Effects of L-Carnitine on the Nutritive Value of Extruded Full-Fat Soybean in Weaned Pigs[a]

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ABSTRACT : A total of 80 piglets (5.85±0.62 kg BW; 21 d of age) were used to study the effect of carnitine addition to extruded full-fat soybean (EFS) diets on the growth of 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 each. Treatments were 1) SBM (positive control), 2) EFS without carnitine (negative control), 3) EFS with 50 ppm carnitine, 4) EFS with 100 ppm carnitine and 5) EFS with 150 ppm carnitine. During d 0 to 14, piglets were fed diets containing 3,400 kcal ME, 23% crude protein, 1.65% lysine, 0.9% Ca and 0.8% P and for the period of d 15 to 28, piglets were fed diets supplying 3,300 kcal ME, 20% crude protein, 1.55% lysine, 0.9% Ca and 0.8% P. The urease activity of EFS (0.18) were three times higher than SBM (0.07). During d 0-14, pigs fed SBM had greater ADG and ADFI compared to pigs fed extruded full-fat soybean diets (p<0.05). Feed conversion ratio was not different among treatments. No linear or quadratic effect of carnitine addition was found in growth performance. During d 15-28, piglets fed SBM diet also showed better ADG and FCR with no significant differences among treatments. Feed intake tended to increase as carnitine addition level was increased (p=0.10). For overall period (d o to 28), the best performance was observed in pigs fed SBM diet. CP digestibility was higher in pigs fed SBM diet than piglets fed EFS diet at d 14, and DM and CP digestibility tended to be higher in pigs fed SBM diet at d 28. Blood metabolites (BUN, glucose and cholesterol)were not affected by treatments. In conclusion, based on the results of this study piglets at 21 d of age appeared to be not ready for extruded full-fat soybean (FFSB) in their diets. Piglets fed extruded FFSB showed decreased growth rate compared to piglets fed SBM diet. Nutrient utilization was also poor in piglets fed extruded FFSB diets. L-carnitine addition at the level of 50 to 150 ppm was not effective in improving the growth performance of pigs fed EFS diets. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 9 : 1263-1271)*

Key Words : L-Carnitine, Extruded Full Fat Soybean, Growth, Serum, Weaned Pigs

INTRODUCTION

Full fat soybean (FFSB) contains relatively high oil compared to SBM and extruded FFSB can be an excellent source of amino acids and energy for poultry (Mateos, 1996), dairy cattle (Schwarz, 1996) and growing-finishing pigs (Kim et al., 1995; Kovacs, 1996; Campabada, 1996; Kim et al., 1998a). Several studies have attempted to incorporate FFSB in nursery piglet diets. Kim and Kim (1997) reported an improved performance of 21 days old piglets fed dry extruded FFSB compared to piglets fed SBM diet. Kim et al. (1998b) also observed slightly improved feed efficiency when they replaced soybean meal and soy oil with dry extruded FFSB in nursery piglet diets and suggested that the protein and fat in FFSB were utilized well by nursery piglets. But they found no significant improvement in either weight gain or feed efficiency. However, in our previous study (Piao et al., 1999), dry extruded FFSB was found to be inferior to SBM in their nutritional value for early-weaned piglets probably due to the high concentration of anti-nutritional factors.

Recent researches have shown that there might be a need for added carnitine in swine diets (Newton and Haydon, 1988; Owen et al., 1994, 1996). Some studies with neonatal pigs and weaned pigs have shown that L-carnitine might be beneficial when added to the diets for neonatal (Baltzell et al., 1987; Coffey et al., 1991; Honeyfield and Froseth, 1991; Kempen and Odle, 1993, 1995) and weaned pigs (Weeden et al., 1990; Newton and Burtle, 1992; Owen et al., 1994, 1996). Carnitine is involved in conversion of long chain fatty acid to their acyl carnitine derivatives which are transported across the mitochondrial membrane. Carnitine is also found to play an important role in medium chain fatty acid oxidation (Kempen and Odle, 1993). The role of carnitine in fatty acid oxidation has been well reviewed by a number of researchers (Bieber et al., 1982; Borum, 1983; Bremer, 1983; Bieber, 1988; Owen et al., 1997).

Thus, the hypothesis examined in this study was if carnitine improves the utilizability of oil in extruded FFSB. It has been recognized that fat addition in nursery pig diets was not as effective as expected (Tokach et al., 1995).

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MATERIALS AND METHODS

A total of 80 piglets (5.85±0.62 kg BW; 21 d of age) were used to study the effect of carnitine addition to extruded full-fat soybean (EFS) diets on the growth of weaned pigs. Pigs were allotted into five treatments based on body weight, in a completely randomized block design. Treatments were 1) SBM (positive control), 2) EFS without carnitine (negative control), 3) EFS with 50 ppm carnitine, 4) EFS with 100 ppm carnitine and 5) EFS with 150 ppm carnitine. Each treatment has 4 replicates of 4 heads each. Extruded FFSB was prepared with an Insta-ProTM extruder at 600 kg/hour of production rate with 130~150℃ of final exit temperature.

During d 0 to 14, piglets were fed diets containing 3,400 kcal/kg ME, 23% crude protein, 1.65% lysine, 0.9% Ca and 0.8% P. For the period of d 15 to 28 postweaning, piglets were fed diets supplying 3,300 kcal/kg ME, 20% crude protein, 1.55% lysine, 0.9% Ca and 0.8% P (table 1). Vitamins and minerals were supplied to exceed the requirements suggested by the NRC (1998). The experimental diets were fed as mash form and piglets had ad libitum access to feed and fresh water via nipple waterers. Chromic oxide (Cr_2O_3, 0.20%) were added to the diets as an indigestible marker to allow digestibility determination. For the determination of apparent fecal digestibilities, 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 week 1 and week 3, respectively.

Piglets were housed in an environmentally controlled feeding room in which temperature was maintained at 31℃ during the first week and decreased by 1~2℃ each week. Four piglets were housed in a 1×1.5 m pen with concrete slot floor. Each pen was equipped with a nipple waterer and a feeder. Weight gain and feed intake were recorded weekly and the wasted feed was collected, dried and

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

Treatment	Soybean meal	Extruded full-fat soybean (carnitine addition, ppm)			
		0	50	100	150
Corn	19.12	17.20	17.20	17.20	17.20
Soybean meal	17.50	0.00	0.00	0.00	0.00
Extruded full-fat soybean	0.00	20.00	20.00	20.00	20.00
Milk replacer	17.00	17.00	17.00	17.00	17.00
Lactose	23.00	23.00	23.00	23.00	23.00
Soy oil	5.40	4.80	4.80	4.80	4.80
Fish meal	5.30	5.30	5.30	5.30	5.30
Spray dried plasma protein	7.00	7.00	7.00	7.00	7.00
Spray dried blood meal	2.90	2.90	2.90	2.90	2.90
Mono calcium phosphate	1.00	1.00	1.00	1.00	1.00
Limestone	0.65	0.65	0.65	0.65	0.65
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
Methionine (98%)	0.15	0.15	0.15	0.15	0.15
Lysine (78%)	0.00	0.04	0.04	0.04	0.04
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]					
ME (kcal/kg)	3,341.00	3,343.00	3,343.00	3,343.00	3,343.00
CP (%)	22.92	22.83	23.19	23.16	23.06
Lysine	1.64	1.63	1.64	1.66	1.64
Methionine	0.49	0.48	0.48	0.47	0.48
Calcium	0.87	0.86	0.85	0.85	0.84
Phosphorus	0.76	0.75	0.74	0.75	0.75

[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 composition of experimental diets (d 15 to 28)

Treatment	Soybean meal	Full-fat soybean (carnitine addition, ppm)			
		0	50	100	150
Corn	32.00	30.50	30.50	30.50	30.50
Soybean meal	16.50	0.00	0.00	0.00	0.00
Extruded full-fat soybean	0.00	18.50	18.50	18.50	18.50
Milk replacer	14.00	14.00	14.00	14.00	14.00
Lactose	20.00	20.00	20.00	20.00	20.00
Soy oil	3.10	2.54	2.54	2.54	2.54
Fish meal	4.00	4.00	4.00	4.00	4.00
Spray dried plasma protein	5.00	5.00	5.00	5.00	5.00
Spray dried blood meal	2.00	2.00	2.00	2.00	2.00
Mono calcium phosphate	1.30	1.30	1.30	1.30	1.30
Limestone	0.80	0.80	0.80	0.80	0.80
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	0.05	0.05	0.05	0.05
Methionine (98%)	0.14	0.14	0.14	0.14	0.14
Lysine (78%)	0.24	0.30	0.30	0.30	0.30
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]					
ME (kcal/kg)	3341.00	3343.00	3347.00	3345.00	3348.00
CP (%)	20.45	20.34	20.48	20.67	20.50
Lysine	1.38	1.35	1.36	1.37	1.37
Methionine	0.44	0.42	0.43	0.43	0.42
Calcium	0.85	0.89	0.87	0.86	0.85
Phosphorus	0.76	0.75	0.74	0.75	0.73

[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; vholine 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.

weighted for accurate calculation of feed intake.

Analyses of proximate nutrients composition of experimental diets and excreta were 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 Bomb Calorimeter (Parr Instrument Co., Model 1241, USA). Chromium was measured using an atomic absorption spectrophotometer (Shimadzu, AA6145F, Japan). The fatty acid composition of the experimental diets were measured using gas chromatography (HP 5890, Hewlett-Packard Co., USA) according to the method of Lepage and Roy (1986).

Soybean meal and extruded FFSB were analyzed for urease activity according to the method of Caskey and Knapp (1944). And serum urea nitrogen (BUN), total glucose (TG) and total cholesterol (TC) were analyzed using commercially available kits (Chungll Chem., Korea).

Statistical analysis for the present data was carried out by comparing means according to LS means procedure using General Linear Model (GLM) procedure of SAS (1985) package program. Pen means were used as an experimental unit. The linear and quadratic effect of carnitine addition was also examined using data for without positive control.

RESULTS AND DISCUSSION

1) Chemical composition of EFS

The analyzed nutrients content of SBM and extruded full-fat soybean (EFS) is presented in table 2. The urease activity was three times higher for EFS (0.18) than SBM (0.07) which is consistent with our previous study (Piao et al., 1999) and Faber and Zimmerman (1973). Contrarily, Kim and Kim (1997) and Kim et al. (1998a, b) reported a lower urease activity for dry extruded FFSB compared to that of SBM.

2) Growth performance

During the first two weeks after weaning (d 0 -14), pigs fed SBM had greater average daily gain (ADG) and average daily feed intake (ADFI) compared to pigs fed extruded full-fat soybean diets ($p<0.05$, table 4). However, feed conversion ratio (FCR) was not different among treatments. No linear or quadratic effect of carnitine addition was found in growth performance.

During d 15-28, piglets fed SBM diet also showed numerically better ADG and FCR with no significant differences among treatments. Feed intake tended to increase as carnitine addition level was increased ($p=0.10$).

For overall period (d o to 28), the best performance was observed in pigs fed SBM diet. This result probably resulted from the high urease activity of extruded FFSB, which is consistent with our previous study (Piao et al., 1999), but contrary to the results reported by Kim and Kim (1997) and Qiao et al. (1998) who observed an improved performance of piglets fed dry extruded FFSB diets compared to piglets fed SBM diet. As suggested by Piao et al. (1999), the different performance observed between our study and the reports by Kim and Kim (1997) could be resulted from the different processing condition. The FFSB used in the study of Kim and Kim (1997) had an extremely low urease activity, but in this study, the urease activity was found to be three times higher than that of SBM.

Qiao et al. (1998) also reported an improved ADG of piglets fed extruded FFSB (140℃ of final exit temperature) diet compared to piglets fed SBM diet (311 vs 302 g). But the age of piglets and the kind of breed were different. We used 21 d old piglets (Landrace × Duroc × Large White) and Qiao et al. (1998) used 35 d old piglets (Landrace × Duroc × Beijing Black).

L-carnitine addition at the level of 100 ppm tended to increase ADG by 8% compared to no carnitine addition, but no significant difference was detected. FCR was not affected by L-carnitine. As a whole, no effect of L-carnitine addition was found in this study.

Kempen and Odle (1995) demonstrated that carnitine is responsible for the increase in β-oxidation in newborn pigs which in turn increased the level of acetyl-CoA production. By increasing the level of dietary L-carnitine, β-oxidation will be stimulated, thus, increasing fatty acid breakdown. In another study, Kempen and Odle (1993) found that carnitine increased the fatty acid oxidation rate by as much as 20% when the energy provided as medium chain fatty acid exceeded 50% of the metabolic needs of the neonatal pigs.

In contrast, Honeyfield and Froseth (1991) suggested that L-carnitine did not seem to be the limiting factor of piglet energy metabolism in their experiments with neonatal pigs. They emphasized the presence of fat in the sows diet as well as adequate lysine for the piglet for more efficient utilization of energy.

Owen et al. (1994) reported that dietary L-carnitine addition reduced daily fat accretion and improved feed conversion ratio when fed during the nursery phase. In their 35 days trial, pigs fed 1,000 ppm L-carnitine were more efficient in feed utilization and pigs fed 750 ppm L-carnitine had the lowest daily fat accretion.

Table 3. Chemical composition of soybean meal and extruded full-fat soybean

Item	Soybean meal	Extruded full-fat soybean
Urease activity, pH rise	0.07	0.18
Proximate nutrients :		
Gross energy (kcal/kg)	4344.23	5144.94
Dry matter (%)	89.13	92.59
Crude ash (%)	5.61	5.12
Crude protein (%)	43.77	37.27
Crude fat (%)	1.44	15.50
Minerals (%) :		
Calcium	0.21	0.22
Phosphorus	0.67	0.60
Amino acid (%) :		
Essential amino acids		
Threonine	1.90	1.47
Valine	1.67	1.41
Cystine	0.33	0.49
Methionine	0.52	0.47
Isoleucine	1.59	1.38
Leucine	2.92	2.36
Tyrosine	1.40	1.18
Phenylalanine	1.98	1.68
Lysine	2.14	2.02
Histidine	0.97	0.94
Arginine	2.38	2.04
Submean	17.80	15.45
Nonessential amino acids		
Aspargine	4.56	3.08
Serine	2.17	1.67
Glutamic acid	7.93	5.97
Proline	1.92	1.58
Glycine	1.41	1.38
Alanine	1.57	1.41
Submean	19.55	15.09
Average	37.35	30.53

Table 4. Growth performance of piglet fed the experimental diets*

Treament	SBM	Full-fat soybean (Carnitine addition, ppm)				SE[1]
		0	50	100	150	
D 0~14						
ADG (g)	324^{a}	222^{b}	214^{b}	249^{b}	224^{b}	10.67
ADFI (g)	366^{a}	291^{bc}	274^{c}	323^{b}	289^{bc}	9.35
Feed/Gain	1.13	1.31	1.29	1.30	1.30	0.03
D 14~28						
ADG (g)	616	572	582	606	585	6.96
ADFIF (g/)	878^{a}	792^{b}	819^{ab}	859^{a}	838^{ab}	11.02
Feed/Gain	1.43	1.39	1.41	1.42	1.44	0.01
D 0~28						
Weight gain (g/day)	470^{a}	396^{b}	398^{b}	428^{b}	405^{b}	7.91
Feed intake (g/day)	622^{a}	546^{c}	549^{c}	591^{ab}	563^{bc}	8.42
Feed/Gain	1.33	1.37	1.37	1.38	1.39	0.02

* Initial body weight was 5.85±0.62 kg.

[1] Pooled standard error.

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

In another study, Owen et al. (1996) re-confirmed that 1,000 ppm L-carnitne improved feed conversion ratio and reduced carcass lipid accretion in early-weaned pigs. Heo et al. (1998) reported that 500 ppm L-carnitine supplementation increased ADG by 7.2% ($p<0.01$) compared to pigs fed control diet. Newton and Haydon (1988) reported that pigs fed up to 6,000 ppm L-carnitine had increased weight gain from d 0 to 20 after weaning. They suggested that improved performance of pigs fed carnitine might be related to lysine intake and the age or size of pigs. The reports by Owen et al. (1994, 1996), Heo et al. (1998) and Newton and Haydon (1988) suggest that the level of L-carnitine addition in our study might be too low to be effective in energy utilization of piglets. However, Galvez et al. (1996) found an improved feed conversion ratio in their two experiments using 25 ppm and 50 ppm L-carnitine in the diets for weaned piglets which is contrary to the result of this study. In contrast, Hoffman et al. (1993) did not observe improvement in growth performance by added L-carnitine. They used 3 days-old piglets as an experimental subject and found no improvement in weight gain and feed conversion ratio during 60 days trial.

Owen et al. (1996) suggested that diet composition and nutrient levels might explain this variation in response. Newton and Burtle (1992) found high levels of dietary lysine (1.5% total lysine) to be detrimental to growth performance when supplemental L-carnitine was fed to nursery pigs.

Recently our research team (Cho et al., 1998a, b) conducted an experiment to investigate the effect of L-carnitine on growth performance of pigs fed different level of dietary lysine (1.40, 1.60 and 1.80% lysine of the diet). L-carnitine supplementation showed a tendency to improve the feed conversion ratio when the level of amino acids was appropriate (1.60% of the diet), but no significant effect was found. L-carnitine addition at the level of 50 to 150 ppm was not appeared to have any effect on the energy utilization in FFSB in weaned piglets.

3) Nutrients digestibility and blood metabolites

At d 14, apparent fecal crude protein (CP) digestibility was higher in pigs fed SBM diet than piglets fed EFS diets with L-carnitine levels of 0 to 50 ppm. At d 28, dry matter and CP digestibility was also tended to be higher in pigs fed SBM diet.

Nutrients digestibility observed in this study also conflicted with the reports of Qiao et al. (1998) and Kim and Kim (1997) who reported an improved dry matter digestibility in piglets fed dry extruded FFSB in one experiment and no difference in another experiment. However, the result is in agreement with the report by Marty et al. (1994) who observed a higher ileal lysine digestibility in SBM compared to extruded FFSB. In this study, this lower digestibility presumably account for the inferior growth performance of pigs fed EFS diets.

The SBM diet had higher amino acids digestibility than EFS diets for piglets at d 14 as presented in table 6 ($p<0.05$). The SBM diet had more digestible average amino acids than EFS diets with 0 and 50 ppm L-carnitine at d 28 ($p<0.05$; table 7).

Blood urea nitrogen (BUN), total glucose (TG) and total cholesterol (TC) level were examined and no difference was detected among treatments at either d 14 or d 28 (table 8).

In conclusion, based on the results of this study

Table 5. Apparent total tract digestibility of proximate nutrients in weaned pigs fed the experimental diets

Treament	SBM	Full-fat soybean (Carnitine addition, ppm)				SE[1]	P value	
		0	50	100	150		Linear	Quaratic
Day 14								
Dry matter	82.24	79.74	80.96	81.35	80.92	0.36	NS[2]	NS
Crude ash	53.18	47.95	51.78	53.96	53.56	1.31	NS	NS
Crude protein	75.26[a]	68.56[b]	72.12[ab]	72.45[ab]	72.02[ab]	0.73	NS	NS
Crude fat	60.42[b]	68.98[a]	71.92[a]	67.56[ab]	61.39[b]	1.37	0.0311	0.0194
Calcium	73.84	73.31	71.88	74.15	76.30	0.80	NS	NS
Phosphorus	61.36	57.18	59.89	64.15	63.14	1.14	0.0615	NS
Day 28								
Dry matter	84.70[a]	81.16[bc]	79.76[c]	82.20[bc]	82.90[ab]	0.49	0.1309	NS
Crude ash	66.24[a]	65.66[a]	59.83[b]	66.62[a]	64.74[ab]	0.93	NS	NS
Crude protein	80.07[a]	76.56[ab]	74.12[b]	77.88[ab]	77.75[ab]	0.64	NS	NS
Crude fat	77.14	75.54	75.18	74.19	77.08	0.86	NS	NS
Calcium	79.88[a]	68.17[ab]	66.27[b]	79.03[ab]	71.94[ab]	2.13	NS	NS
Phosphorus	68.61	71.34	66.22	71.52	69.47	0.76	NS	NS

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

[1] Pooled standard error.

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

Table 6. Apparent total tract amino acids digestibility of weaned pigs fed the experimental diets (D 14)

Treatment	SBM	Full-fat soybean (Carnitine addition, ppm)				SE[1]	P value	
		0	50	100	150		Linear	Quadratic
Essential amino acids (%)								
THR	82.95[a]	75.01[b]	75.01[b]	73.06[b]	70.21[b]	1.17	0.0398	0.0990
VAL	77.92[a]	75.10[ab]	71.43[b]	72.14[b]	72.91[ab]	0.88	NS[2]	NS
CYS	84.37[a]	80.45[ab]	80.58[ab]	72.14[b]	73.04[b]	1.62	0.0561	NS
MET	80.51[ab]	86.84	86.84	78.60[ab]	73.37[b]	1.91	0.0036	0.0161
ILE	77.46[a]	65.64[b]	65.64[b]	69.53[ab]	64.77[b]	1.55	NS	NS
LEU	76.71	68.76	76.40	70.16	67.94	1.87	NS	NS
TYR	73.86	68.11	68.11	70.08	64.30	1.99	NS	NS
PHE	76.21	70.14	70.14	73.92	71.43	1.57	NS	NS
LYS	83.17[a]	65.50[b]	65.50[b]	72.73[b]	70.27[b]	1.77	NS	NS
HIS	83.25[a]	75.87[ab]	73.58[b]	76.83[ab]	73.83[b]	1.29	NS	NS
ARG	81.42[a]	74.76[bc]	68.90[c]	75.91[ab]	75.31[ab]	1.20	NS	NS
Submean	79.53[a]	72.52[ab]	72.25[ab]	72.71[ab]	70.34[b]	1.22	NS	NS
Non essential amino acids (%)								
ASP	85.47[a]	76.30[c]	77.87[bc]	81.84[ab]	76.47[c]	1.02	NS	NS
SER	83.65[a]	75.88[b]	76.44[b]	75.02[b]	73.64[b]	1.09	NS	NS
GLU	85.43	81.38	77.67	84.19	78.14	1.26	NS	NS
PRO	79.67[a]	71.80[ab]	71.80[b]	73.37[ab]	71.72[b]	1.13	NS	NS
GLY	75.44[a]	71.80[ab]	68.46[b]	69.18[b]	68.28[b]	0.94	NS	NS
ALA	72.19[a]	67.82[ab]	65.10[b]	66.68[ab]	64.49[b]	0.98	NS	NS
Submean	82.83[a]	76.66[b]	74.66[b]	78.07[ab]	74.22[b]	0.97	NS	NS
Average	81.20[a]	73.43[b]	73.43[b]	75.34[b]	72.24[b]	1.03	NS	NS

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

[1] Pooled standard error.

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

Table 7. Apparent total tract amino acids digestibility of weaned pigs fed the experimental diets (D 28)

Treatment	SBM	Full-fat soybean (Carnitine addition, ppm)				SE[1]	P value	
		0	50	100	150		Linear	Quadratic
Essential amino acids (%)								
THR	87.26^{a}	83.12^{b}	82.70^{b}	89.05^{a}	86.35^{a}	0.66	0.0167	0.0446
VAL	87.98^{a}	82.62^{b}	77.02^{c}	83.62^{b}	87.34^{a}	1.00	0.0276	0.0024
CYS	87.66^{b}	83.37^{b}	85.37^{b}	87.64^{b}	94.59^{a}	1.05	0.0014	0.0002
MET	90.84^{ab}	86.04^{c}	86.04^{c}	88.36^{bc}	91.35^{a}	0.65	0.0006	0.0012
ILE	85.19^{a}	75.48^{b}	75.48^{b}	87.66^{a}	87.03^{a}	1.22	0.0009	0.0044
LEU	89.37^{a}	85.15^{bc}	83.44^{c}	88.20^{a}	87.17^{ab}	0.57	0.0357	NS
TYR	86.69^{a}	82.24^{b}	82.24^{b}	89.29^{a}	86.17^{a}	0.81	0.0122	0.0271
PHE	89.88^{a}	82.10^{b}	75.15^{c}	86.81^{a}	87.20^{a}	1.29	0.0251	0.0275
LYS	89.65^{a}	86.85^{abc}	82.90^{c}	85.22^{bc}	88.89^{ab}	0.76	NS[2]	0.0304
HIS	88.39^{a}	85.29^{b}	81.02^{c}	85.11^{b}	90.20^{a}	0.77	0.0123	0.0001
ARG	88.51^{ab}	88.76^{ab}	84.16^{c}	87.81^{b}	91.10^{a}	0.65	NS	0.0025
Submean	88.53^{a}	81.33^{b}	81.33^{b}	87.28^{a}	88.32^{a}	0.69	0.0041	0.0042
Non essential amino acids (%)								
ASP	88.10^{b}	85.31^{c}	85.31^{c}	90.15^{a}	86.41^{bc}	0.50	NS	NS
SER	88.93^{a}	85.93^{b}	85.87^{b}	89.89^{a}	87.79^{ab}	0.49	0.0627	NS
GLU	88.86^{ab}	87.48^{b}	87.47^{b}	90.65^{a}	87.63^{b}	0.42	NS	NS
PRO	87.48^{a}	82.63^{b}	77.65^{b}	82.09^{b}	82.02^{b}	0.83	NS	NS
GLY	84.91^{a}	80.29^{bc}	77.94^{c}	82.79^{ab}	84.87^{a}	0.75	0.0083	0.0089
ALA	84.45^{a}	81.09^{a}	75.13^{b}	82.51^{a}	84.22^{a}	0.90	0.0680	0.0213
Submean	87.70^{a}	84.96^{bc}	83.60^{c}	88.18^{a}	86.16^{ab}	0.48	0.0974	NS
Average	88.14^{a}	84.61^{b}	82.36^{b}	87.69^{a}	87.36^{a}	0.57	0.0115	0.0310

[a,c] Means with different superscripts in the row differ ($p<0.05$).
[1] Pooled standard error. [2] Not significant, $p>0.05$, respectively.

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

Treament	SBM	Full-fat soybean (Carnitine addition, ppm)				SE[1]	P value	
		0	50	100	150		Linear	Quadratic
Blood urea nitrogen (mmol/dl)								
d 14	7.45	9.05	10.43	9.85	12.18	0.32	0.0551	NS
d 28	7.03	7.43	8.00	7.18	8.20	0.44	NS[2]	NS
Total glucose (mg/g)								
d 14	84.40	87.70	85.60	91.30	90.40	1.97	NS	NS
d 28	96.80	103.70	91.60	97.30	98.20	2.53	NS	NS
Total cholesterol (mg/g)								
d 14	122.0	127.0	135.8	122.4	137.7	11.1	NS	NS
d 28	102.4	100.0	103.7	112.4	112.2	19.0	NS	NS

[a,b] Means with different superscripts in the row differ ($p<0.05$).
[1] Pooled standard error. [2] Not significant, at $p<0.05$.

the use of extruded FFSB to diet for weaned pigs has negative effect on growth performances of weaned pigs at 21 d of age. Piglets fed extruded FFSB showed a slightly decreased growth rate compared to piglets fed SBM diet. Nutrient utilization was also inferior in piglets fed extruded FFSB diets. L-carnitine addition at the level of 50 to 150 ppm was not effective in improving the growth performance of pigs fed EFS diets.

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