Effects of Extruded Full Fat Soybean in Early-Weaned Piglets[a]

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ABSTRACT : A total of 80 piglets (5.18±0.61 kg of BW; 16 d of age) were fed experimental diets to evaluate the effect of extruded full-fat soybean (EFS) on the growth of early 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 animals each. Treatments consisted of diets representing substitutional ratios of EFS for soybean meal. 1) 100:0 (SBM), 2) 75:25 (EFS 25), 3) 50:50 (EFS 50), 4) 25:75 (EFS 75) and 5) 0:100 (EFS 100). During phase Ⅰ (d 0 to 7), piglets were fed diets containing 3,340 kcal ME, 26% crude protein, 1.85% lysine, 1.0% Ca and 0.9% P. For phase Ⅱ (d 8 to 21), piglets were fed diets supplying 3,340 kcal ME, 23% crude protein, 1.65% lysine, 0.9% Ca and 0.8% P. Urease activity (pH rise) of EFS (0.18) was three times higher than that of SBM (0.06) indicating that processing conditions were not efficient enough to inactivate urease activity. During the first week postweaning, pigs fed SBM had significantly greater average daily gain (ADG), average daily feed intake (ADFI) and better feed conversion ratio (FCR) compared to pigs fed FFS diets. Linear negative effect on growth rate was found as the inclusion rate of FFS increased. During d 8 - 21 postweaning, piglets fed EFS 50 diet showed the best ADG and FCR despite no significant difference between treatment SBM and EFS 25 have been observed. Overall, piglets fed diets up to 50% FFS inclusion rate exhibited similar weight gain. Only piglets fed EFS 100 diet showed a significantly decreased growth rate. No other significant effect was found in feed intake and feed conversion ratio. At d 7, dry matter digestibility was higher in pigs fed SBM diet than piglets fed EFS 75 diet ($p<0.05$) and crude protein digestibility was higher in piglets fed SBM diet than piglets fed EFS 50, EFS 75 and EFS 100 ($p<0.05$). At d 21, no difference other than in phosphorus digestibility was detected. This indicates that piglets at 21 d postweaning are capable of utilizing nutrients from FFS. No treatment effects were detected in blood metabolites. The data suggests that piglets at 16 d of age are not sufficiently mature to use extruded FFS in their diets. Nevertheless, FFS seemed to be able to replace upto 50% of SBM in weaned piglet diet. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 5 : 645-652*)

Key Words : Extruded Full Fat Soybean, Growth, Early Weaned Pigs

INTRODUCTION

Soybean protein in the form of soybean meal (SBM) has long been a predominant protein source in animal diets due to its abundance and low price. However, with the advent of new processing technologies, there has been an effort to use whole soybean as feed ingredient in various animal species (Waldroup and Hazen, 1978; Zhang et al., 1993; Marty and Chavez, 1993; Kim et al., 1998a, b). Because raw soybean has several anti-nutritional factors which impair growth rate and feed efficiency of animal, it should be properly treated to inactivate or eliminate its soybean trypsin inhibitors and heat treatment has been a major processing method for this purpose. Among heat treatment, extrusion was reported as the best processing technique to improve the nutritional value of full-fat soybean (Marty and Chavez, 1993). Properly processed soybeans can be an excellent protein sources for swine. Full-fat soybeans (EFS) contain about 37% crude protein and relatively high oil (18%) compared to extracted soybean meal (Marty and Chavez, 1993). Using EFS in swine diets can be attractive to feed producers depending on the price of soybeans and processing costs versus the prices of SBM and soy oil (Kim et al., 1998a). Full-fat soybean has been demonstrated as an excellent source of amino acids and energy for poultry (Mateos et al., 1996), dairy cow (Schwarz et al., 1996) and growing-finishing pigs (Kim et al., 1995; Kovacs et al., 1996; Campabadal, 1996; Kim et al., 1998a). There have been several attempts to incorporate full-fat soybean in diets of piglet (Kim and Kim, 1997; Kim et al., 1998b). Kim and Kim (1997) reported an improved performance of 21 days old piglets fed dry EFS compared to piglets fed SBM diet and observed better small intestinal integrity in piglets fed dry EFS. Kim et al. (1998b) also observed slightly improved feed efficiency when they replaced soybean meal and soy oil with dry EFS in nursery piglet diets and suggested that the protein and fat in EFS were well utilized by early weaned piglets. But they found no significant improvement in either weight gain or feed efficiency.

Still, there has been scarce information on the use of EFS in the diet of early-weaned piglet (i.e. 16 days old). Thus, the objectives of this study was to

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Table 1. Formula and chemical composition of experimental diets (Day 0 to 7)

	SBM	EFS 25	EFS 50	EFS 75	EFS 100
Ingredients (%) :					
Corn	9.30	8.80	8.40	8.30	7.90
Dried skim milk	20.00	20.00	20.00	20.00	20.00
Dried whey	15.00	15.00	15.00	15.00	15.00
Soybean meal	12.00	9.00	6.00	3.00	0.00
Extruded full fat soybean	0.00	3.00	6.00	9.00	12.00
Bakery	8.00	8.00	8.00	8.00	8.00
Lactose	18.00	18.00	18.00	18.00	18.00
Soy oil	1.30	1.45	1.50	1.50	1.50
Fish meal	3.60	3.60	3.60	3.60	3.60
Spray dried plasma protein	9.00	9.00	9.00	9.00	9.00
Spray dried blood meal	1.15	1.50	1.85	2.00	2.40
Monocalcium phosphate	0.90	0.90	0.90	0.90	0.90
Limestone	0.68	0.68	0.68	0.68	0.68
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%)	0.05	0.05	0.05	0.05	0.05
Lysine (78%)	0.02	0.01	0.00	0.01	0.00
Cr_2O_3	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]:					
ME (kcal/kg):	3,288.00	3,287.00	3,280.00	3,275.00	3,265.00
CP (%)	26.34	26.29	26.26	26.09	26.10
Lysine (%)	1.88	1.88	1.88	1.88	1.88
Methionine (%)	0.51	0.51	0.51	0.51	0.51
Threonine (%)	1.08	1.08	1.08	1.08	1.09
Calcium (%)	1.01	1.01	1.01	1.01	1.01
Phosphorus (%)	0.90	0.90	0.90	0.90	0.90

[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_6, 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] Calaulated value.

SBM=SBM:EFS (100:0), EFS 25=SBM:EFS (75:25), EFS 50=SBM:EFS (50:50), EFS 75=SBM:EFS (25:75), EFS 100=SBM:EFS (0:100).

evaluate the nutritive value and to determine the optimal inclusion level of EFS in early-weaned piglet diets.

MATERIALS AND METHODS

A total of 80 piglets (5.18±0.61 kg BW; 16 d of age) were used to evaluate the effect of extruded full-fat soybean (EFS) on performance, nutrient digestibility and amino acids digestibility of early weaned pigs. Pigs were allotted into five treatments based on body weight, in a completely randomized block design. Each treatment has 4 replicates with 4 heads per pen. Extruded full-fat soybean was prepared using an Insta-Pro™ extruder maintained at 600 kg/hour with 130~150℃ of processing temperature without any steam or moisture addition. Treatments consisted of diets containing different ratio of soybean: extruded full-fat soybean; 1) 100:0 (SBM), 2) 75:25 (EFS 25), 3) 50:50 (EFS 50), 4) 25:75 (EFS 75) and 5) 0:100 (EFS 100). During phase (d 0 to 7), piglets were fed diets containing 3,340 kcal ME, 26% crude protein, 1.85% lysine, 1.0% Ca and 0.9% P. For the period of d 8 to 21 postweaning (phase Ⅱ), piglets were fed diets supplying 3,340 kcal ME, 23% crude protein, 1.65% lysine, 0.9% Ca and 0.8% P (table 1, 2). The experimental diets were fed as mash form. Chromic oxide (Cr_2O_3, 0.25%) was used as an indigestible marker to allow digestibility determination. Fecal samples were collected by rectal massage with four pigs in each treatment. Collected samples were pooled for each pen and dried in air-forced drying

Table 2. Formula and chemical composition of experimental diets (Day 8 to 21)

	SBM	EFS 25	EFS 50	EFS 75	EFS 100
Ingredients (%) :					
Corn	19.20	18.80	18.40	18.20	17.69
Dried skim milk	14.00	14.00	14.00	14.00	14.00
Dried whey	15.00	15.00	15.00	15.00	15.00
Soybean meal	12.00	9.00	6.00	3.00	0.00
Extruded full fat soybean	0.00	3.00	6.00	9.00	12.00
Bakery	6.50	6.50	6.50	6.50	6.50
Lactose	18.00	18.00	18.00	18.00	18.00
Soy oil	1.44	1.45	1.44	1.44	1.44
Fish meal	2.00	2.00	2.00	2.00	2.00
Spray dried plasma protein	8.00	8.00	8.00	8.00	8.00
Spray dried blood meal	1.00	1.40	1.80	2.20	2.55
Monocalcium phosphate	0.90	0.90	0.90	0.90	0.90
Limestone	0.82	0.82	0.82	0.82	0.82
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%)	0.06	0.06	0.06	0.06	0.06
Lysine (78%)	0.04	0.03	0.01	0.00	0.00
Threonine (50%)	0.08	0.08	0.07	0.06	0.05
Cr_2O_3	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]:					
ME (kcal/kg)	3,287.00	3,285.50	3,282.00	3,280.00	3,280.00
CP (%)	23.02	23.02	23.02	23.02	23.00
Lysine (%)	1.61	1.61	1.61	1.61	1.61
Methionine (%)	0.45	0.45	0.45	0.45	0.45
Threonine (%)	1.00	1.00	1.00	1.00	1.00
Calcium (%)	0.90	0.90	0.90	0.90	0.90
Phosphorus (%)	0.80	0.80	0.80	0.80	0.80

[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_6, 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] Calaulated value.

SBM=SBM:EFS (100:0), EFS 25=SBM:EFS (75:25), EFS 50=SBM:EFS (50:50), EFS 75=SBM:EFS (25:75), EFS 100=SBM:EFS (0:100).

oven then ground with 1 mm Wiley mill for chemical analysis. Digestibility was determined at the end of each phase.

Piglets were housed in a environmentally controlled feeding room 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 piglets 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.

Analysis 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 was measured using the UV-visible spectrophotometer (Hitachi, U-1000, Japan) and gross energy content of feeds and excreta were measured using the 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 was measured using gas chromatography according to the method of Lepage and Roy (1986).

Blood samples were collected from jugular vein to analyze serum urea nitrogen (BUN), total glucose (TG) and total cholesterol (TC) at the end of each phase. After collection of blood sample, serum was isolated, and then measured blood traits using BUN, TG and TC kit (Asan co., Korea). And serum urea nitrogen (BUN), total glucose (TG) and total cholesterol (TC) were analyzed using commercially available kits (ChungIl Chem., Korea).

Soybean meal was analyzed in duplicate for urease activity according to the method of Caskey and Knapp (1944).

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

Chemical composition

Chemical composition of EFS used in this experiment was given in table 3. The protein and amino acid contents of soybean products were similar to those listed by NRC (1998). Urease activity (pH rise) of FFSB (0.18) was three times higher than that of SBM (0.06). These values are much higher than the values reported by Kim and Kim (1997) who reported the value 0.01 for dry extruded whole soybean and 0.02 for SBM. This might indicate that the processing condition was different between our experiment and that of Kim and Kim (1997). However, higher urease activity for FFSB was in agreement with the report of Faber and Zimmerman (1973) who reported that about 2.2 times higher urease activity for extruded FFSB than that of SBM. Other possibility is the quality of soy products used in this study. Chemical analysis showed that SBM had over 2% crude oil which is a bit higher than generally reported value (less than 1%) (Marty and Chavez, 1993).

Growth performance

During the first week postweaning, pigs fed SBM had greater average daily gain (ADG, $p<0.05$), average daily feed intake (ADFI, NS) and better feed conversion ratio (FCR) compared to pigs fed extruded full-fat soybean diets (table 4). A linear negative effect in growth rate was found in pigs fed the experimental diets as the inclusion rate of FFSB increased. No significant difference was found in ADFI but there was a trend that ADFI decreased as FFSB inclusion level was increased ($p<0.11$). Feed utilization was linearly affected by FFSB inclusion level. During d 8-21 postweaning, piglets fed EFS 50 diet showed the best ADG and FCR with no significant differences among treatments SBM, EFS 25, EFS 50 and EFS 75.

Table 3. Chemical composition of experimental ingredients

Item	Soybean meal (SBM)	Extruded full-fat soybean (EFS)
Urease activity, pH rise	0.06	0.18
Proximate nutrients:		
Gross energy (kcal/kg)	4,275.18	5,261.97
Crude ash (%)	5.86	4.94
Crude protein (%)	46.47	36.75
Crude fat (%)	2.17	16.90
Minerals (%):		
Ca	0.20	0.27
P	0.68	0.56
Amino acid (%):		
Essential amino acids		
Threonine	1.79	1.39
Valine	2.32	1.70
Cystine	0.61	0.51
Methionine	0.69	0.60
Isoleucine	2.09	1.61
Leucine	3.53	2.60
Tyrosine	1.50	1.48
Phenylalanine	1.82	1.65
Lysine	1.99	1.71
Histidine	1.01	0.86
Arginine	2.70	2.26
Subtotal	20.05	16.38
Non essential amino acids		
Aspartic acid	3.51	2.83
Serine	2.31	1.67
Glutamic acid	8.63	5.96
Proline	2.29	1.96
Glycine	1.68	1.32
Alanine	2.25	1.50
Subtotal	20.67	15.24
Total	40.72	31.62
Fatty acids :		
Saturated		
C14:0	-	-
C16:0	17.08	15.20
C18:0	3.86	5.61
Monounsaturated		
C18:1	15.98	18.76
Polyunsaturated		
C18:2	55.81	49.95
C18:3	7.27	10.48

Piglets fed diets with higher FFSB inclusion rate showed a continuous decrease in growth rate. But, in a quadratic response ($p<0.05$), the growth rate was highest at the 6% supplementation of full-fat soybean to the diet (EFS 50). Overall, piglets fed diets up to 50% EFS inclusion rate exhibited similar weight gain.

Table 4. Effects of experimental diets consisting of different ratios of soybean meal to full fat soybean on the growing performance of piglet

Treatment	SBM	EFS 25	EFS 50	EFS 75	EFS 100	PSE[1]	p value	
							Linear	Quadratic
Day 0~7								
ADG (g)	309[a]	280[ab]	281[ab]	254[ab]	212[b]	14.45	0.0266	0.0815
ADFI (g)	301	284	305	261	235	13.22	0.1076	NS
FCR	0.97[c]	1.02[bc]	1.09[ab]	1.03[abc]	1.12[a]	0.02	0.0110	0.0385
Day 8~21								
ADG (g)	441[abc]	458[ab]	481[a]	427[bc]	397[c]	9.20	0.0549	0.0053
ADFI (g)	576	565	574	512	512	13.12	0.0331	0.0964
FCR	1.31	1.23	1.19	1.20	1.29	0.02	NS	0.0174
Day 0~21								
ADG (g)	397[a]	399[a]	414[a]	369[ab]	335[b]	9.21	0.0124	0.0057
ADFI (g)	484	471	484	428	420	15.88	0.0238	0.0645
FCR	1.22	1.18	1.17	1.16	1.26	0.02	NS	0.0288

[1] Pooled standard error.
[a,b,c] Means with different superscript in the row differ ($p<0.05$).
Average initial and final body weight were 5.18±0.61 kg and 13.22±1.22 kg, respectively.

Table 5. Nutrients digestibility of experimental diets consisting of different rations of soybean meal to full fat soybeans for early weaned piglets

Treatment	SBM	EFS 25	EFS 50	EFS 75	EFS 100	SE[1]	p value	
							Linear	Quadratic
Day 7								
Dry matter	83.00[a]	80.00[ab]	79.75[ab]	78.75[b]	79.75[ab]	0.53	0.0348	0.0184
Crude protein	75.50[a]	71.25[ab]	69.75[b]	69.50[b]	70.50[b]	0.76	0.0303	0.0041
Crude fat	61.50	60.25	60.50	58.00	54.00	1.20	0.0360	NS
Calcium	56.75	49.00	55.25	53.25	56.75	1.71	NS	NS
Phosphorus	47.75	44.50	42.75	44.00	41.50	1.50	NS	NS
Day 21								
Dry matter	80.00	80.75	82.50	80.50	81.25	0.40	NS	NS
Crude protein	74.00	74.00	74.75	74.00	74.50	0.42	NS	NS
Crude fat	44.25	50.25	51.50	46.75	51.50	1.45	NS	NS
Calcium	66.75	64.75	69.50	69.00	70.00	1.02	NS	NS
Phosphorus	43.00[b]	47.50[ab]	55.00[a]	51.25[ab]	51.50[ab]	1.53	0.0467	0.0289

[a,b] Means with different superscripts in the row differ ($p<0.05$).
[1] SE : Pooled standard error.

Only piglets fed EFS 100 diet showed a significantly decreased growth rate. No other significant effect was found in feed intake or feed conversion ratio. However, a tendency of linear decrease in feed intake was found as the FFSB inclusion level was increased. For overall period (d 0 to 21), the best performance was observed in pigs fed EFS 50 diet. This result could probably be associated with the high urease activity of FFS observed in this study and different source of protein in making iso-nitrogenous experimental diets. Kim and Kim (1997) reported an improved performance of piglets fed dry EFS diets compared to piglets fed SBM diet. This might be the result of different processing conditions or feed processing method. Kim and Kim (1997) pelleted the experimental diets after extrusion processing of soybean, but we fed piglets the experimental diets in mash form after extrusion of soy products. Thus, Kim and Kim (1997) applied one more heat treatment for their experimental diets. Then, the result of Kim and Kim (1997) showed a much lower urease activity for the dry extruded FFSB compared to our products. Kim et al. (1998b) also reported an improved feed utilization in piglets fed dry EFS compared to piglets fed SBM diet regardless of protein:energy ratio adjustment. Contrary to the results reported by Kim and Kim (1997) and Kim et al. (1998), no improvement was detected in this study. It

Table 6. Amino acid digestibility of experimental diets with different ratios of soybean meal and full fat soybean for early weaned piglets (D 7)

Treatment	SBM	EFS 25	EFS 50	EFS 75	EFS 100	SE[1]	p value	
							Linear	Quadratic
Essential amino acids :								
Threonine	75.50	68.25	69.00	67.75	74.25	1.42	NS	0.1006
Valine	78.00[a]	67.00[b]	82.50[a]	82.75[a]	74.25[ab]	1.79	NS	NS
Cystine	86.50[a]	75.25[ab]	67.75[b]	65.75[b]	84.75[a]	2.89	NS	0.0100
Methionine	80.25[ab]	77.50[ab]	89.25[a]	90.25[a]	71.25[b]	2.30	NS	NS
Isoleucine	87.75[a]	68.25b	68.75[b]	69.50[b]	65.25[b]	2.09	0.0009	0.0003
Leucine	77.25[a]	70.75[ab]	69.50[b]	71.25[ab]	71.75[ab]	1.03	NS	0.0465
Tyrosine	82.75[a]	72.50[ab]	63.25[b]	73.25[ab]	62.00[b]	2.33	0.0109	0.0259
Phenylalanine	75.25[a]	68.50[abc]	61.50[c]	65.00[bc]	69.25[ab]	1.39	NS	0.0011
Lysine	90.00[a]	77.50[b]	69.75[c]	74.25[bc]	77.00[b]	1.78	0.0159	0.0001
Histidine	89.50[a]	75.50[b]	71.00[b]	73.00[b]	66.75[b]	2.19	0.0004	0.0005
Arginine	87.50[a]	71.25[b]	61.00[b]	67.75[b]	70.25[b]	2.54	0.0282	0.0007
Subtotal	83.75[a]	71.50[b]	69.25[b]	72.00[b]	71.50[b]	1.42	0.0106	0.0004
Non-essential amino acids :								
Aspartid acid	77.00	70.00	70.50	69.00	76.00	1.39	NS	NS
Serine	75.00	71.25	71.25	72.00	74.25	1.11	NS	NS
Glutamic acid	81.75	80.25	78.25	80.50	75.00	0.73	0.0061	0.0211
Proline	83.75	80.00	81.00	81.25	83.25	0.72	NS	NS
Glycine	71.50[a]	62.50[b]	60.75[b]	61.00[b]	61.75[b]	1.40	0.0243	0.0088
Alanine	68.00[a]	58.25[b]	62.75[ab]	63.75[ab]	60.00[b]	1.22	NS	NS
Subtotal	78.50	74.00	74.00	74.75	74.00	0.75	NS	NS
Total	81.75[a]	72.50[b]	71.25[b]	73.25[b]	72.50[b]	1.11	0.0180	0.0020

[a,b] Means with different superscripts in the row differ (p<0.05).
[1] SE - Pooled standard error.
[2] NS, * - not significant, at <0.05.

was assumed that the higher urease activity as an indicator of anti-nutritional factors of raw soybean impaired growth performance of piglets fed EFS 75 or EFS 100 diet. The quality of SBM used in this study can be another reason and the age of piglets is different. Sixteen-day-old piglets might be too young for the utilization high level of soy protein. Nevertheless, the overall growth data suggested that EFS could replace SBM up to 50% and could be limited to 6% of the diet.

Nutrients digestibility and blood metabolites

At d 7, dry matter digestibility was higher in pigs fed SBM diet than piglets fed EFS 75 diet (p<0.05) and crude protein digestibility was significantly higher in piglets fed SBM diet than piglets fed EFS 50, EFS 75 and EFS 100 diet (p<0.05). Linear effect of FFSB inclusion rate was detected for digestibilities of dry matter, crude protein and crude fat. At d 21, however, no difference other than phosphorus digestibility was detected. It appeared that piglets at 21 d postweaning was capable of utilizing nutrients in EFS diet. Nutrients digestibility observed in this study also conflicted with the result of Kim and Kim (1997) who reported an improved dry matter and nitrogen digestibility in piglets fed dry EFS in one experiment and no difference in another experiment. However, the results are in agreement with data of Marty et al. (1994) who observed a higher ileal lysine digestibility in pig fed SBM diet compared to EFS diet. It was assumed that the lower nutrients digestibility of EFS was attributed to the high urease activity, high quality of SBM and younger age of piglets used in this study. Also this lower digestibility presumably account for the slightly inferior growth performance of pigs fed EFS diets.

Amino acids in the SBM diet were more digestible amino acids than that of EFS diets for piglets at d 7 as presented in table 6 (p<0.05). During d 8-21, no significant difference was found in average amino acids digestibility, but the digestibility of essential amino acids was higher in piglets fed SBM, EFS 25, EFS 50 diets than piglets fed EFS 75 and EFS 100 diets (table 7).

Blood urea nitrogen (BUN), total glucose (TG) and total cholesterol (TC) level was examined but no difference was detected among treatments at either d 7 or d 21 (table 8).

In conclusion, based on the results of this study, piglets of 16 d of age are not ready to use high level

Table 7. Amino acid digestibility of experimental diets with different ratios of soybean meal and full fat soybean for early weaned piglets (D 21)

Treatment	SBM	EFS 25	EFS 50	EFS 75	EFS 100	SE[1]	p value	
							Linear	Quadratic
Essential amino acids:								
Threonine	73.00^{b}	78.25^{a}	75.25^{ab}	76.25^{ab}	77.00^{ab}	0.71	NS	NS
Valine	69.50^{c}	74.75	79.25^{a}	76.50^{ab}	74.75^{b}	0.91	NS	0.0004
Cystine	54.25^{b}	73.00^{a}	73.50^{a}	58.50^{b}	54.50^{b}	2.57	NS	0.0065
Methionine	96.75^{a}	81.25^{b}	80.75^{b}	72.25^{bc}	67.25^{c}	2.57	0.0001	0.0001
Isoleucine	76.25^{a}	72.50^{a}	75.75^{a}	73.50^{a}	64.50^{b}	1.32	0.0096	0.0095
Leucine	79.75	79.00	80.00	65.75	74.75	1.41	0.0138	0.0474
Tyrosine	81.50	80.75	84.25	78.75	82.00	0.82	NS	NS
Phenylalanine	81.50^{a}	79.25^{a}	79.00^{a}	69.50^{b}	72.75^{b}	1.23	0.0004	0.0022
Lysine	85.25^{a}	82.25^{ab}	80.00^{b}	80.00^{b}	78.75^{b}	0.73	0.0012	0.0031
Histidine	85.50^{a}	82.75^{ab}	74.00^{bc}	61.25^{d}	66.50^{cd}	2.43	0.0001	0.0001
Arginine	84.25^{a}	83.25^{a}	82.75^{a}	76.75^{b}	72.25^{b}	1.25	0.0001	0.0001
Subtotal	79.75^{a}	79.50^{a}	79.00^{a}	73.25^{b}	73.75^{b}	0.87	0.0012	0.0045
Non-essential amino acids:								
Aspartid acid	53.00^{c}	78.00^{a}	71.25b	74.00^{ab}	72.75^{ab}	2.11	0.0139	0.0003
Serine	74.75^{b}	81.75^{a}	79.75^{a}	80.50^{a}	83.00^{a}	0.79	0.0033	0.0075
Glutamic acid	85.75^{a}	84.25^{ab}	82.75^{ab}	81.50^{b}	83.00^{ab}	0.59	0.0397	0.0446
Proline	84.50	86.25	83.75	86.25	87.00	0.65	NS	NS
Glycine	72.75^{a}	72.25^{a}	69.25^{a}	47.75^{b}	50.25^{b}	2.76	0.0001	0.0001
Alanine	73.50^{ab}	71.50^{b}	75.75^{ab}	78.25^{ab}	78.75^{a}	1.04	0.0149	NS
Subtotal	77.75	81.00	78.00	78.00	79.25	0.59	NS	NS
Total	78.75	80.25	78.75	75.75	76.50	0.67	0.0307	NS

a,b Means with different superscripts in the row differ ($p<0.05$).
[1] SE - Pooled standard error.

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

Treatment	SBM	EFS 25	EFS 50	EFS 75	EFS 100	SE[1]	p value	
							Linear	Quadratic
BUN (Blood urea nitrogen)								
Day 0	8.25	8.90	8.73	8.98	8.68	0.31	NS*	NS
Day 7	9.15	9.43	9.35	9.33	9.55	0.32	NS	NS
Day 21	8.78	9.98	10.08	10.50	10.88	0.44	NS	NS
TG (Total glucose)								
Day 0	94.40	98.20	98.60	95.00	94.70	2.13	NS	NS
Day 7	85.30	89.10	81.70	82.80	86.50	1.97	NS	NS
Day 21	86.70	90.40	87.10	88.00	99.00	2.53	NS	NS
TC (Total cholesterol)								
Day 0	6.60	6.72	6.32	6.53	7.47	0.38	NS	NS
Day 7	13.99	10.00	12.37	10.74	8.72	1.11	NS	NS
Day 21	21.08	13.18	16.42	12.37	12.97	1.90	NS	NS

[1] SE : Pooled standard error.
* Not significant, at<0.05.

of extruded FFSB as much as that of soybean meal. Piglets fed extruded FFSB showed a slightly decreased growth rate compared to SBM diet fed control. Nutrient utilization was also inferior in piglets fed extruded FFSB diets. Nevertheless, FFSB seemed to be able to replace up to 50% of SBM in weaned piglet diet.

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