EFFECT OF REPLACING DRIED SKIM MILK WITH SOY PRODUCTS ON FUNCTION AND MORPHOLOGY OF THE SMALL INTESTINE IN NURSERY PIGS

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Summary

Sixty-six pigs (averaging 21 d of age and 11.8 lb) were used in a 7-d experiment to evaluate the effects of specially processed soy products on function and morphology of the small intestine. Treatments were: 1) corn-milk products control; 2, 3, 4, and 5) simple corn-based diets with either soybean meal, soy isolate[2], soy concentrate[3], or modified soy flour[4] as the major protein source; 6) a high nutrient density diet (HNDD) containing 20% dried skim milk and 20% dried whey; 7, 8, and 9) the HNDD with soy isolate, soy concentrate, or modified soy flour plus lactose replacing 100% of the dried skim milk. Xylose absorption was determined from plasma collected on d 6 post-weaning. On d 7 post-weaning, serum was collected for determination of antisoy titers, and four pigs/trt were sacrificed for collection of tissues to determine villus height and crypt depth. The milk diet was more digestible than the other treatments, and the complex diets were more digestible than the simple diets. Nitrogen from soy isolate and concentrate was more digestible than N from soy flour in the simple diets. Pigs fed diets with the specially processed soy products had lower antisoy titers than pigs fed diets with soybean meal. However, diets with the specially processed soy products resulted in lower xylose absorptions than the diet with soybean meal. Pigs fed the corn-milk products control tended to have longer villi and lower crypt depths than pigs fed the other treatments. In conclusion, it appears that the specially processed soy products were better utilized than soybean meal but of lower nutritional value than milk products. Of the specially processed soy products, soy protein isolate had the greatest nutritional value in simple diets, but the soy products were of similar nutritional value in the complex diets.

(Key Words: Starter, Performance, SBM, Process, Soybean, Digestion.)

Introduction

Previous research indicates that the presence of dietary antigens is associated with villus atrophy and increased crypt cell mitosis (which increases the crypt depth), both of which affect the absorptive capability of the gut. The major storage proteins of the soybean (glycinin and β-conglycinin) are suggested as two such dietary antigens. Recent interest in replacing milk products in weanling pig diets with less expensive soy products has led to concern about mild allergic responses to soy proteins causing malabsorption in the small intestine. This

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experiment was designed to test the effects of replacing the protein from milk products with specially processed soy products (i.e., soy isolate, soy concentrate, or modified soy flour) on the functional integrity of the small intestine in weanling pigs.

Procedures

Sixty six crossbred pigs were weaned at 21 d of age (avg wt=11.8 lb) and started immediately on the experimental diets. Pigs were housed (six per pen) in an environmentally controlled nursery (4 × 5 ft pens) equipped with woven wire flooring. Each pen had a self-feeder and nipple waterer so feed and water could be consumed ad libitum.

The experimental diets (Table 1) were fed for the duration of the 7-d experiment. Treatments were: 1) corn-milk products control; 2,3,4, and 5) simple corn-based diets with either soybean meal, soy isolate, soy concentrate or modified soy flour as the major protein source; 6) a HNDD with 20% dried skim milk and 20% dried whey; 7, 8, and 9) the HNDD with soy isolate, soy concentrate, or modified soy flour plus lactose replacing 100% of the dried skim milk. The diets were fed in mash form and contained .25 % chromic oxide as an indigestible marker for determination of apparent digestibility of N and DM.

Table 1. Diet Composition[a]

		Simple	Complex
Ingredient, %	Milk	Soybean meal	HNDD
Corn	17.14	17.09	35.49
Soybean meal (48% CP)	—	27.33	16.60
Dried skim milk	30.00	—	20.00
Dried whey	20.00	—	20.00
Lactose	—	30.10	—
Corn gluten meal	15.00	15.00	—
Cornstarch	10.00	—	—
Soy oil	5.00	5.00	5.00
Lysine-HCl	.20	.32	—
Vit/Min/Antibiotic	2.41	4.91	2.66
Chromic oxide	.25	.25	.25
Totals	100.00	100.00	100.00
Calculated composition, % [b]			
Lactose, %	30.10	30.10	25.00
g Lysine/Mcal DE	3.43	3.45	3.56

[a]Cornstarch, and either soy isolate, soy concentrate, or modified soy flour replaced the soybean meal in the simple diets. Lactose and either soy isolate, soy concentrate, or modified soy flour replaced the skim milk in the complex diets.
[b]Formulated to contain 23.5% crude protein for the simple diets and 21.0% crude protein for the complex diets, and all diets contained 1.5% lysine, .9% Ca, and .8% P.

On d 6 of the experiment, a solution of xylose and water (10% w/v) was infused into the stomach of each pig at the rate of .45 ml/lb body weight. The pigs were fasted for 12 h and denied water for 4 h prior to infusing to ensure an empty stomach and intestinal tract. Blood was collected 1 h post-infusion, and the plasma was analyzed for xylose concentration.

On d 7, serum samples were collected for determination of antisoy antibody titers using an ELISA procedure. Four pigs from each treatment were sacrificed, and tissue samples were obtained from the duodenum 6 in. from the pyloric valve. Villus height and crypt depth were determined by light microscopy. Also, fecal samples were collected from the distal colon for determination of apparent digestibility of N and DM.

Results and Discussion

Chemical composition of the protein sources used in the experiments is given in Table 2. The DM and CP values are those typical for the various protein sources, with the exception of the soy concentrate that was lower in CP than the expected 70% CP. The amino acid values are also those typical for the various protein sources, and as one would expect, as protein concentration of the products goes down (from 94.5 to 47.4 %) so does the concentration of lysine (from 5.9 to 3.1 %) and the other amino acids. Analyzed values for glycinin and β-conglycinin antigenic activity indicated that soybean meal had extremely high activity (i.e., too high to quantify), and the other products had little to no activity.

Table 2. Chemical Composition of Protein Sources

Item	Dried skim milk	Dried whey	Soybean meal	Soy isolate	Soy concentrate	Modified soy flour
DM, %[a]	94.0	93.0	90.0	94.0	94.0	93.0
CP, %[a]	34.3	13.3	47.4	94.5	58.7	55.3
Amino acids, %[b]						
Lysine	2.5	.9	3.1	5.9	3.8	3.4
Tryptophan	.4	.2	.7	.9	.8	.6
Threonine	1.6	.9	1.9	3.8	2.3	2.3
Glycinin titer, log[2a]	0	0	>10	0	0	0
β-conglycinin titer, log[2a]	0	0	>10	5	0	0
Lactose, %[b]	52.0	74.5	—	—	—	—
Ca, %[b]	1.28	.86	.26	.09	.45	.34
P, %[b]	1.02	.76	.64	.78	.87	.70

[a]Analyzed values.
[b]Values from NRC (1988) and ADM Technical Report (1989).

Data from the experiment are given in Table 3. The corn-milk products control had greater DM digestibility than the other diets (P<.02). The simple diets had lower N (P<.006) and DM (P<.07) digestibilities than the complex diets. Of the experimental soy products, the isolate and concentrate had higher N digestibility than the modified soy flour (P<.10), with this response being pronounced only in the simple diets.

Pigs fed the corn-soybean meal and HNDD diets had higher (P<.02) antibody titers for glycinin and β-conglycinin than pigs fed diets with soy isolate, soy concentrate, and modified soy flour. The trend for higher titers for pigs given the complex diets vs the simple diets suggests that the presence of soybean meal in the diets, even at low levels, still resulted in elevated anti-soy titers in blood serum. Pigs fed the corn-milk products diet had longer villi (P<.11) and tended to have lower crypt depths than pigs fed the other treatments. The xylose absorption test indicated that pigs fed the complex diets absorbed more xylose than pigs fed the simple diets (P<.05), suggesting a more functional gut wall.

In conclusion, it appears that the specially processed soy products were better utilized and less allergenic than soybean meal in simple diets, but were of lower nutritional value than milk products. The soy isolate and soy concentrate were better utilized than modified soy flour in the simple diets, but those differences were not apparent in the complex diets.

Table 3. Effects of Soy Products on Nutrient Digestibility and Intestinal Morphology in Nursery Pigs[a]

		Simple				Complex				
Item	Milk	Soybean meal	Soy isolate	Soy conc.	Modified soy flour	HNDD	HNDD + Isolate	HNDD + Conc.	HNDD + Flour	CV
Digestibility, %										
N[b]	71.2	52.1	68.1	63.0	54.1	74.6	65.3	68.0	65.3	13.0
DM[c]	85.1	72.3	81.5	79.0	76.1	82.8	78.9	80.9	79.1	5.8
Blood criteria										
Xylose absorption, $mmol \cdot l^{-1}$ [d]	.60	.64	.54	.60	.52	1.13	.53	.45	.85	43.4
Anti-soy titers, log^2 [e]	5.15	7.53	5.94	5.53	4.36	7.92	5.53	6.74	6.74	29.9
Morphology										
Villus height, µm[f]	252	209	223	216	222	232	195	213	197	20.4
Crypt depth, µm[g]	336	336	347	347	347	337	345	361	360	13.3
Height: Depth[h]	.75	.62	.64	.62	.64	.69	.57	.59	.55	22.1

[a] Pigs were 21 d of age at initiation of the experiment (11.8 lb) and were fed the dietary treatments for 7 d.
[b] Simple vs Complex (P<.006), Iso & Conc vs Flour (P<.10), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.02).
[c] Milk vs others (P<.02), Simple vs Complex (P<.07), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.02).
[d] Simple vs Complex (P<.05), SBM & HNDD vs Iso & Conc & Flour (P<.002), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.03), Iso & Conc vs Flour X Simple vs Complex (P<.05).
[e] SBM & HNDD vs Iso & Conc & Flour (P<.02).
[f] Milk vs others (P<.11).
[g] No treatment effect (P>.43).
[h] No treatment effect (P>.13).