Effects of Various Fat Sources and Lecithin on the Growth Performance and Nutrient Utilization in Pigs Weaned at 21 Days of Age

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ABSTRACT : A total of 125 pigs (5.8 kg of BW) were allotted in a completely randomized block design. Treatments were coconut oil, corn oil, soybean oil, tallow and tallow+lecithin. Each treatment had 5 replicates with 5 pigs per replicate.

From d 0 to 7, pigs fed vegetable oil supported greater average daily gain (ADG) and improved feed/gain (F/G) compared to pigs fed the animal fat. Addition of lecithin to tallow increased ADG by 7.2%. Feed intake were similar for all treatment groups. From d 8 to 14, pigs fed coconut oil and soy oil showed better ADG and average daily feed intake (ADFI) than any of the others. From d 15 to 21, pigs fed the tallow diets had lower gains ($p < 0.05$) than those fed diets that contained vegetable oil and tallow with added lecithin. The effect of different fat sources on gain became smaller with age. Feed intakes were similar between the vegetable oil and lecithin supplemented diets each week postweaning except for pigs fed tallow ($p < 0.05$). Feed : gain ratios were superior during the initial 2 weeks postweaning period when pigs were provided vegetable oil diet compared with pigs fed tallow. All pig groups had similar feed:gain ratios during 3 weeks. Combinations of tallow with lecithin tended to have intermediate feed/gain ratio. It was found that vegetable oils were much better in improving growth rate of the piglets. Lecithin significantly improved growth rate and feed efficiency of the pigs through the whole experimental period compared to tallow. Coconut oil was the most effective in improving growth of pigs during the first two weeks postweaning. Corn oil had equal value with soy oil in improving growth performance of weaned pigs.

When vegetable oil was added, the digestibilities of nutrients except for minerals were higher than when the tallow was fed. Nutrients digestibility was similar among vegetable oils. The addition of lecithin to tallow increased digestibility of gross energy, dry matter, ether extract and crude protein. Crude ash and phosphorus digestibility were not affected by the treatments. Dry matter excretion was not different among treatments except for tallow which showed significantly higher dry matter excretion ($p < 0.05$), while nitrogen excretion was significantly decreased in pigs fed vegetable oil sources. However, Phosphorus excretion was not affected by the different fat sources.

(**Key Words**: Pigs, Coconut Oil, Soy Oil, Corn Oil, Tallow, Lecithin, Growth)

INTRODUCTION

Dietary fat enhances ADG and feed/gain (F/G) of early weaned pigs (Crampton and Ness, 1954; Atteh and Leeson, 1983; Lawrence and Maxwell, 1983) and improves digestibility of fatty acids (Frobish et al., 1970). Contrary to these results, in some studies added fat did not improve either growth or feed efficiency in weanling pigs, typically during the first 1 to 2 week postweaning (Peo et al., 1957; Frobish et al., 1970; Leibbrandt et al., 1975; Atteh and Leeson, 1983; Lawrence and Maxwell, 1983; Cera et al., 1988ac, 1989; Howard et al., 1990; Li et al., 1990).

These differences may be a result of several factors that influence the response to dietary fat additions; absorption of one fatty acid can be modified by other 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) and dietary fat source or concentration (Hamilton and McDonald, 1969; Frobish et al., 1970; Cera et al., 1988a). Chain length, degree of saturation of fatty acids and their arrangement within the triglyceride molecule are important factors in determining the degree of fat

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digestibility in chicks (Calloway et al., 1956) and pigs (Eusebio et al., 1965). Fat source may also influence nutrient digestibility by altering intestinal morphology. Dietary corn oil addition shortened the villus length of young pigs (Cera et al., 1988a).

Although fat digestibility increases with age postweaning, lipids of vegetable origin always have higher digestibilities than those of animal source (Cera et al., 1988b, 1989). This is consistent with less extensive micelle formation with saturated vs. unsaturated fatty acid in the intestinal tract of swine initially postweaning (Borgstrom, 1967; Freemen et al., 1968). Recent evidence, however, indicates that, compared with fatty acids of corn oil or tallow, dietary nonesterified medium-chain fatty acids have higher digestibilities and may enhance nitrogen retention (Cera et al., 1989). Pigs performed better on diets containing either soybean oil and coconut oil than on diets containing tallow (Turlington, 1988).

Coconut oil contains a high proportion of medium-chain fatty acids; compared with diets containing corn oil or tallow, coconut oil resulted in a higher fat digestibility and improved nitrogen retention with postweaning pigs (Cera et al., 1989). Medium-chain triglyceride, a purified re-esterified triglyceride from coconut oil containing C8:0 and C10:0 fatty acids, is used in human infant formulas where it is absorbed efficiently and improves nitrogen retention (Roy et al., 1975; Bach and Babayan, 1982; Brady et al., 1982).

Because fat is insoluble in water, and difficult to handle in a water medium, emulsification is required for the digestion of fat, particularly tallow. Lecithin, a phospholipid extracted commercially from soybeans, has a potential use as an exogenous emulsifier to enhance the utilization of dietary fat. Lecithin increased the apparent digestibility of dietary fat in pig diets (Jones et al., 1990a, b; Øverland et al., 1993a,b). In addition, lecithin can serve as a highly digestible energy source in animal feeds by itself.

Research investigating the effect of lecithin on performance of young pigs is inconsistent and limited (Frobish et al., 1969; Kanyo et al., 1985; Van Wormer and Pollman, 1985, Jones et al., 1990a,b; Øverland et al., 1993a,b). Utilization of dietary fat by the young pig, especially during the first week after weaning is limited (Cera et al., 1989; 1990b). The addition of lecithin may enhance the utilization of tallow by young pigs as well as serve as a highly digestible energy source per se.

Therefore, the objective of this study was to investigate the effect of fat sources and lecithin on 1) pig performance, 2) total apparent digestibility of nutrients.

MATERIALS AND METHODS

Three way crossbred (Landrace × Large White × Duroc) barrows weaned at 21 days of age were used as experimental animals. At 21 days of age, a total of 125 pigs averaged 5.8 kg of body weight were chosen and allotted in a completely randomized block design. Treatments were coconut oil, corn oil, soybean oil, tallow and tallow+lecithin. Each treatment had 5 replicates with 5 pigs per replicate.

During phase Ⅰ (0 to 7 d postweaning), all pigs were fed a common high nutrient density diet (table 1). The phase Ⅰ diet was formulated to contain 3.60 Mcal ME/kg, 1.55% lysine (Jin et al., 1997), phase Ⅱ diet (table 2) were formulated to contain 1.35% lysine with fortified methionine, threonine, tryptophan to get optimum inter-amino acids ratio suggested by Chung and Baker (1992), 0.9% Ca, and 0.8% P.

The pigs were kept in concrete-floored pens, and feed and water were provided *ad libitum* during the entire experimental period of 3 weeks. The temperature was maintained at the range of 26 to 30℃ through the experimental period. Body weight and feed intake were recorded weekly.

For measuring the digestibilities of experimental diets, pigs were fed diets containing 0.25% Cr_2O_3 during the second week of the experimental period and feces were collected three days, three times (08:00, 14:00 and 20:00) a day, after four days of adjustment period. Fecal samples were dried in an air-forced drying oven at 60℃ for 72 hours and then ground with 1 mm mesh Wiley mill for chemical analysis.

Feed and fecal samples were analyzed for proximate analysis and mineral composition by AOAC methods (1990). Chromium was measured using atomic absorption spectrophotometer (Shimadzu, AA6145F, Japan). The fatty acid composition of the experimental diets were measured using gas chromatography according to the method of Lepage and Roy (1986). For energy utilization, energy values of feed and feces were measured by adiabatic oxygen bomb calorimeter (Model 1241, Parr Instrument Co., Molin, IL).

Statistical analysis were conducted using GLM procedure of SAS package (1985), and treatment means were compared using Duncan's multiple range test (Duncan, 1955)

RESULTS AND DISCUSSION

Dietary fatty acid composition of phase Ⅱ diets contributed by the indigenous feedstuff lipid plus that

Table 1. Formula and chemical composition of experimental diets in phase I

Item	Coconut oil	Corn oil	Soybean oil	Tallow	T+Lecithin
Ingredients (%)					
Corn	30.81	30.81	30.81	30.81	30.81
Soybean meal	18.60	18.60	18.60	18.60	18.60
Dried whey	25.00	25.00	25.00	25.00	25.00
Spray-dried plasma protein	6.00	6.00	6.00	6.00	6.00
Fish Meal	5.00	5.00	5.00	5.00	5.00
Spray-dried blood meal	2.00	2.00	2.00	2.00	2.00
Coconut oil	10.00	–	–	–	–
Corn oil	–	10.00	–	–	–
Soybean oil	–	–	10.00	–	–
Tallow	–	–	–	10.00	9.00
Lecithin	–	–	–	–	1.00
Limestone	0.1	0.1	0.1	0.1	0.1
Monocalcium phosphate	1.70	1.70	1.70	1.70	1.70
Salt	0.20	0.20	0.20	0.20	0.20
Vit. Min.[1]	0.25	0.25	0.25	0.25	0.25
Antibiotics	0.20	0.20	0.20	0.20	0.20
Methionine	0.14	0.14	0.14	0.14	0.14
Tryptophan	0.03	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]					
ME (Mcal/kg)	3.60	3.60	3.60	3.60	3.60
CP (%)	22.70	22.70	22.70	22.70	22.70
	(22.56)[3]	(22.58)	(22.61)	(22.53)	(22.59)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.76)	(0.75)	(0.75)	(0.74)	(0.75)
Lysine (%)	1.55	1.55	1.55	1.55	1.55
	(1.52)	(1.52)	(1.53)	(1.51)	(1.53)
Methionine (%)	0.47	0.47	0.47	0.47	0.47
	(0.43)	(0.44)	(0.43)	(0.43)	(0.43)
Threonine (%)	1.01	1.01	1.01	1.01	1.01
	(0.98)	(0.97)	(0.97)	(0.98)	(0.98)
Tryptophan (%)	0.28	0.28	0.28	0.28	0.28

[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; Pantothenic acid, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 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; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Calculated value.

[3] Analyzed value.

from the supplemental fat are reported in table 3. The fatty acid composition of phase I diets were not measured. The coconut oil diet contained approximately 55.61% medium-chain (C12:0 to C14:0) fatty acid (MCFA) and 44.39% long-chain fatty acid (C 16:0 to 18). Tallow and T+lecithine diet were high in long chain saturated fatty acid (33.01 and 30.25%). The soybean oil and corn oil diets were relatively high in proportion of unsaturated long-chain fatty acids (81.05 and 79.97%) compared to animal fat source.

1. Growth performance

From d 0 to 7, pigs fed vegetable oil had higher average daily gain (ADG) and better feed/gain (F/G) than

Table 2. Formula and chemical composition of experimental diets in phase II

Item	Coconut oil	Corn oil	Soybean oil	Tallow	T+Lecithin
Ingredients (%)					
Corn	45.61	45.61	45.61	45.61	45.61
Soybean meal	22.50	22.50	22.50	22.50	22.50
Dried whey	10.00	10.00	10.00	10.00	10.00
Spray-dried plasma protein	2.00	2.00	2.00	2.00	2.00
Fish Meal	5.00	5.00	5.00	5.00	5.00
Spray-dried blood meal	2.00	2.00	2.00	2.00	2.00
Coconut oil	10.00	–	–	–	–
Corn oil	–	10.00	–	–	–
Soybean oil	–	–	10.00	–	–
Tallow	–	–	–	10.00	9.00
Lecithin	–	–	–	–	1.00
Limestone	0.2	0.2	0.2	0.2	0.2
Monocalcium phosphate	1.85	1.85	1.85	1.85	1.85
Salt	0.20	0.20	0.20	0.20	0.20
Vit. Min.[1]	0.25	0.25	0.25	0.25	0.25
Antibiotics	0.20	0.20	0.20	0.20	0.20
Methionine	0.09	0.09	0.09	0.09	0.09
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]					
ME (Mcal/kg)	3.60	3.60	3.60	3.60	3.60
CP (%)	21.07	21.07	21.07	21.07	21.07
	(20.96)[3]	(20.98)	(20.96)	(20.95)	(20.98)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.75)	(0.76)	(0.75)	(0.76)	(0.74)
Lysine (%)	1.35	1.35	1.35	1.35	1.35
	(1.32)	(1.33)	(1.34)	(1.32)	(1.33)
Methionine (%)	0.42	0.42	0.42	0.42	0.42
	(0.40)	(0.41)	(0.40)	(0.41)	(0.41)
Threonine (%)	0.90	0.90	0.90	0.90	0.90
	(0.86)	(0.87)	(0.86)	(0.85)	(0.86)
Tryptophan (%)	0.26	0.26	0.26	0.26	0.26

[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; Pantothenic acid, 3,000 mg; Choline chloride. 30,000 mg; Niacin, 8,000 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; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.
[2] Calculated value.
[3] Analyzed value.

pigs fed the animal fat and pigs fed tallow plus lecithin tended to have intermediate ADG. Addition of lecithin to tallow increased ADG by 7.2%. Feed intake were similar among all treatment groups. It was found that coconut oil was the best oil source for weaned pigs, however no significant difference was found in ADG among vegetable oil sources.

From d 8 to 14, pigs fed coconut oil and soy oil showed better ADG and average daily feed intake (ADFI) than any other treatments. From d 15 to 21, pigs fed the tallow diet had lower gains ($p<0.05$) than those fed diets containing vegetable oil and tallow with added lecithin. The results can be supported by the study of Turlington (1988) who reported that pigs performed better on diets containing either soybean oil and coconut oil than on diets containing tallow. Better utilizability of coconut oil was reported by several researchers (Cera et al., 1989; Roy et al., 1975; Bach and Babayan, 1982; Brady et al., 1982). It seemed that as pigs grow, the effect of different oil sources became smaller. The improvement in fat utilization with age postweaning have been well documented by numerous previous researches (Cera et al., 1988b, 1990b; Howard et al., 1990; Li et al., 1990; Øverland et al., 1993a). Cera et al. (1988a) reported that increase in apparent digestibility of fat during the early postweaning period in all diet groups resulted in a net improvement of 10 percentage units (79 to 89%) from week 1 to 4 when pigs were fed supplemental corn oil, whereas an overall increase of approximately 17 percentage units occurred when lard (68 to 85%) or tallow (65 to 82%) diets were provided from 1 to 4 week postweaning.

Table 3. Fatty acid composition of experimental diets in phase II[a]

Item[b]	Coconut oil[c]	Corn oil	Soy oil	Tallow	T+Lecithin[d]
Fatty acids, % of total fatty acids					
C 12:0	14.91	–	–	–	–
C 14:0	14.70	0.55	–	–	–
C 16:0	12.82	14.53	14.49	22.28	20.06
C 18:0	3.80	4.96	4.46	10.73	10.19
C 18:1	12.28	23.62	23.85	38.47	35.81
C 18:2	15.49	51.65	52.94	28.52	32.89
C 18:3	–	4.70	4.26	–	0.10
C 20:0	–	–	–	–	0.20
C 22:0	–	–	–	–	0.07

[a] Gas chromatographic analysis of dietary lipid follwing derivatization to fatty acid methyl esters.
[b] Number of carbon atoms and double bonds to the left and right of colomn, respectively.
[c] Supplemented at the level of 10% of the diet.
[d] 9% tallow and 1% lecithin of the diet.

The reason that animal fat utilization is limited in the pig before 35 d of age is not well understood. The lower digestibility of fat by weanling pigs during the initial period after weaning may be part of the problem (Leibbrandt et al., 1975; Cera et al., 1988a,b). The lower digestibility may be due to a myriad of reasons. Dietary fat causes the sloughing of intestinal villous cells, impairing digestion immediately after weaning (Cera et al., 1988a). The young pig also has decreased levels of fatty acid binding protein during the first 2 wks after weaning (Reinhart et al., 1989). Furthermore, enzyme secretion and activity may be limited immediately after weaning at an early age. Jensen et al. (1997) reported that in weaned pigs, lipase, colipase and carboxyl ester hydrolase activities decreased at weaning. They also reported that the development of lipase, colipase and carboxyl ester hydrolase activity decreased postweaning. Several researchers (Scherer et al., 1973; Corring et al., 1978; Lindemann et al., 1986; Cera et al., 1990a) have reported that lipase activity and sectetion by pancreatic tissue increased with increasing age after weaning. Quantity of calcium and copper in the small intestine may decrease fat absorption by increasing the formation of fatty acid soaps (Atteh and Leeson, 1983).

Feed intake were similar between the vegetable oil and lecithin supplemented diets each week postweaning compared to pigs fed tallow ($p<0.05$). Feed:gain ratios were superior during the initial 2 weeks postweaning period when pigs were provided vegetable oil diet compared with pigs fed tallow. All pig groups had similar feed:gain ratios during 3 weeks. Combinations of tallow with lecithin tended to have intermediate F/G.

Contrasts were expressed between treatments (table 4), and showed that vegetable oils were much better in improving growth rate of the piglets. Lecithin significantly improved growth rate and feed efficiency of pigs through the whole experimental period compared to tallow. Coconut oil was found to be more effective in improving growth of pigs during the first two weeks postweaning. Corn oil had equal value with soy oil in improving growth performance of weaned pigs.

The improved feed:gain ratio of pigs fed the vegetable oil diet compared to the tallow diet presumably reflects the increased in dietary energy utilization of the vegetable oil diet with more efficient utilization of the medium-chain or unsaturated fatty acid.

Table 4. Effects of various fat sources on growing performance in weaned pigs

Treatments	Coconut oil	Corn oil	Soy oil	Tallow	T+Lecithin	SE
D 0 to 7						
ADG (g)	247^{a}	239^{ab}	234^{ab}	215^{c}	230^{b}	7.52
ADFI (g)	271^{a}	264^{a}	261^{ab}	246^{b}	261^{ab}	10.22
F/G	1.09^{a}	1.10^{a}	1.11^{a}	1.14^{b}	1.13^{b}	0.01
D 8 to 14						
ADG (g)	411^{a}	399^{b}	412^{a}	380^{c}	397^{b}	7.43
ADFI (g)	475^{a}	463^{b}	476^{a}	459^{b}	467^{ab}	11.74
F/G	1.15^{a}	1.16^{a}	1.15^{a}	1.20^{b}	1.17^{b}	0.01
D 0 to 14						
ADG (g)	329^{a}	319^{bc}	323^{ab}	297^{d}	314^{c}	7.19
ADFI (g)	373^{a}	364^{b}	368^{ab}	352^{c}	364^{b}	10.72
F/G	1.13^{a}	1.14^{a}	1.14^{a}	1.18^{c}	1.16^{b}	0.01
D 15 to 21						
ADG (g)	497^{a}	499^{a}	500^{a}	479^{b}	499^{a}	10.10
ADFI (g)	703^{a}	703^{a}	701^{a}	680^{b}	701^{a}	20.32
F/G	1.41^{ab}	1.40^{ab}	1.39^{a}	1.42^{b}	1.40^{ab}	0.01
D 0 to 21						
ADG (g)	385^{a}	379^{bc}	382^{ab}	358^{d}	375^{c}	8.06
ADFI (g)	483^{a}	477^{b}	479^{b}	462^{c}	477^{b}	13.85
F/G	1.25^{d}	1.25^{a}	1.25^{a}	1.28^{c}	1.27^{b}	0.01

Contrasts[1]	A	B	C	D	E
D 0 to 7					
ADG (g)	0.0001	0.0746	0.0351	0.1947	0.0056
ADFI (g)	0.0045	0.5224	0.1711	0.7529	0.0580
F/G	0.0001	0.0001	0.0010	0.0001	0.0001
D 8 to 14					
ADG (g)	0.0001	0.0144	0.0050	0.7036	0.0001
ADFI (g)	0.0028	0.2014	0.0249	0.4917	0.0011
F/G	0.0001	0.0489	0.1077	0.2730	0.0001
D 0 to 14					
ADG (g)	0.0001	0.0017	0.0004	0.1417	0.0001
ADFI (g)	0.0001	0.1139	0.0040	0.8944	0.0001
F/G	0.0001	0.0002	0.0024	0.0032	0.0001
D 15 to 21					
ADG (g)	0.0001	0.7944	0.2782	0.8315	0.0001
ADFI (g)	0.0001	0.7545	0.8441	0.6104	0.0001
F/G	0.0298	0.6964	0.2083	0.7498	0.0100
D 0 to 21					
ADG (g)	0.0001	0.0023	0.0009	0.1495	0.0001
ADFI (g)	0.0001	0.1460	0.0110	0.9119	0.0001
F/G	0.0001	0.0075	0.1241	0.0440	0.0001

^{a,b,c} Figures in the same row without the same superscripts are significantly different at $p<0.05$.

[1] A: Tallow vs. Vegetable oils, B: Lecithin vs. Vegetable oils, C: Coconut vs. Corn or Soy oil, D: Soy oil vs. Corn oil, E: Tallow vs. Lecithin.

2. Nutrients digestibility

Apparent gross energy (GE), dry matter (DM), ether extract (EE) and crude protein (CP) digestibilities were summarized in table 5. When vegetable oil was added, the digestibilities of nutrients were higher compared to tallow. Digestibility was similar among vegetable oils. Results are consistent with previous report (Friedman and Nylund, 1980). Coconut oil, corn oil and soybean oil were more digestible than tallow (Cera et al., 1988a, 1990a; Li et al., 1990).

Coconut oil contains high proportion of MCFA in esterified form. Fatty acids less than 12 carbons in length largely enter the portal blood and are rapidly oxidized by the liver (Bremer, 1980; Bach and Babayan, 1982). Bloom et al. (1951) demonstrated that the C12:0 fatty acid (lauric acid) enters the peripheral blood circulation, largely in esterified form following absorption rather than via direct portal absorption. Moreover unsaturated fats (e.g., soybean oil and corn oil) have increased ability to partition into the micellar phase (Freeman, 1969) and could be expected to have higher digestibility than long-chain saturated fats (e.g., tallow).

In vitro studies have demonstrated that bile salts were excellent solubilizers of medium-chain fatty acids (Friedman and Nylund, 1980). Consequently, medium-chain fatty acids may more readily enter the micellar phase of the lipid-bile interface than do long-chain fatty acids (Hofmann, 1963). Medium-chain fatty acids also have been reported to be preferentially liberates from mixed triacylglycerols (Bach and Babayan, 1982). Hydrolysis of esterified fatty acids by pancreatic lipase also was reported to proceed at faster rates from coconut oil than from tallow (Aumaitre, 1972).

The addition of lecithin to tallow increased digestibility of GE, DM, EE and CP. This is consistent with the work of other researchers (Auger et al., 1947; Polin, 1980; Jones et al., 1992) in which the addition of lecithin increased digestibility of fat sources with long-chain saturated fatty acids. Freeman (1969), Borgstrom (1974) and Reynier et al. (1985) reported that amphiphiles such as lecithin can increase the size of bile salt micelles, thereby increasing the interior capacity of micelles so that more fatty acids may be incorporated. Jones et al. (1990a,b) and Øverland et al. (1993a,b) also reported that lecithin increased the apparent digestibility of dietary fat in diets to pigs. The marked improvement in digestibility of tallow when lecithin was used as an emulsifier was in agreement with the reports by Freeman (1969) and Borgstrom (1974) that the capacity of bile salt micelles to solubilize long-chain saturated fatty acids and sterols is increased in the presence of phospholipids. Addition of emulsifiers to the diets increased N digestibility and changes in GE and DM digestibilities tended to parallel with fat digestibility. Jones et al. (1990a) found that lecithin increased the digestibility of soy oil by 3.5% and of tallow by 9.3% but had no effect on the digestibility of coconut oil and decreased the digestibility of lard when added to diets for young pigs. Emulsifying agents promote the incorporation of fatty acids into micelles and Augur et al. (1947) and Polin (1980) reported that increased digestibility of fat when lecithin was mixed with the fat before it was fed to rats and chicks, respectively. Because lecithin enhances micelle formation, Jones et al. (1992) designed an experiment to determine the effects of adding lecithin and lysolecithin to diets for weanling pigs with various fat sources and found that digestibilities of unsaturated (soybean oil) and medium chain length (coconut oil) fat sources were greater than those of long-chain saturated animal fats (tallow and choice white grease). Indeed, digestibility of blend of tallow and lecithin was comparable to that of soybean oil and coconut oil without emulsifier, with 30 to

Table 5. Effects of various fat sources on nutrient digestibilities in weaned pigs (%)

Treatments	Gross Energy	Dry matter	Nitrogen	Ether Extract	Crude ash	Phosphorus
Coconut oil	86.75[a]	87.29[a]	84.53[a]	83.38[a]	70.45	71.29
Corn oil	85.79[a]	87.13[a]	83.25[a]	82.32[a]	71.33	71.81
Soybean oil	85.84[a]	87.45[a]	84.44[a]	83.73[a]	71.71	71.90
Tallow	84.42[b]	84.93[c]	81.10[b]	79.77[b]	70.39	70.43
T+Lecithin	84.88[b]	86.81[b]	84.14[a]	82.94[a]	70.41	70.87
SE[1]	2.56	3.39	1.28	2.37	1.26	1.54

[1] Pooled standard error, n=25.

[a,b,c] Figures in the same column with different superscripts are significantly different at $p < 0.05$.

50% less cost per calorie. The exactly same results were observed in our study.

Crude ash and phosphorus digestibility were not affected by the treatments.

3. Nutrients excretion

The effects of various fat sources on nutrient excretion were recorded in table 6. Dry matter excretion was not different among treatments except tallow which showed significantly higher dry matter excretion ($p < 0.05$), while nitrogen excretion was improved in pigs fed vegetable fat sources, especially soy oil or coconut oil. These results might be due to high nitrogen digestibility of pigs fed vegetable fat sources as mentioned above. Phosphorus excretion was not affected by the different fat sources.

Table 6. Effects of various fat sources on nutrient excretion in weaned pigs (g/kg body weight gain)

Treatments	Dry matter	Nitrogen	Phosphorus
Coconut oil	155.89[a]	6.37[a]	2.86
Corn oil	154.73[a]	6.77[ab]	2.71
Soybean oil	155.97[a]	6.08[a]	2.62
Tallow	171.27[b]	7.22[b]	2.69
T+Lecithin	156.07[a]	6.90[b]	2.58
SE[1]	3.05	0.85	0.34

[1] Pooled standard error, n=25.

[a,b] Figures in the same column without the same superscripts are significantly different at $p < 0.05$.

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