USING IMMUNOLOGICAL CRITERIA TO PREDICT UTILIZATION OF SOYBEAN PROTEINS BY THE EARLY-WEANED PIG[1]

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Summary

Two trials were conducted to determine the suitability of soybean products for baby pigs. For trial 1, 40 weanling pigs were orally infused with .01 lb/pig/d of either dried skim milk (control), soybean meal (48% CP), soy protein concentrate, extruded soy protein concentrate, or soy protein isolate from d 7 to 12 of age, weaned at 21 d of age, and fed a diet containing the corresponding protein source until d 7 postweaning. Sows were fed a corn-corn gluten meal-based diet supplemented with lysine and tryptophan to avoid exposure of pigs to soybean proteins. All pigs were sacrificed at 28 d of age. In Trial 2, 48 pigs were utilized, with preweaning treatments identical to those in Trial 1 except the soy protein isolate was not used as a treatment. They were fed a diet containing the same protein source for 2 wk postweaning, then fed a common diet with 4% soybean oil and 1.25% lysine for 3 wk. Growth performance was measured. Results indicated that pigs fed diets containing soybean meal had lower villus height and rate of gain than pigs on any other treatments. There were no differences in villus height and crypt depth among soy protein concentrate, extruded soy protein concentrate, and soy protein isolate. In the growth trial, pigs fed the diet containing extruded soy protein concentrate had the highest ADG compared to other soybean products tested. Decreased villus height and increased serum anti-soy IgG titers, coinciding with inferior performance and presence of residual antigenic protein in the digestive tract of baby pigs fed soybean meal, indicate that conventionally processed, commercial soybean meal retain antigens that cause immunological changes in early-weaned pigs.

(Key Words: Piglet, Soybeans, Hypersensitivity, Small Intestine, Performance.)

Introduction

Research indicates that pigs fed diets containing commercially prepared soybean meal (SBM) have a transient hypersensitivity (allergy) response to soybean proteins. Sensitization and challenge by proteins present in SBM may lead to abnormalities in digestive processes, including disorders in digesta movement and an inflammatory response in the intestinal mucosa of the early-weaned pig. Soybean protein concentrate, prepared by hot aqueous-ethanol extraction of soybean meal, contains a low level of immunologically active glycinin and β-conglycinin. Therefore, the present study was designed to use certain in vitro and in vivo immunological criteria to predict the effects of soybean products on growth performance of pigs.

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Experimental Procedures

Trial 1

Sows were fed a corn-corn gluten meal (14% CP) diet from d 109 of pregnancy through lactation in order to limit passive transfer of maternal anti-soybean protein antibodies to the baby pigs through colostrum.

Forty crossbred pigs from six litters (avg birth wt of 2.9 lb) were utilized. Eight pigs were infused orally every day with .01 lb/pig/d of either dried skim milk, soybean meal (48% CP), soy protein concentrate, extruded soy protein concentrate, or soy protein isolate through a stomach tube from d 7 to d 12 of age. The pigs were weaned on d 21 and kept in an environmentally controlled nursery. From d 21 to 28 of age, they were fed diets containing the corresponding protein sources ad libitum (Table 1). All pigs from each treatment were sacrificed on d 28 of age. Samples of the small intestine were taken for electron and light microscope determination of villus height, crypt depth, and villus area. Ileal digesta samples were collected for determination of titers of residual antigenic proteins. One day prior to sacrifice, blood samples were taken from the jugular vein to measure immunoglobulin G (IgG) titers to the soybean proteins, glycinin, and β-conglycinin.

Trial 2

Forty-eight weanling pigs (21 d of age and avg initial wt of 10.3 lb) were utilized to determine the effect of dried skim milk, soybean meal, soy protein concentrate, and extruded soy protein concentrate on starter pig performance and apparent digestibilities of dry matter (DM) and nitrogen (N). Pigs were allotted by litter, sex, and weight to one of the four dietary treatments. Sows were treated as described in Trial 1. The pigs were orally infused with one of the four protein sources (.01 lb/d) from d 7 through d 12 of age and fed a diet containing the same protein source for 2 wk postweaning; then all pigs were fed the same corn-soybean meal diet containing 4% soybean oil and 1.25% lysine for 3 wk. Four pens per treatment were used, with three pigs per pen. Pigs were housed in an environmentally controlled nursery in pens (4 ft × 5 ft) equipped with a woven wire floor, nipple waterers, and four-hole self-feeders. Feed and water were offered ad libitum.

For the first 11 d of the study, pigs were fed a diet containing .25 % chromic oxide. At d 11, fecal samples were collected from pigs by rectal massage, frozen, and stored for later analysis. Apparent digestibility of DM and N were calculated using chromic oxide as an indigestible marker. Antisoy-antibody titers and skin-fold thickness were also measured at d 7 postweaning.

Results

Pigs fed soybean meal had shorter villus height and greater crypt depth (Table 2) than pigs fed either dried skim milk or the other soybean products ($P<.01$). Pigs fed soybean meal had less ($P<.01$) villus area than pigs fed either dried skim milk or the other soybean products tested. Pigs dosed with soybean meal prior to weaning, and then fed a diet containing soybean

Table 1. Diet Composition, %[a]

Ingredient, %	Milk protein (control)	Soybean meal	Soy protein concentrate	Extruded soy protein concentrate	Soy protein isolate
Ground corn	10.00	7.50	7.50	7.50	7.50
Oat groats	29.13	11.69	27.08	27.08	32.54
Dried skim milk	35.00				
Dried whey	20.00				
Soybean meal (48% CP)		38.13			
Soy protein concentrate			24.07		
Extruded soy protein concentrate				24.07	
Soy protein isolate					21.06
Dicalcium phosphate	.24	2.26	2.29	2.29	1.90
Limestone	.26	.41	.39	.39	.80
Fat[b]	4.78	7.74	6.37	6.37	3.86
Trace mineral[c]	.12	.12	.12	.12	.12
Vitamin premix[d]	.09	.09	.09	.09	.09
Lactose	31.50	31.50	31.50	31.50	31.50
L-lysine.HCL	.10	.10	.13	.13	.03
Copper sulfate[e]	.09	.09	.09	.09	.09
Salt	.35	.35	.35	.35	.35
Santoquin-66	.02	.02	.02	.02	.02
Total	100	100	100	100	100

[a]All diets formulated to contain 1.35% lysine, .8% Ca, .7% P, and 3.5 Mcal ME per kg of diet.
[b]Supplemental fat in each diet included 2% soybean oil and the rest was pork fat.
[c]Provided the following in the complete diet (ppm): Zn, 70; Fe, 50; Mn, 25; Cu, 5; Co, .5; I, .7; Se, .3.
[d]Provided the following per lb of complete diet: Vitamin A, 2,000 IU; vitamin D3, 20 IU; vitamin E, 6.67 IU; vitamin K, 1.32 mg; riboflavin, 2.0 mg; niacin, 12.0 mg; d-pantothenic acid, 8.0 mg; vitamin B 12, 8 μg.
[e]Supplied complete diet with 240 ppm supplemental copper.

meal after weaning showed high titers of immunoglobulin G antibodies against glycinin and β-conglycinin (Table 2).

Pigs fed a diet containing soybean meal had lower ($P<.05$) ADG and higher F/G than pigs fed the diet containing dried skim milk (Table 3) at 2 wk postweaning. Pigs treated with extruded soy protein concentrate had higher ($P<.01$) ADFI than pigs fed dried skim milk. Pigs given soybean protein concentrate had poorer ($P<.05$) F/G than pigs given dried skim milk. There were no differences in ADG, ADFI, and F/G among the treatments from 3 to 5 wk

Table 2. The Effect of Soybean Protein Products on Gut Morphology of Pigs

Item	Milk protein (control)	Soybean meal	Soy protein concentrate	Extruded soy protein concentrate	Soy protein isolate	SE
Villus height, μm[a]	266.2	175.0	207.3	230.0	216.8	47.1
Crypt depth, μm[b]	198.0	222.4	214.1	195.9	189.7	33.7
Villus area, μm^2[c]	26915.0	16495.0	22191.3	21563.1	19068.1	6941.0
Anti-soy, IgG (log 2)	3.86	6.67	3.83	4.25	2.56	1.3

[a]Milk > soybean meal, soy protein concentrate, extruded soy protein concentrate and soy protein isolate ($p<.01$); Soybean meal < milk protein, soy protein concentrate, extruded soy protein concentrate and soy protein isolate ($P<.01$).

[b]Soybean meal > milk protein, soy protein concentrate, extruded soy protein concentrate, and soy protein isolate ($P<.01$).

[c] Milk protein > soybean meal, soy protein concentrate, extruded soy protein concentrate, and soy protein isolate ($P<.01$).

[d]Soybean meal > milk protein, soy protein concentrate, extruded soy protein concentrate, and soy protein isolate ($P<.01$); extruded soy protein concentrate > soy protein isolate.

postweaning.

At 14 d postweaning, pigs fed a diet containing dried skim milk had higher ($P<.03$) N digestibilities than soybean meal fed pigs (Table 4). Pigs fed a diet containing soybean meal had lower ($P<.04$) DM digestibilities than pigs fed a diet containing extruded soy protein concentrate. Pigs fed both soy protein concentrate and extruded soy protein concentrate had higher ($P<.01$) N digestibilities than those fed soybean meal.

Discussion

The present study showed that pigs dosed with soybean meal at d 7 to d 12, and fed a diet containing soybean meal after weaning had shorter ($P<.01$) villus height and greater crypt depth than those primed with dried skim milk and fed a diet containing dried skim milk postweaning. Pigs treated with milk protein had larger villus area than pigs treated with either soybean meal or the other soybean products. However, pigs given soy protein concentrate, extruded soy protein concentrate, and soy protein isolate and then fed diets containing the corresponding protein sources had larger villus area than those treated with soybean meal, indicating that some antigenic materials were eliminated with special processing techniques. Extrusion processing of the soy protein concentrate (i.e., after alcohol extraction) improved pig performance. Consistent with previous reports, pigs dosed with soybean meal prior to weaning and then fed a diet containing soybean meal after weaning showed high titers of IgG antibodies against dietary soybean proteins.

Table 3. Effect of Soybean Protein Products on Starter Pig Performance

Item	Milk protein	Soybean meal	Soy protein concentrate	Extruded soy protein concentrate	SE
ADG, lb					
Wk 1[a]	.38	.28	.33	.36	.13
Wk 2[b]	.54	.44	.45	.55	.11
Wk 2 to 5	1.02	.96	.95	1.00	.18
Wk 0 to 5	.79	.75	.75	.83	.13
AFI, lb					
Wk 1[c]	.47	.45	.51	.48	.06
Wk 2[d]	.48	.49	.53	.57	.11
Wk 2 to 5	1.70	1.66	1.66	1.69	.20
Wk 0 to 5	1.21	1.21	1.19	1.24	.13
F/G					
Wk 1	1.42	1.96	1.64	1.67	.83
Wk 2[e]	.93	1.17	1.21	1.05	.27
Wk 2 to 5	1.67	1.73	1.75	1.67	.34
Wk 0 to 5	1.53	1.63	1.59	1.54	.27

[a]Milk > soybean meal and soy protein concentrate (P<.08).
[b]Milk > soybean meal (P<.05); extruded soy protein concentrate vs soybean meal and soy protein concentrate (P<.05).
[c]Soy protein concentrate and extruded soy protein concentrate vs soybean meal (P<.04);
[d]Extruded soy protein concentrate vs milk (P<.01).
[e]Milk vs soybean meal (P<.04), milk vs soy protein concentrate, extruded soy protein concentrate (P<.04).
Four replications per treatment with three pigs per pen.

Pigs infused with soybean meal preweaning and then fed a diet containing soybean meal showed poorer growth performance during the 2 wk postweaning compared to pigs fed a diet containing soy protein concentrate. We postulate that antigenic materials remaining in the soybean meal may cause gastrointestinal disorders and damage to villi, influence the digestive process, depress N and DM apparent digestibility, and lower ADG and F/G in pigs.

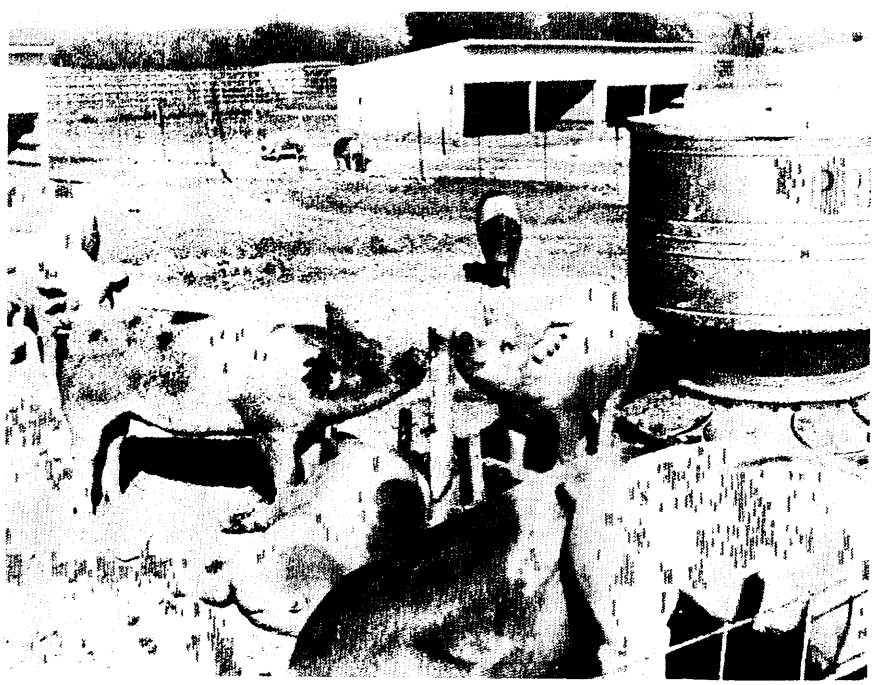
In conclusion, baby pigs dosed with soybean meal and then fed a diet containing soybean meal processed by conventional methods showed decreased growth performance, lowered villus height, and increased serum anti-soy protein IgG titers compared to those fed a diet formulated from milk protein. However, there was no effect on those criteria when pigs were treated with milk protein, soy protein concentrate, extruded soy protein concentrate, or soy protein isolate.

Table 4. Effect of Soybean Protein Products on Dry Matter and Nitrogen Digestibility in Pigs

Item	Milk protein	Soybean meal	Soy protein concentrate	Extruded soy protein concentrate	SE
DM, %[a]	88.5	87.3	88.6	89.8	1.5
N, %[b]	83.0	79.7	81.4	85.7	1.9

[a]Extruded soy protein concentrate > soybean meal (P<.04).
[b]Milk > soybean meal (P<.03); extruded soy protein concentrate > soybean protein concentrate and soybean meal (P<.01).

The study suggests that some antigenic activity may be eliminated with alcohol extraction, especially when followed by extrusion treatment, resulting in improved starter pig growth performance.



Outdoor facilities at the KSU swine farm.