Effects of Sodium Sulfite and Extrusion on the Nutritional Value of Soybean Meal in Piglets Weaned at 21 Days[a]

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ABSTRACT : A total of 80 weaned piglets (Landrace×Yorkshire×Large White) were used in a 28-day growth assay to determine the optimal inclusion level of sodium sulfite (Na_2SO_3) as an extrusion enhancer of soybean meal for nursery piglets. piglets (21 d of age, 6.04 kg of BW) were grouped into 4 treatments in a completely randomized block design. Treatments were: 1) Extruded SBM (Control), 2) Extruded SBM with 0.5% Na_2SO_3 (0.5 ESBM), 3) Extruded SBM with 1.0% Na_2SO_3 (1.0 ESBM) and 4) Extruded SBM with 1.5% Na_2SO_3 (1.5 ESBM). Each treatment has 4 replicates of 5 heads per pen. In phase Ⅰ (d 0 to 14), diets supplied 3,400 kcal ME/kg, 23% crude protein, 1.65% lysine, 0.50% methionine, 0.9% Ca and 0.8% P. Phase Ⅱ (d 14 to 28) diets contained 3,300 kcal ME/kg, 21% crude protein, 1.45% lysine, 0.45% methionine, 0.9% Ca and 0.8% P. For d 0 to 14, piglets fed 1.5 ESBM had greater ADG, ADFI and FCR compared to piglets fed control and 0.5 ESBM diet. ADG was significantly higher in piglets fed 1.5 ESBM diet than other groups ($p<0.05$) except 1.0 ESBM. In phase Ⅱ (d 14 to 28), there was no significant differences in production traits among treatments. For overall period (d 0 to 28), piglets fed diets with high sodium sulfite grew faster than piglets fed control and 0.5 ESBM diets. The highest ADG and the best FCR were obtained in piglets fed diets with 1.5 ESBM during the entire period. Piglets fed 1.5 ESBM diet showed significantly higher crude protein digestibility than 0.5 ESBM ($p<0.05$) at d 14 post-weanling, but not at d 28 post-weanling. There were no significant differences in digestibilities of total amino acids. In conclusion, the addition level of 1~1.5% sodium sulfite for SBM extrusion could be favorable for rate and efficiency of growth in weaning pigs. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 7 : 974-979*)

Key Words : Piglets, Growth, Sodium Sulfite, Extruded Soybean Meal

INTRODUCTION

Soybean meal is the most common protein source in swine diets. However, it contains various anti-nutritional factors such as trypsin inhibitors, lectins, and antigenic proteins (e. g., glycinin and β-conglycinin). Most anti-nutritional factors in soybean meal are known to be labile to heat, thus to avoid the harmful effect of these anti-nutritional factors, heating process is often applied (Chae et al., 1984). Among heating processes, extrusion is the most common method to improve the nutritional values of protein sources of plant origin. However, heat processing does not completely inactivate all anti-nutritional factors (Friedman and Gumbmann, 1986) and often over-heating impairs the nutritional value of soybean meal by reducing amino acids bioavailability (Chae et al., 1984).

To maximize the effect of extrusion, some researchers added sodium sulfite as an extrusion enhancer, and obtained positive effect on rate and efficiency of piglets (Freidman et al., 1984; Sessa et al., 1988; Herkelman et al., 1991; Kim and Kim, 1997). It was suggested that sulfite ions destroy the disulfide bonds and alter the protein structure of trypsin inhibitors or structural protein in soybean products (Friedman et al., 1984; Sessa et al., 1988). Friedman and Gumbmann (1986) reported that sulfite additions to soy flour before heating improved its nutritional value in rats. Furthermore, it was suggested that sodium sulfite addition could reduce the time required for extrusion processing to inactivate anti-nutritional factors in raw soybeans, thus avoid over-heating and improve the nutritional value of extruded soybean (Burnham et al., 1994)

However, the effects of sulfite on the nutritional value of full-fat soybeans are not well understood (Friedman and Gumbmann, 1986) and data are limited. Kim and Kim (1997) reported that sodium sulfite addition prior to extrusion improved weight gain and feed utilization in young pigs fed dry extruded whole soybean. The optimal addition level for the sodium addition was not studied, however.

The objective of this research is to evaluate the optimal inclusion level of sodium sulfite as an extrusion aid in processing SBM for early-weaned piglet diets.

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MATERIALS AND METHODS

A total of 80 weaned piglets (Landrace×Yorkshire ×Large White) were used in a 28 day growth assay to determine the effects of sodium sulfite (Na_2SO_3) as an extrusion enhancer of soybean meal for nursery piglets. Piglets (21 d of age, 6.04±0.37 kg BW) were grouped into 4 treatments in a completely randomized block design. Treatments were; 1) Extruded SBM (Control), 2) Extruded SBM with 0.5% Na_2SO_3 (0.5 ESBM), 3) Extruded SBM with 1.0% Na_2SO_3 (1.0 ESBM) and 4) Extruded SBM with 1.5% Na_2SO_3 (1.5 ESBM). Each treatment has 4 replicates with 5 heads per pen. Soybean meal was extruded using an Insta-Pro™ extruder at 26.6 kg/min of feeding rate, 120~130℃ processing temperature and with 750 g/hour moisture addition rate. In phase I (d 0 to 14), diets supplied 3,400 kcal ME/kg, 23% crude protein, 1.65% lysine, 0.50% methionine, 0.9% Ca and 0.8% P. Phase II (d 14 to 28) diets contained 3,300 kcal ME/kg, 21% crude protein, 1.45% lysine, 0.45% methionine, 0.9% Ca and 0.8% P (table 1). Adequate amount of vitamins and minerals were supplied, as suggested by the NRC (1998). Chromic oxide (Cr_2O_3, 0.20%) were used as an indigestible marker to allow digestibility determination. Fecal samples were collected from four pigs in each treatment at the end of phase. Collected samples were pooled for each pen and dried in air-forced drying oven, and then ground with 1 mm Wiley mill for chemical analyses. Digestibility was determined at week 2 and 4, respectively.

Pigs were housed in a concrete-floored pens with a feeder and a nipple waterer, and allowed *ad libtum* access to feed and water throughout experimental period.

Room temperature was maintained at 29±1℃ by a gas heater and air ventilation was controled with electric fans during the entire period. For one day before the beginning of the experiment, piglets were fed commercial diet for adaptation to solid feed.

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 was measured using the UV-visible spectrophotometer (Hitachi, U-1000, Japan) and gross energy content of feeds and excreta were measured using a bomb calorimeter (Parr Instrument Co., Model 1241, USA). Chromium was measured using an atomic absorption spectrophotometer (Shimadzu, AA6145F, Japan). Soybean meal was analyzed in duplicate for urease activity according to the method of Caskey and Knapp (1944).

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

Table 1. Formula and chemical composition of the experimental diets

	Phase I (Day 0~14)	Phase II (Day 15~28)
Ingredients:		
Corn	29.30	48.73
Dried skim milk	13.16	-
Lactose	10.00	-
Soybean meal	25.000	30.00
Milk replacer[1]	10.00	10.00
Spray dried plasma protein	3.15	2.67
Soy oil	5.16	4.15
Monocalciumphosphate	1.485	1.69
Limestone	0.803	1.10
Salt	0.20	0.20
Vit. min. mix.[2]	0.47	0.47
Avilamycin	0.02	0.02
Methionine (50%)	0.468	0.397
Lysine-HCl (78%)	0.233	0.258
Threonine (50%)	0.347	0.110
Cr_2O_3	0.20	0.20
Total	100.00	100.00
Chemical composition[3]		
ME (kcal/kg)	3,401	3,300
CP (%)	23.00	21.00
Lysine (%)	1.65	1.45
Methionine (%)	0.50	0.45
Met.+Cys. (%)	0.96	0.87
Threonine (%)	1.04	0.94
Calcium (%)	0.90	0.90
Phosphorus (%)	0.80	0.80

[1] Whey 89.3%, soy flour 10% and silicate 0.7%.

[2] 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; Folic acid, 40 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; BHT, 5,000 mg.

[3] Calaulated value.

RESULTS AND DISCUSSION

Nutrient compositions of soybean meal used in this experiment are given in table 2. Protein and amino acid concentrations of the soybean products were

Table 2. Chemical composition of soybean meal as affected by extrusion with graded level of Na_2SO_3

Item	Control (ESBM)	0.5 ESBM	1.0 ESBM	1.5 ESBM
Urease activity, pH rise	0.05	0.04	0.03	0.03
Proximate nutrients:				
Ash (%)	6.16	5.98	6.54	5.61
CP (%)	39.41	38.49	38.46	37.77
Fat (%)	1.70	1.54	2.15	1.90
Minerals (%) :				
Ca	0.19	0.21	0.16	0.20
P	0.60	0.60	0.60	0.68
Amino acid (%) :				
Essential amino acids				
Threonine	1.32	1.33	1.34	1.69
Valine	1.54	1.58	1.56	1.54
Cystine	0.35	0.33	0.36	0.41
Methionine	0.51	0.47	0.50	0.52
Isoleucine	1.56	1.53	1.36	1.51
Leucine	2.61	2.62	2.45	2.54
Tyrosine	1.19	1.17	1.18	1.15
Phenylalanine	1.82	1.79	1.85	1.76
Lysine	2.09	2.15	2.17	2.22
Histidine	0.94	0.94	0.96	0.91
Arginine	2.26	2.10	2.36	1.93
Subtotal	16.17	16.00	16.09	16.17
Non essential amino acids				
Aspartic acid	3.91	3.82	3.96	3.84
Serine	1.69	1.62	1.65	1.65
Glutamic acid	6.27	6.25	6.07	6.26
Proline	1.74	1.91	1.49	1.59
Glycine	1.37	1.36	1.46	1.37
Alanine	1.52	1.51	1.54	1.46
Subtotal	16.51	16.47	16.17	16.17
Total	32.68	32.47	32.26	32.34

Control : SBM extruded without Na_2SO_3.
0.5 ESBM : SBM extruded with 0.5% Na_2SO_3.
1.0 ESBM : SBM extruded with 1.0% Na_2SO_3.
1.5 ESBM : SBM extruded with 1.5% Na_2SO_3.

similar to those listed by NRC (1998). The extrusion with sodium sulfite had minor effects on the urease activities. A range of 0.05 to 0.20 of urease activity (pH change) was considered as an indicator of properly processed soybean meal (Wright, 1981). The urease activities of extruded soybean meal used in this study are in this range (table 2).

For d 0 to 14, piglets fed 1.5 ESBM had greater average daily gain (ADG), average daily feed intake (ADFI) and better feed conversion ratio (FCR) than those piglets fed control and 0.5 ESBM diets (table 3). During phase Ⅱ, ADG of piglets fed 1.5 ESBM was improved (11%) as compared to control group even though there was no significant difference. For

Table 3. Growth performance of piglet fed the experimental diets

Treatment	Control (ESBM)	0.5 ESBM	1.0 ESBM	1.5 ESBM	SE[1]
Phase Ⅰ (d 0~14)					
ADG (g/day)	246^{b}	230^{b}	268^{ab}	316^{a}	11.89
ADFI (g/day)	266^{ab}	243^{b}	280^{ab}	328^{a}	12.88
Feed/gain	1.09	1.06	1.06	1.03	0.02
Phase Ⅱ (d 15~28)					
ADG (g/day)	572	573	603	635	11.92
ADFI (g/day)	842	828	845	868	14.31
Feed/gain	1.48	1.45	1.40	1.37	0.03
Overall (d 0~28)					
ADG (g/day)	408^{b}	402^{b}	435^{ab}	475^{a}	10.84
ADFI (g/day)	554	535	562	598	12.06
Feed/gain	1.36	1.34	1.30	1.26	0.02

[1] Pooled standard error.
[a,b,c] Means with different superscripts in the same row differ ($p<0.05$).
Control: SBM extruded without Na_2SO_3.
0.5 ESBM: SBM extruded with 0.5% Na_2SO_3.
1.0 ESBM: SBM extruded with 1.0% Na_2SO_3.
1.5 ESBM: SBM extruded with 1.5% Na_2SO_3.

the overall period (d 0 to 28), piglets fed diets with 1.5 sodium sulfite (1.5 ESBM) grew faster than piglets fed control diet due to the higher weight gain during phase Ⅰ. The highest ADG and the best FCR were found in piglets fed diets with 1.5 ESBM during the entire period. The improved ADG of pigs fed 1.5 ESBM might be obtained by increased feed intake as compared to control and 0.5 ESBM. Feed efficiency was also improved by the addition of sodium sulfite due probably to reduced urease activity as shown in table 2. The improved performance of pigs fed 1.5 ESBM over control was clear during phase I than during phase II. Body weight change during the experimental period is shown in figure 1. Pigs fed 1.5 ESBM diet showed consistently higher body weight and ADG throughout the entire experimental period. Though no significant difference was detected between 1.0 ESBM and 1.5 ESBM, there was a trend that pigs fed 1.5 ESBM had heavier body weight at d 14 ($p=0.0949$) and d 28 ($p=0.1082$).

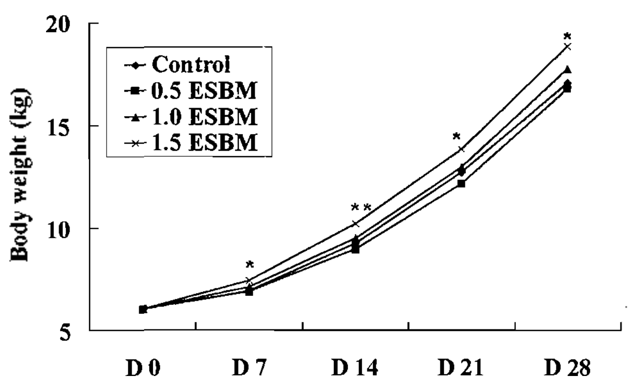
Our results are in agreement with the results of Kim and Kim (1997) and Burnham et al. (1994, 1995), who reported that piglets fed extruded SBM diets with sodium sulfite tended to have higher rate and efficiency of gain than piglets fed extruded soybean diets without sodium sulfite. Kim and Kim (1997) indicated that the performance of piglets fed extruded full-fat soybeans was improved with an addition of 0.1% sodium sulfite.

The improved performance observed in our study

Table 4. Apparent total tract digestibility of proximate nutrients in weaned piglets fed the experimental diets

Treament	Control (ESBM)	0.5 ESBM	1.0 ESBM	1.5 ESBM	SE[1]	Probability[2] Na_2SO_3 vs Con.
Day 14						
Dry matter	83.74	83.11	84.42	85.77	0.49	NS
Crude ash	51.70	53.51	56.26	57.18	1.10	NS
Crude protein	82.39[ab]	80.51[b]	82.13[ab]	85.89[a]	0.82	NS
Crude fat	56.51	56.31	56.12	61.54	1.66	NS
Calcium	69.36[b]	76.36[a]	77.89[a]	76.76[a]	1.27	*
Phosphorus	51.36	53.14	58.41	57.62	1.41	NS
Day 28						
Dry matter	80.52	80.61	80.97	80.73	0.41	NS
Crude ash	50.89	48.08	48.53	49.93	1.42	NS
Crude protein	79.02	77.57	77.70	79.62	0.49	NS
Crude fat	65.72	60.34	64.72	61.47	1.43	NS
Calcium	65.52[b]	69.31[ab]	78.33[a]	75.70[a]	1.84	*
Phosphorus	51.77	53.74	51.36	53.04	1.35	NS

[a,b] Means with different superscripts in the same row differ ($p<0.05$).
[1] SE : Pooled standard error; [2] NS, *: Not significant, $p<0.05$, respectively.



* Differs from control and 0.5 ESBM ($p<0.05$).
** Differs from control and 0.5 ESBM ($p<0.05$) or 1.0 ESBM ($p<0.1$).

Figure 1. Body weight changes of experimental pigs by weekly basis

and that of Kim and Kim (1997) might be due to the improved nutritional value of soybean by extrusion with sodium sulfite. Friedman and Gumbmann (1986) suggested that sodium metabisulfide may improve the nutritional value of soybean protein by breaking disulfide bonds within the structure of soybean proteins in addition to its effect on the trypsin inhibitors. Sulfite ions have been shown to cleave disulfide bonds in thiols and S-sulfonic acid derivatives (Cecil and Mcphee, 1955). Herkelman et al. (1991), also reported that the growth performance of chicks fed soybeans heated for 10 or 20 minutes was improved with an addition of 2% sodium metabisulfite.

During phase I (d 0 to 14), piglets fed 1.5 ESBM showed higher crude protein digestibility compared to 0.5 ESBM ($p<0.05$, table 4). Calcium digestibility was found to be higher in sodium sulfite added group ($p<0.05$). During phase II (d 28), no differences were found in digestibility of proximate nutrients except calcium, which was found to be higher ($p<0.05$) in 1.0 ESBM and 1.5 ESBM compared to control diet. As a whole, piglets fed 1.5 ESBM diet showed improved nutrients digestibilities than piglets fed control diet (table 4).

Kim et al. (1995a, b) indicated that nitrogen digestibility of dry extruded whole soybean (DEWS) tended to increase when sodium sulfite was added to the diet. Sodium sulfite has been reported to improve the nutritive value of extruded soybean meal by improving nutrients digestibility and decreasing trypsin inhibitor (urease activity) concentrations (Kim and Kim, 1997). The higher protein digestibility could be the effect of destruction of disulfide bonds in the trypsin inhibitor and structural protein in soy product by sodium sulfite addition (Friedman and Gumbmann, 1986). They also observed an improved nitrogen digestibility in rats when they added sodium sulfite during heat processing of soy flour.

There were no differences in total amino acid digestibilities at d 14 post-weaning. Although, no significance was detected, total average amino acid digestibility was numerically higher for 1.5 ESBM than others. A similar trend in amino acids digestibility was found at d 28 post-weanling. Kim et al. (1994, 1995a, b) indicated that piglets fed dry extruded whole soybean (DEWS) with sodium sulfite tended to have greater amino acid digestibilities

Table 5. Apparent total tract amino acids digestibility of weaned piglets fed the experimental diets (D 14)

Treatment	Control (ESBM)	0.5 ESBM	1.0 ESBM	0.5 ESBM	SE[1]	Probability[2] Na_2SO_3 vs Con.
Essential amino acids (%)						
Threonine	86.53	88.10	85.96	86.56	0.90	NS
Valine	82.30	83.46	83.76	88.06	1.25	NS
Cystine	89.73	89.41	90.95	91.83	0.85	NS
Methionine	85.90	82.39	84.22	87.66	1.16	NS
Isoleucine	83.63	82.83	80.98	86.00	1.13	NS
Leucine	85.35	84.58	84.55	88.72	0.96	NS
Tyrosine	86.86	87.72	80.42	86.88	1.32	NS
Phenylalanine	83.97	81.47	81.24	86.68	0.97	NS
Lysine	84.45	83.68	85.69	88.39	0.82	NS
Histidine	87.90^{ab}	85.84^{b}	89.45^{ab}	90.46^{a}	0.71	NS
Arginine	89.37^{ab}	86.99^{b}	89.80^{a}	91.56^{a}	0.56	NS
Subtotal	85.59	85.01	84.86	88.24	0.84	NS
Non essential amino acids (%)						
Aspartid acid	81.69	78.10	86.80	86.20	1.61	NS
Serine	88.03	87.62	88.57	87.43	0.85	NS
Glutamic acid	90.20	90.23	90.71	90.93	0.60	NS
Proline	86.96^{c}	86.86^{c}	89.53^{b}	93.24^{a}	0.73	*
Glycine	81.69	74.53	86.59	81.07	1.42	NS
Alanine	76.86	74.72	78.75	81.32	1.23	NS
Subtotal	85.89	85.41	87.94	88.30	0.79	NS
Total	85.73	85.20	86.37	88.27	0.80	NS

[a,b] Means with different superscripts in the samw row differ ($p<0.05$).
[1] SE : Pooled standard error; [2] NS, *: Not significant, $p<0.05$, respectively.

Table 6. Apparent total tract amino acids digestibility of weaned piglets fed the experimental diets (D 28)

Treatment	Control (ESBM)	0.5 ESBM	1.0 ESBM	1.5 ESBM	SE[1]	Probability[2] Na_2SO_3 vs Con.
Essential amino acids (%)						
Threonine	83.11^{ab}	77.94^{b}	82.12^{ab}	85.26^{a}	1.00	NS
Valine	77.85	81.87	78.25	82.27	1.01	NS
Cystine	90.95^{a}	90.32^{a}	89.54^{ab}	82.39^{b}	1.39	NS
Methionine	86.88^{ab}	88.61^{a}	83.83^{bc}	80.66^{c}	1.00	NS
Isoleucine	84.09^{a}	81.20^{ab}	76.13^{b}	79.79^{ab}	1.17	NS
Leucine	84.30^{a}	82.90^{a}	77.78^{b}	78.26^{b}	0.99	*
Tyrosine	83.38^{ab}	87.62^{a}	77.42^{b}	83.17^{ab}	1.38	NS
Phenylalanine	83.07	87.41	83.32	86.37	0.76	NS
Lysine	83.81	84.90	83.12	86.00	0.57	NS
Histidine	85.78^{b}	85.24^{b}	85.40^{b}	89.89^{a}	0.77	NS
Arginine	89.32^{a}	89.55^{a}	86.13^{b}	89.94^{a}	0.57	NS
Subtotal	83.35	85.06	81.22	83.97	0.71	NS
Non essential amino acids (%)						
Aspartid acid	84.95	83.93	84.32	86.19	0.63	NS
Serine	87.13	84.24	83.76	83.50	0.85	NS
Glutamic acid	89.16^{a}	87.70^{ab}	86.17^{b}	87.37^{ab}	0.48	NS
Proline	81.18^{c}	83.34^{bc}	88.99^{a}	85.32^{b}	0.90	*
Glycine	82.85^{a}	75.89^{b}	76.26^{b}	77.55^{b}	0.99	*
Alanine	79.49^{a}	73.65^{b}	74.89^{ab}	78.78^{a}	0.93	NS
Subtotal	85.56	83.61	84.00	84.71	0.50	NS
Total	84.45	84.43	82.57	84.31	0.55	NS

[a,b] Means with different superscripts in the samw row differ ($p<0.05$).
[1] SE: Pooled standard error; [2] NS, *: Not significant, $p<0.05$, respectively.

measured at the terminal ileum compared to piglets fed SBM, roasted soybean or DEWS.

When comparing nutrients digestibility between d 14 and 28, the digestibility of proximate nutrients was slightly decreased as the level of sodium sulfite increased at d 28 than d 14. And the digestibility of amino acids was also showed the same trend.

In conclusion, addition of sodium sulfite prior to extrusion (1~1.5%) as an extrusion enhancer for SBM was favorable for rate and efficiency of growth in early weaned piglets.

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