.0119
Crude protein	75.60[a]	71.13[b]	69.54[b]	69.50[b]	70.88[b]	0.74	NS	NS	NS
Crude fat	72.19	70.50	70.68	69.13	68.89	1.00	NS	NS	NS
Calcium	61.66	59.00	66.12	63.33	67.05	1.21	NS	NS	NS
Phosphorus	55.23	54.33	53.57	53.99	52.64	1.02	NS	NS	NS
Day 28									
Dry matter	89.79	90.52	92.36	90.66	91.21	0.38	NS	NS	NS
Crude ash	60.03[b]	61.19[ab]	68.23[a]	64.08[ab]	67.17[a]	1.13	NS	NS	0.0220
Crude protein	80.24	79.15	79.74	79.25	79.58	0.40	NS	NS	NS
Crude fat	71.92	76.79	74.64	71.14	72.20	0.94	NS	NS	NS
Calcium	69.35	66.03	69.36	69.03	70.18	0.74	NS	0.0577	NS
Phosphorus	60.35	62.37	65.27	61.39	62.67	0.80	NS	NS	NS

[a,b] Means with different superscripts in the row differ ($p<0.05$).

[1] Pooled standard error.

[2] A: Soy oil vs other, B: soy oil & tallow vs corn oil & tallow, C: 25% tallow vs 50 % tallow.

[3] Not significant, $p>0.05$, respectively.

Table 6. Apparent fecal digestibility of amino acids of phase I diets for weaned pigs

Treatment	S100	S75	S50	C75	C50	SE[1]	Contrast[2]		
							A	B	C
Essential amino acids (%)									
THR	81.05[ab]	79.95[b]	81.67[a]	79.85[a]	80.88[ab]	0.26	NS[3]	NS	NS
VAL	79.72[bc]	81.86[abc]	83.65[a]	78.52[c]	82.86[ab]	0.62	NS	0.0049	NS
CYS	82.49[b]	87.67[a]	88.04[a]	81.29[b]	87.24[a]	0.87	NS	0.0009	NS
MET	81.95[b]	83.56[ab]	86.70[a]	80.75[b]	85.90[a]	0.69	0.0612	0.0059	NS
ILE	83.46	83.41	85.25	82.27	84.46	0.66	NS	NS	NS
LEU	82.47[ab]	82.37[ab]	85.69[a]	81.27[b]	84.90[ab]	0.63	NS	0.1103	NS
TYR	83.44[abc]	82.49[bc]	85.07[a]	82.24[c]	84.26[ab]	0.34	NS	NS	NS
PHE	84.64	82.33	82.64	83.44	81.85	0.78	NS	NS	NS
LYS	85.08	82.98	85.69	83.88	84.89	0.44	NS	NS	NS
HIS	81.31[ab]	81.02[ab]	84.60[a]	80.11[b]	83.80[a]	0.59	NS	0.0829	NS
ARG	85.91[a]	82.51[b]	87.31[a]	84.71[ab]	86.52[a]	0.56	NS	NS	0.0986
Submean	82.87[b]	82.74[bc]	85.12[a]	81.67[c]	84.32[a]	0.31	NS	0.0010	NS
Non essential amino acids (%)									
ASP	79.96	79.68	79.53	78.35	77.36	0.74	0.0093	0.0004	0.1301
SER	80.70	79.44	81.82	79.05	79.83	0.60	NS	NS	NS
GLU	81.25	82.01	82.15	79.60	79.98	0.57	NS	NS	NS
PRO	81.26	79.49	82.30	86.09	83.23	0.56	NS	NS	NS
GLY	80.53	80.63	82.49	78.88	80.75	0.82	NS	NS	NS
ALA	81.81[ab]	83.38[ab]	84.85[a]	80.16[b]	82.66[ab]	0.61	NS	NS	NS
Submean	80.92	80.77	82.19	79.27	80.15	0.43	NS	NS	NS
Average	81.89[bc]	81.76[bc]	83.66[a]	80.47[c]	82.24[ab]	0.31	NS	0.0076	NS

[a,b] Means with different superscripts in the row differ ($p<0.05$).

[1] Pooled standard error.

[2] A: Soy oil vs other, B: soy oil & tallow vs corn oil & tallow, C: 25% tallow vs 50 % tallow.

[3] Not significant, $p>0.05$, respectively.

usually occurs 2 to 3 weeks or more after weaning (Owsley et al., 1986; Cera et al., 1988a).

In phase II (d 15 to 28) period, ADG, ADFI and FCR were not significantly different among treatments, according to this result, it may be said that pigs developed their digestive capacity for fat as they grow. Cera et al. (1988a, b, 1989) reported that fat digestibility was improved as pigs aged and the differences in fat digestibility due to the different fat sources was disappeared by 4 weeks of age.

For the whole experimental period (d 0 to 28), the best performance was found in pigs fed S50 diet (figure 1). pigs fed soy oil-tallow blends showed better ADG ($p<0.05$) and tended to have better FCR ($p<0.076$) than those fed corn oil-tallow blends.

For phase I diet, as shown in table 5, pigs fed soy oil showed numerically higher DM, CP and fat digestibility than other treatments but not significantly different. For phase II diet, no differences were found in proximate nutrients digestibility except crude ash which was found to be higher in 50% tallow:50% vegetable oil diets than control diet.

As a whole, pigs fed 50% tallow:50% vegetable oil diets, showed a trend to show higher nutrients digestibilities than pigs fed control diet. Apparent DM, CP and fat digestibility were increased with time postweaning for each treatment, as has been observed by Leibbrandt et al. (1975), Cunninghan and Brisson (1955), Lloyd et al. (1957), Frobish et al. (1970) and Cera et al. (1988a, b, 1989).

Factors affecting digestibility of fat have been reviewed by Elwyn et al. (1991) who reported that perhaps the most important factor is the ratio of unsaturated to saturated fatty acids and digestibility declines as this ratio falls below 1.5:1. Shorter-chain fatty acids are easier to digest than long-chain fatty acids, but these contain less energy per gram. A high level of nonesterified fatty acids reduces digestibility (Elwyn, 1991).

For phase II diet, there were no differences in total amino acid digestibilities (table 6). Though, average amino acids digestibility was numerically higher for pigs fed 50% tallow:50% vegetable diets, no significance was detected. Similar trend in aminoacids digestibility of phase II diet was found (table 7).

All pig groups had similar BUN concentrations at d 0, d 14 and d 28. The combination of soy oil or corn oil with tallow produced slightly higher serum triglycerides and total cholesterol combination

Table 7. Apparent fecal digestibility of amino acids of phase II diets for weaned pigs

Treatment	S100	S75	S50	C75	C50	SE[1]	Contrast[2]		
							A	B	C
Essential amino acids (%)									
THR	85.65	83.45	84.67	84.13	84.25	0.56	NS[3]	NS	NS
VAL	84.32	85.36	86.65	87.20	86.66	0.63	NS	NS	NS
CYS	87.09^{b}	91.17^{b}	91.04^{b}	96.25^{a}	91.63^{b}	0.89	NS	NS	0.0089
MET	86.55^{b}	87.06^{b}	89.70^{ab}	91.77^{a}	87.24^{b}	0.63	NS	NS	0.0032
ILE	88.07	86.91	88.25	87.23	87.02	0.62	NS	NS	NS
LEU	87.07	85.87	88.69	86.19	85.24	0.53	NS	NS	NS
TYR	88.04	85.99	88.07	87.35	86.17^{c}	0.47	NS	NS	NS
PHE	89.24^{ab}	85.83^{ab}	85.64^{ab}	90.05^{a}	84.57^{c}	0.82	0.1094	0.0310	NS
LYS	89.68	86.49	88.69	86.48	85.72	0.66	NS	NS	NS
HIS	85.91^{b}	84.52^{b}	87.60^{ab}	85.84^{b}	89.45^{a}	0.58	0.0117	NS	NS
ARG	90.51^{ab}	86.01^{c}	90.31^{b}	91.30^{ab}	93.39^{a}	0.66	0.0020	0.0094	0.0147
Submean	87.47^{ab}	86.24^{b}	88.12^{a}	88.61^{a}	87.40^{ab}	0.27	NS	0.1055	0.0087
Non essential amino acids (%)									
ASP	81.62	82.68	78.43	81.46	84.32	0.87	NS	NS	NS
SER	80.80	82.44	80.72	82.98	84.50	0.74	NS	NS	NS
GLU	80.55^{b}	85.01^{a}	81.05^{a}	83.48^{ab}	84.25^{ab}	0.66	NS	NS	NS
PRO	82.12^{ab}	82.49^{ab}	81.20^{b}	80.56^{b}	85.82^{a}	0.68	0.0103	NS	NS
GLY	80.13	83.62	81.39	81.50	83.83	0.70	NS	NS	NS
ALA	80.99^{b}	86.38^{a}	83.75^{ab}	82.03^{b}	84.70^{ab}	0.68	NS	0.0160	NS
Submean	81.04^{c}	83.77^{ab}	81.09^{c}	82.00^{bc}	84.57^{a}	1.14	0.0039	NS	NS
Average	84.25^{b}	85.01^{ab}	84.61^{ab}	85.30^{ab}	85.98^{a}	0.22	0.0309	NS	NS

[a,b] Means with different superscripts in the row differ ($p<0.05$).

[1] Pooled standard error.

[2] A: Soy oil vs other, B: soy oil & rallow vs corn oil & rallow, C: 25% tallow vs 50% tallow.

[3] Not significant, $p>0.05$, respectively.

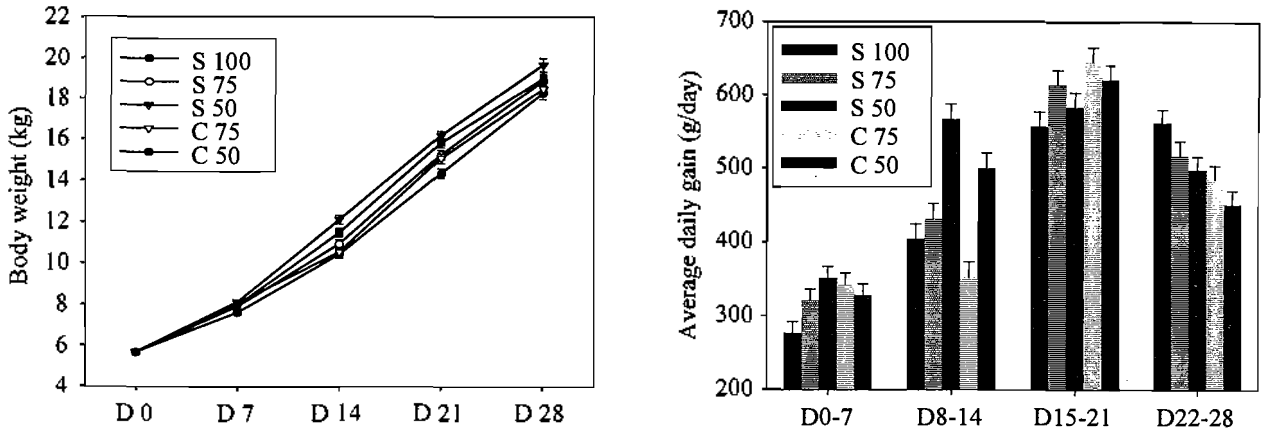

Figure 1. Body weight and daily gain changes of pigs fed the experimental diets

Table 8. Plasma concentrations of urea nitrogen, glucose and total cholesterol of pigs fed experimental diets

Treatment	S100	S75	S50	C75	C50	SE[1]	Contrast[2]		
							A	B	C
Blood urea nitrogen (mmol/dl)									
D 0	8.50	8.90	8.73	8.97	8.68	0.79	NS[3]	NS	NS
D 14	8.20	9.55	10.43	9.85	10.18	0.43	NS	NS	NS
D 28	8.47	8.43	8.80	8.35	8.43	1.23	NS	NS	NS
Triglyceride (mg/dl)									
D 0	52.90	52.20	56.40	54.31	55.40	1.44	NS	NS	NS
D 14	56.90	56.45	67.10	58.80	62.40	1.72	NS	NS	NS
D 28	62.30[b]	66.20[ab]	67.35[a]	67.05[ab]	70.45[a]	1.85	0.0042	0.0903	0.0305
Total cholesterol (mg/dl)									
D 0	61.15	65.27	69.12	67.23	67.77	1.27	NS	NS	NS
D 14	72.23	75.41	81.69	77.16	79.67	1.80	NS	NS	0.0629
D 28	91.70	94.70	98.58	95.74	97.77	1.93	NS	NS	NS

[a,b] Means with different superscripts in the row differ ($p<0.05$).
[1] Pooled standard error.
[2] A: Soy oil vs other, B: soy oil & tallow vs corn oil & tallow, C: 25% tallow vs 50% tallow.
[3] Not significant, $p>0.05$, respectively.

compared with the soy oil alone. This results consistent with the pigs study reported by Cera et al. (1989).

Based on the results of this experiment, tallow:soy (or corn) oil blends diets improved growth rate and feed efficiency and the ratio of 50% tallow plus 50% soy (or corn) oil blends diets appeared to be desirable for growth and nutrient utilization of weaned pigs.

REFERENCES

Allee, G. L., D. H. Baker and G. A. Leveille. 1971. Fat utilization and lipogenesis in the young pig. J. Nutr. 101:1415.

AOAC. 1990. Official method of analysis (15th ed.). Association of official analytical chemists, Washington, DC.

Atteh, J. O. and S. Leeson. 1983. Effect of increasing dietary fat, calcium and phosphorus levels on pigs. San. J. Anim. Sci. 63:699.

Bayley, H. S. and D. Lewis. 1965. The use of fats in pig feeding. 2. The digestibility of various fats and fatty acids. J. Agric. Sci. (Camb.) 64:373.

Bayley, H. S. and D. Lewis. 1965. The use of fats in pig feeding. 2. The digestibility of various fats and fatty acids. J. Agric. Sci. (Camb.) 64:373.

Bruegger, S. J. and J. H. Conrad. 1972. Effects of orally administered albumin and corn oil on blood constituents, survival and weight gain in neonatal pigs. J. Anim. Sci. 34:411-415.

Calloway, D. H., G. W. Kurtz, J. J. Mcmullen and L. V. Thomas. 1956. The absorbability of natural and modified fats. Food Res. 21:621.

Cera, K. R., D. C. Mahan and G. A. Reinhart. 1988a. Weekly digestibility of diets supplemented with corn oil, lard or tallow by weanling swine. J. Anim. Sci. 66:1430.

Cera, K. R., D. C. Mahan and G. A. Reinhart. 1988b.

Effect of dietary dried whey and corn oil on weanling pig performance, fat digestibility and nitrogen utilization. J. Anim. Sci. 66:1438.

Cera, K. R., D. C. Mahan and G. A. Reinhart. 1989. Apparent fat digestibility and performance responses of postweaning swine fed diets supplemented with coconut oil, corn oil or tallow. J. Anim. Sci. 67:2040.

Cera, K. R., D. C. Mahan and G. A. Reinhart. 1990. Evaluation of various extracted vegetable oil, roasted soybean, medium-chain triglyceride and an animal-vegetable fat blends for postweaning swine. J. Anim. Sci. 68:2756-2765.

Cera, K. R., D. C. Mahan and R. F. Cross. 1988c. Effect of age, weaning and postweaning diet on small intestinal growth and jejunal morphology in young swine. J. Anim. Sci. 66:574.

Crampton, E. W. and O. M. Ness. 1954. A meal mixture suitable as the entire ration to be self-fed dry to pigs weaned at ten days of age. J. Anim. Sci. 13:357.

Cunningham, H. M. and G. J. Brisson. 1957. J. Anim. Sci. 16:370.

Dove, C. R. and K. D. Haydon. 1991. The effect of copper addition to diets with various iron levels on the performance and hematology of weanling swine. J. Anim. Sci. 69:2013.

Dove, C. R. and K. D. Haydon. 1992. The effect of copper and fat addition to the diets of weanling swine on growth performance and serum fatty acids. J. Anim. Sci. 69:2013.

Dove, C. R. 1995. The effect of copper level on nutrient utilization of weanling pigs. J. Anim. Sci. 73:166.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics. 11:1.

Elwyn, R. M., E. U. Duane and J. L. Austin. 1991. Swine Nutrition. pp. 133-145.

Eusebio, J. A., V. W. Hays, V. C. Speer and J. T. McCall. 1965. Utilization of fat by young pig. J. Anim. Sci. 24:1001.

Frobish, L. T., V. W. Hays, V. C. Speer and R. C. Ewan. 1970. Effect of fat source and level on utilization of fat by young pigs. J. Anim. Sci. 30:197.

Hamilton, R. M. G. and B. E. McDonald. 1969. Effect of dietary fat source on the apparent digestibility of fat and the composition of fecal lipids on the young pig. J. Nutr. 97:33.

Jin, C. F., J. H. Kim, In K. Han, H. J. Jung and C. H. Kwon. 1998. Effects of various fat sources and lecithin on the growth performance and nutrient utilization in pigs weaned at 21 days of age. Asian-Aus. J. Anim. Sci. 11:176.

Jones, D. B., J. D. Hancock, D. L. Harmon and C. E. Walker. 1992. Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids, and growth performance in weanling pigs. J. Anim. Sci. 70:3473.

Koga, A. and S. Kimura. 1980. Influence of restricted diet on the cell cycle in the crypt of mouse small intestine. J. Nutr. Sci. Vitaminol. 26:33.

Lawrence, N. J. and C. V. Maxwell. 1983. Effect of dietary fat source and level on the performance of neonatal and early weaned pigs. J. Anim. Sci. 57:936.

Leibbrandt, V. D., R. C. Ewan, V. C. Speer and D. R. Zimmeman. 1975. Effect of age and calorie:protein ratio on performance and body composition of baby pigs. J. Anim. Sci. 40:1070.

Lepage, G. and C. C. Roy. 1986. Direct trans- esterification of all classes of lipids in a one-step reaction. J. Lipid. Res. 27:114.

Li, D. F., J. L. Nelssen, P. G. Reddy, F. Blecha, J. D. Hancock, G. L. Allee, R. D. Goodband and R. D. Klemm. 1990. Transient hypersensitivity to soybean meal in the early-weaned pig. J. Anim. Sci. 68:1790.

Liepens, A. and E. Dehaven. 1978. A rapid method of cell drying for scanning electron microscopy. Scanning Electron Microsc. 2:37.

Lindemann, M. D., S. G. Cornelius, S. M. El Kandelgy, R. L. Moser and J. E. Pettigrew. 1986. Effect of age, weanling and diet on digestive enzyme levels in the piglet. J. Anim. Sci. 62:1298.

Lloyd, L. E. and E. W. Crampton. 1957. The relation between certain characteristics of fats and oils and their apparent digestibility by young pigs, young guinea pigs and pups. J. Anim. Sci. 16:377.

Luo, X. G. and C. R. Dove. 1996. Effect of dietary copper and fat on nutrient utilization, digestive enzyme activities and tissue mineral levels in weanling pigs. J. Anim. Sci. 74:1888-1896.

NRC. 1998. Nutrient requirements of swine (10th Ed.). National Academy Press. Washington, DC.

Owsley, W. F., D. E. Ott and L. F. Tribble. 1986. Effect of nitrogen and energy source on nutrient digestibility in the young pig. J. Anim. Sci. 63:492.

Peo, E. R. Jr., G. C. Ashtron, V. C. Speer and D. V. Catron. 1957. Protein and fat requirements of baby pigs. J. Anim. Sci. 16:885.

Pettigrew, J. E. J. 1981. Supplemental dietary fat for peripartal sows; A review. J. Anim. Sci. 53:107-117.

Tokach, M., J. E. Pettigrew, L. J. Johnston, M. Øverland, J. W. Rust and S. G. Cornelius. 1995. Effect of adding fat and (or) milk products to the weanling pig diet on performance in the nursery and subsequent grow-finish stages. J. Anim. Sci. 73:3358-3368.

Tuelington, H. 1988. The effect of protein carbohydrate and fat sources on nutrient digestibility of the early weaned pig. Ph. D. Dissertation. Kansas State Univ., Manhattan.