Effects of Fat Sources on Growth Performance, Nutrient Digestibility, Serum Traits and Intestinal Morphology in Weaning Pigs

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ABSTRACT : This experiment was conducted to investigate the effects of fat sources on growth performance, nutrient digestibility, serum traits and intestinal morphology in weaning pigs. A total of 128 weaning pigs (Landrace×Large White×Duroc, 21±2 days of age, 5.82±0.13 kg of average initial body weight) were allotted in a randomized complete block (RCB) design with four treatments: 1) corn oil, 2) soybean oil, 3) tallow and 4) fish oil. Each treatment had 8 replicates with 4 pigs per pen. During phase I period (d 0 to 14), pigs fed corn oil or soybean oil diet tended to show higher ADG and FCR than any other treatments although there was no significant difference. During phase II period (d 15 to 28), pigs fed corn oil diet showed better ADG and ADFI than pigs fed soybean oil, tallow or fish oil. For overall period, growth performance of weaning pigs was improved ($p<0.05$) when pigs were fed soybean oil or corn oil. Apparent digestibility of energy and fat was improved when pigs were fed corn oil diet ($p<0.05$). Supplementation of corn oil resulted in higher serum triglyceride concentration than the other treatments ($p<0.05$). However, there was a lower cholesterol concentration when corn oil was provided compared to tallow or fish oil. Pigs fed corn oil tended to have increased villus height compared with soybean oil, tallow or fish oil treatment ($p<0.05$). This experiment suggested that vegetable oils such as corn oil or soybean oil, were much better fat source for improving growth performance of weaning pigs. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 7 : 1035-1040)***

Key Words : Fat, Growth Performance, Nutrient Digestibility, Intestinal Morphology

INTRODUCTION

Fats and oils are an important energy source for pigs from the very first days of their life. The addition of dietary fat has been recommended and is supported by the fact the activity of pancreatic lipase reaches at a maximum between 3 and 5 weeks of age in suckling pig (Corring et al., 1978; Lindemann et al., 1986).

Weaning of the pig represents a dramatic change in the source of nutrients from a low-carbohydrate and high-fat liquid diet to a high-carbohydrate and low-fat solid feed, which results in a critical period of underfeeding and a growth retardation in the immediate period following weaning (Le Dividich et al., 1980; Seve, 1982). Pigs can effectively use the sow milk fat during suckling period (Moser and Lewis, 1980; Pettigrew, 1981), consequently they may be able to utilize very efficiently the supplemented fat in the starting diet during nursing and postweaning.

In addition, it has been shown that the use of dietary fat has a positive overall contribution during growth of weaning pigs. Because dietary fat may reduce the weaning "stress" (Mersmann et al., 1973; Lawrence and Maxwell, 1983), increase growth rate, improve the feed to gain ratio (Attech and Leeson, 1983; Lawrence and Maxwell, 1983) and enhance the digestibility of fatty acids (Frobish et al., 1970). Contrary to these results, in some studies, demonstrated that growth rate of feed efficiency was not improved by dietary fat in weaning pigs (Peo et al., 1957; Lawrence and Maxwell, 1983; Cera et al., 1988c). These differences may be a result of several factors that affect the response of weaning pigs to the addition of dietary fat, such as interactions between the different fatty acids of the diet (Bayley and Lewis, 1965), the relationship between the fat content and amino acids (Allee et al., 1971), the age of the pigs (Lindemann et al., 1986; Cera et al., 1988b), addition of Cu (Dove and Haydon, 1992; Dove, 1993; Luo and Dove, 1996) and mainly the concentration and composition of the dietary fat source (Hamilton and McDonald, 1969; Frobish et al., 1970; Cera et al., 1988a; Li et al., 1990).

Therefore, the objective of this study was to investigate the effect of various fat sources on the growth performance, nutrient digestibility, serum traits and intestinal morphology in weaning pigs.

MATERIALS AND METHODS

This study was conducted with 128 crossbred pigs (Landrace×Large White×Duroc) to evaluate the efficacy of various fat sources on growth performance, nutrient digestibility, serum traits and intestinal morphology in weaning pigs. Pigs were weaned at 21±2 days of age with 5.82±0.13 kg average body weight and were allotted using a randomized complete block (RCB) design. Treatment diets consisted of corn-soybean meal-milk replacer diets containing an 5% supplemental fat level from either 1) corn oil, 2) soy oil, 3) tallow or 4) fish oil. Each treatment had 8 replicates with 4 pigs per pen.

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Table 1. Formulation and chemical composition of experimental diets (Phase I)

	Corn oil	Soybean oil	Tallow	Fish oil
Ingredients (%):				
Corn	16.50	16.50	16.50	16.50
Milk replacer	27.00	27.00	27.00	27.00
SBM	20.50	20.50	20.50	20.50
Lactose	17.00	17.00	17.00	17.00
Corn oil	5.00	-	-	-
Soybean oil	-	5.00	-	-
Tallow	-	-	5.00	-
Fish oil	-	-	-	5.00
Fish meal	4.30	4.30	4.30	4.30
SDPP	7.00	7.00	7.00	7.00
MCP	1.02	1.02	1.02	1.02
Limestone	0.66	0.66	0.66	0.66
Vit. Mix.[1]	0.20	0.20	0.20	0.20
Min. Mix.[2]	0.30	0.30	0.30	0.30
Salt	0.30	0.30	0.30	0.30
Avilamycine	0.05	0.05	0.05	0.05
L-Lysine·HCl	0.09	0.09	0.09	0.09
DL-Methionine	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00
Chemical composition[3]:				
ME (kcal/kg)	3,480	3,480	3,444	3,466
CP (%)	23.02	23.02	23.02	23.02
Lys (%)	1.69	1.69	1.69	1.69
Met+Cys (%)	0.82	0.82	0.82	0.82
Ca (%)	0.91	0.91	0.91	0.91
P (%)	0.82	0.82	0.82	0.82

[1] Supplied per kg diet: 8,000 IU vitamin A, 2,500 IU vitamin D_3, 30 IU vitamin E, 3 mg vitamin K, 1.5 mg thiamin, 10 mg riboflavin, 2 mg vitamin B_6, 40 μg vitamin B_{12}, 30 mg pantothenic acid, 60 mg niacin, 0.1 mg biotin, 0.5 mg folic acid.
[2] Supplied per kg diet: 200 mg Cu, 100 mg Fe, 150 mg Zn, 60 mg Mn, 1 mg I, 0.5 mg Co, 0.3 mg Se.
[3] Calculated value.

Table 2. Formulation and chemical composition of experimental diets (Phase II)

	Corn oil	Soybean oil	Tallow	Fish oil
Ingredients (%):				
Corn	36.00	36.00	36.00	36.00
Milk replacer	18.90	18.90	18.90	18.90
SBM	17.39	17.39	17.39	17.39
Lactose	10.00	10.00	10.00	10.00
Corn oil	5.00	-	-	-
Soybean oil	-	5.00	-	-
Tallow	-	-	5.00	-
Fish oil	-	-	-	5.00
Fish meal	4.50	4.50	4.50	4.50
SDPP	6.00	6.00	6.00	6.00
MCP	1.02	1.02	1.02	1.02
Limestone	0.66	0.66	0.66	0.66
Vit. Mix.[1]	0.20	0.20	0.20	0.20
Min. Mix.[2]	0.30	0.30	0.30	0.30
Salt	0.00	0.00	0.00	0.00
Avilamycine	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00
Chemical composition[3] :				
ME (kcal/kg)	3,460	3,460	3,420	3,440
CP (%)	21.00	21.00	21.00	21.00
Lys (%)	1.40	1.40	1.40	1.40
Met+Cys (%)	0.34	0.34	0.34	0.34
Ca (%)	0.95	0.95	0.95	0.95
P (%)	0.80	0.80	0.80	0.80

[1] Referred in Table 1. [2] Referred in Table 1. [3] Calculate value.

The chemical composition of experimental diets is presented in Tables 1 and 2. The phase I and II diets were formulated to contain 1.69 and 1.40% lysine, respectively. Other nutrients provided in treatment diets met or exceeded NRC (1998) requirements.

Pigs were allowed *ad libitum* access to water and diets during 21 days growth trial, and the environmental temperature was maintained in the range of 30°C (at the beginning of experiment) to 26°C (at the end of experiment). Body weight and feed intake were recorded weekly to calculate average daily gain (ADG), average daily feed intake (ADFI) and feed/gain (F/G) ratio.

Blood samples were collected weekly from five pigs per treatment. Blood was immediately placed on ice with serum harvested by centrifugation and frozen for later analysis. The blood samples were centrifuged (3,000 rpm) at 5°C for 15 minutes for serum collection. The serum was stored at -20°C until the analyses for triglycerides and total cholesterol.

The fatty acid methyl esters, followed by the method of Lepage and Roy (1986), were separated on a Gas Chromatograph (HP 5890 Series II) equipped with Omegawax 2-4080 capillary column (50 m long and 0.25 I.D.). The injector temperature was 250°C and detector temperature was 260°C.

At the termination of the feeding trial, 3 pigs of each treatment were randomly selected and slaughtered for examining the morphological changes in small intestine including villus height and crypt depth. The samples of small intestine were obtained each (≒ 4 cm in length) at distances of proportionately 0.25, 0.50 and 0.75 m along the gut from the gastric pylorus to the ileo-caecal valve. These were fixed in neutral-buffered formalin and processed by the standard paraffin method. Sections (3-4 cm) were stained with haematoxylin and eosin, and examined under a light microscope. Measurements of villus hight and crypt depth were taken only from sections where the plane of section ran vertically from tip of villus to base of an adjacent crypt. From each section, a calibrated eyepiece graticule was used to measure 10 of the tallest well oriented villi from tip to crypt mouth, and 10 associated crypts from crypt mouth to base (Hampson et al., 1988).

Table 3. Fatty acids composition of fat sources

Fatty acids (%)	Fat sources[1]			
	Corn oil	Soybean oil	Tallow	Fish oil
C14:0	-	-	2.20	13.45
C16:0	11.34	7.24	22.98	27.22
C16:1	-	0.05	1.88	16.85
C18:0	1.14	2.81	28.73	4.74
C18:1 (n-9)	34.38	34.70	39.95	9.78
C18:2 (n-6)	52.62	50.53	4.16	2.64
C18:3 (n-3)	0.52	4.66	0.11	2.40
C20:4 (n-6)	-	-	-	0.87
C20:5 (n-3)	-	-	-	15.51
C22:6 (n-3)	-	-	-	6.54
SFA[2]	12.48	10.05	51.71	31.96
MUFA[3]	34.38	34.70	39.95	9.78
PUFA[4]	53.14	55.19	4.27	27.96
n-6 PUFA	52.62	50.53	4.16	3.51
n-3 PUFA	0.52	4.66	0.11	24.45
P/S ratio[5]	4.26	5.49	0.08	0.87

[1] Energy value (ME): Corn oil, 8,405 kcal/kg; soybean oil, 8,400 kcal/kg; tallow, 7,680 kcal/kg; fish oil, 8,135 kcal/kg. [2] SFA: Saturated fatty acid. [3] MUFA: Monounsaturated fatty acid. [4] PUFA: Polyunsaturated fatty acid. [5] P/S ratio: Ratio of PUFA/SFA. [6] n-3/n-6 ratio: Ratio of n-3 PUFA/n-6 PUFA.

In the metabolic trial, all weaning pigs were placed in an individual metabolic crates and were adjusted to the crates with a constant feed intake for 4 d period. Experimental diets contained 0.2% Cr_2O_3 to determine the digestibility of nutrients, and feces were collected three times a day for three days.

Fecal samples were dried in an air-forced drying oven at 60°C for 72 h and ground using a Wiley Mill with an 1 mm mesh and stored for chemical analysis. Proximate analysis of feed and fecal samples were conducted according to AOAC (1990) methods to determine the apparent digestibility. Chromium contents in diets and feces were measured using an Atomic Absorption Spectrophotmeter (Shimadzu, AA6145F, Japan).

Statistical analysis of data was carried out by comparing means according to LSD (least significant difference) test, using the GLM (general linear model) of the Procedure of SAS (1985) package program.

RESULTS AND DISCUSSION

The analyzed composition of fat sources investigated is shown in Table 3. Energy values of fat sources were as follows: corn oil, 8,405 kcal ME/kg; soybean oil, 8,400 kcal ME/kg; tallow, 7,680 kcal ME/kg; fish oil, 8,135 kcal ME/kg. Soybean oil and corn oil contained long-chain fatty acids predominantly with relatively high proportion as unsaturated fatty acids. Tallow, however, consisted predominantly of mono-unsaturated and saturated long-chain fatty acids, and fish oil contained high level n-3 polyunsaturated of fatty acids (PUFA).

Table 4. Effect of various fat sources on growth performance of weaning pigs

	Fat source				SEM[1]
	Corn oil	Soybean oil	Tallow	Fish oil	
ADG (g)					
0-14 d	261	257	240	245	8.84
15-28 d	519[a]	517[a]	451[b]	426[b]	16.07
0-28 d	390[a]	387[a]	346[b]	336[b]	10.55
ADFI (g)					
0-14 d	352	343	338	325	9.69
15-28 d	738	735	732	701	20.85
0-28 d	545	559	535	513	13.64
Feed/gain ratio					
0-14 d	1.35	1.34	1.41	1.32	0.03
15-28 d	1.43[bc]	1.42[c]	1.62[ab]	1.65[a]	0.04
0-28 d	1.40[b]	1.44[ab]	1.55[a]	1.53[ab]	0.02

[1] Pooled standard error of the mean.
[a,b,c] Means with different superscripts are significantly differ ($p<0.05$).

Sow's milk contains 30 to 40% fat on a dry matter basis (de Mann and Bowland, 1963) and fat composition of sow milk is characterized by high levels of palmitoleic acid (C16:1) when compared to other vegetable oils or animal fats. Utilization of fat in the early-weaned pig is enhanced when fat source contained high level of short-chain fatty acids or long-chain unsaturated fatty acid compared with sources rich in long-chain saturated fatty acids (Lawrence and Maxwell, 1983; Cera et al., 1988b).

The effects of fat sources on growth performance of weaning pigs were shown in Table 4. During the phase I period (d 0 to 14), pigs showed higher ADG and better F/G than any other treatments when pigs fed corn oil or soybean oil, although there was no significant difference. During phase Ⅱ period (d 15 to 28), ADG was higher ($p<0.05$) for pigs fed diets containing corn oil or soybean oil than that in tallow or fish oil. Cumulative results for the 4 week trial demonstrated that pigs fed diets containing vegetable oils, corn or soybean oil, had higher ADG than pigs fed diets tallow or fish oil ($p<0.05$). Average daily feed intake was not affected by treatment during whole experimental period. Differential utilization of dietary fat in weaning pigs may be partially due to fatty acid composition. The fats used in this study differed in both chain length and degree of unsaturation of fatty acids.

Several authors have consistently reported limited, if any, growth response during the first 2 to 3 week postweaning when various supplemental fat sources were added to the diets of 3 to 4 week old weaning pigs (Leibbrandt et al., 1975; Attech and Leeson, 1983; Lawrence and Maxwell, 1983; Cera et al., 1988a, b, 1990b; Howard et al., 1990). 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

Table 5. Effect of various fat sources on apparent digestibility of weaning pigs

Treatment	Fat source				SEM[1]
	Corn oil	Soybean oil	Tallow	Fish oil	
GE (%)	86.43[a]	86.08[ab]	85.92[b]	85.76[b]	0.09
Dry matter (%)	86.85	86.78	86.74	86.82	0.04
Crude protein (%)	82.20[b]	83.32[a]	81.79[b]	81.95[b]	0.20
Crude fat (%)	82.95[a]	82.69[ab]	78.52[c]	78.77[bc]	0.75
Ash (%)	59.54[b]	60.88[b]	63.82[a]	62.19[ab]	0.61

[1] Pooled standard error of the mean.
[a, b, c] Means with different superscripts are significantly differ ($p<0.05$).

Table 6. Effect of various fat sources on serum triglycerides and cholesterol concentration of weaning pigs

Treatment	Fat source				SEM[1]
	Corn oil	Soybean oil	Tallow	Fish oil	
Triglyceride (mg/dl)					
d 7	70.99	70.06	59.20	62.44	3.36
d 14	96.88	77.84	91.76	75.95	5.19
d 21	114.33	95.67	125.53	93.94	6.79
d 28	91.55[a]	88.59[a]	75.94[b]	87.60[ab]	2.74
Average	93.44[a]	83.04[ab]	88.11[ab]	79.98[b]	2.65
Total cholesterol (mg/dl)					
d 7	51.19	46.57	50.06	53.98	2.42
d 14	62.09[ab]	57.21[ab]	70.55[a]	53.63[b]	2.86
d 21	80.39	79.13	85.87	88.83	2.35
d 28	81.92[b]	89.91[ab]	102.13[a]	95.21[ab]	2.75
Average	68.90	68.21	77.15	72.91	1.66

[1] Pooled standard error of the mean.
[a, b] Means with different superscripts are significantly differ ($p<0.05$).

Table 7. Effect of various fat sources on intestinal morphology of weaning pigs

Treatment	Fat source				SEM[1]
	Corn oil	Soybean oil	Tallow	Fish oil	
Duodenum					
Villi height (μm)	511.97[a]	517.87[a]	491.95[a]	397.51[b]	14.26
Crypt depth (μm)	169.73	200.60	215.76	169.75	8.45
Jejunum					
Villi height (μm)	540.79[a]	410.68[ab]	481.60[ab]	364.60[c]	18.31
Crypt depth (μm)	167.88[a]	159.[ab]	160.07[ab]	129.33[b]	5.52
Ileum					
Villi height (μm)	463.81[a]	397.47[b]	370.32[b]	363.08[b]	12.69
Crypt depth (μm)	158.17	127.00	146.41	150.44	5.78
Villi height: Crypt depth					
Duodenum (μm/μm)	3.05	2.91	2.40	2.37	1.65
Jejunum (μm/μm)	3.42	2.67	3.01	2.82	2.25
Ileum (μm/μm)	2.99	3.20	2.70	2.43	1.24

[1] Pooled standard error of the mean.
[a, b, c] Means with different superscripts are significantly differ ($p<0.05$).

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 than corn oil alone. Vegetable oils, however, contain a high proportion of unsaturated rather than saturated fatty acids and have a higher apparent digestibility than the animal fat sources (Sewell and Miller, 1965; Cera et al., 1988b, 1989a, 1990b; Li et al., 1990). Unsaturated fatty acids (e.g. soybean oil) have increased ability to partition into the micellar phase (Freeman, 1969) and could be expected to have higher digestibility than saturated fatty acids (e.g. tallow and lard). Consequently, vegetable oils are more likely to be beneficial in the diets of starter pigs than animal fat sources.

Pigs fed diets supplemented with corn oil had higher ($p<0.05$) apparent digestibility of GE and crude fat compared to animal fat sources (Table 5). Corn oil and soybean oil ($p<0.05$) were more digestible than tallow or fish oil. These results are consistent with most previous reports that fats with long-chain unsaturated fatty acids are hydrolyzed and absorbed at higher rates than those with a higher degree of saturation (Sewell and Miller, 1965; Friedman and Nylund, 1980; Cera et al., 1988b), but the results are in conflict with those of Frobish et al. (1970).

Variation in fat digestibility in young pigs may be influenced by dietary lipid and protein sources. Wilson and Leibholz (1979) indicated a lower tallow digestibility when pigs were fed protein from soybean meal compared with protein from milk. Fat digestibility coefficients from weaning pigs fed 5 or 10% lard also were reported to be higher in diets using casein than in diets containing soy protein (Frobish et al., 1970). Sklan et al. (1975) suggested that the released free fatty acids in the intestinal lumen may be bound to undigested protein, thereby fatty acid absorption could be reduced. Their finding suggested that dietary protein source might influence the utilization of dietary fat, gains and the feed/gain ratios of weaning swine.

The effects of fat sources on serum triglycerides and cholesterol concentrations during each week of the 4 week postweaning period was shown in Table 6.

The feeding of corn oil and soybean oil lowered serum triglycerides compared with the feeding of tallow and fish oil ($p<0.05$). The average serum triglycerides concentration for the overall periods was increased when corn oil was fed and was higher than soybean oil, tallow or fish oil ($p<0.05$). These results implying a higher absorption and higher post-absorptive re-esterification of the dietary fatty acids from this lipid source. These results were consistent with the pigs study reported by Cera et al. (1989) and Piao et al. (2000).

Villus height in jejunum and ileum was higher when corn oil was provided compared to soybean oil, tallow or fish oil (Table 7). However, there were no differences in villi height and crypt depth among the fat sources particularly in duodenum.

Apparent digestibility of fat and gross energy was increased when pigs were fed corn oil. Li et al. (1990) demonstrated pigs fed the combination of soybean oil and coconut oil tended to have increased villus height compared with pigs fed soybean oil or coconut oil alone. Cera et al.

(1988a) reported that pigs fed a diet supplemented with 6% corn oil had shorter villi during the starter phase.

The changes in gut morphology and nutrient digestibility may influence on growth performance of weaning pigs. The reduction of villus height may decrease total luminial villus absorptive area subsequently result in inadequate digestive enzyme action and lower transport of nutrients at the villus surface (Cera et al., 1988a). Based on growth and digestibility data from this experiment, an improvement in growth performance can be expected with the addition of a corn oil to weaning pig diet.

The present study observed that growth performance of the pigs fed fish oil diets was lowerd than for pigs fed corn oil, soybean oil or tallow diets. This seems to be caused mainly by fish oil 5% and fish meal meal 4.5% in fish oil diets.

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