ROASTING AND EXTRUDING AFFECT NUTRIENT UTILIZATION FROM SOYBEANS IN 10- AND 20-LB PIGS

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Summary

Ninety nursery pigs were used in two metabolism experiments to determine the effects of roasting and extruding on the nutritional value of Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor. Treatments for both experiments were: 1) soybean meal; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. The roasting and extrusion treatments were accomplished with a Roast-A-Tron® roaster and an Insta-Pro® extruder. Diets were the soybean preparations (96.5% of the diet) with only vitamins and minerals added as needed to meet or exceed NRC requirements. Daily feed allowance was 5% of initial body wt given as three equal meals. In Exp. 1, 50 weanling pigs (10.4 lb average body wt and 21 d average age) were used. Apparent values for N digestibility, biological value (BV), percentage N retention, gross energy (GE) digestibility, and metabolizable energy (ME) were greater for pigs fed extruded soybeans compared to pigs fed roasted soybeans. Also, N digestibility, BV, and percentage N retention were greater for pigs fed -K soybeans compared to those fed +K soybeans. In Exp. 2, 40 pigs (21.4 lb average body wt and 35 d average age) were allowed to adjust to the nursery environment before use in the experiment. In general, the pigs in Exp. 2 (i.e., the older pigs) had greater utilization of nutrients from all of the soybean products than the younger pigs used in Exp. 1. Digestibilities of DM, N, and GE were greater for pigs fed -K soybeans compared to those fed +K soybeans, and extruded soybeans gave greater digestibilities of DM, N, and GE compared to roasted soybeans. Also, percentage N retention and percentage ME were greater for pigs fed extruded soybeans were greater than for pigs fed roasted soybeans. In conclusion, extruded and -K soybeans were of greater nutritional value than roasted and +K soybeans for 10- and 20-lb nursery pigs.

(Key Words: Pig, Soybean, Roast, Extrude, Metabolism, Nitrogen Retention.)

Introduction

The major constituent that is believed to limit the nutritional value of raw soybeans is a group of small proteins collectively called trypsin inhibitors. Previous research at KSU (Reports of Progress No. 610, page 52 and No. 641, page 40) indicated that pigs fed soybeans without the Kunitz trypsin inhibitor grew faster than pigs fed soybeans with the Kunitz trypsin inhibitor. In other experiments, extrusion processing was superior to roasting for maximizing growth performance and nutrient digestibility in weanling pigs. However, the quantitative effects of roasting and dry extrusion on nutrient utilization (e.g., biological value and metabolizable energy) remain to be determined. Thus, the objectives of the experiments reported herein were to determine the effects of roasting and extruding on the nutritional value of Williams 82 soybeans with (+K) or without (-K) gene expression for the Kunitz trypsin inhibitor on nursery pigs of various ages.

Procedures

Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor were either roasted or extruded and compared to a soybean meal-based control diet (Table 1). The roasting and extrusion treatments were those deemed usual for soybean processing (i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 270°F in a Roast-A-Tron® roaster vs a throughput of approximately 1,500 lb/h and an average barrel temperature of 325°F in an Insta-Pro® dry-extruder). Treatments were: 1) soybean meal; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. Diets were the soybean preparations with only vitamins and minerals added as needed to meet or exceed NRC (1988) requirements. Chromic oxide was added as .25% of the diets to serve as an indigestible marker.

Table 1. Diet Composition (Exp. 1 and 2)

Item	%
Soybean meal[a]	96.49
Monocalcium phosphate	.86
Limestone	1.40
Salt	.30
KSU vitamin premix	.25
KSU mineral premix	.15
KSU selenium premix	.05
Antibiotic[b]	.50
Total	100.00

[a]Roasted and extruded +K and -K soybeans were added in place of soybean meal.
[b]Provided the following per ton of complete diet: 100 g of chlortetracycline, 100 g of sulfathiazole, and 50 g of penicillin.

For Exp. 1, 50 weanling pigs (10.4 lb average body wt) were used in a 10-d metabolism experiment. The pigs were housed in individual cages equipped with woven-wire flooring, and the room was environmentally controlled. The pigs were fed dried skim milk for 3 d of adjustment to the cages and then the experimental diets for 3 d of adjustment before any collections were made. Daily food allowance was 5% of body wt and was divided into three equal feedings given at 7:00 a.m, 1:00 p.m., and 7:00 p.m. Water was consumed on an ad libitum basis. Urine and feces were collected for 4 d. Total urine volume was recorded twice daily and 5% of each collection was kept and frozen for analysis of GE and N. Feces and orts were collected twice daily and frozen. Concentrations of Cr, DM, N, and GE in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N, and GE using the indirect ratio method. Also, concentrations of N and GE in the urine were determined to allow calculation of apparent BV, N retention, and ME. The data were analyzed using the orthogonal comparisons: 1) soybean meal vs extruded and roasted soybeans, 2) -K vs +K soybeans, 3) extruded vs roasted soybeans, and 4) -K vs +K × extruded vs roasted soybeans.

For Exp. 2, the soybean treatments, processing conditions, and animal care were the same as in Exp. 1. However, older pigs (21.4 lb average body wt and 35 d average age) were used in the 10-d metabolism experiment. Analyses of diets, feces, urine samples and the resulting data were as described for Exp. 1.

Results and Discussion

The crude protein and, thus, amino acid concentrations of soybean meal were greater than those of the roasted and extruded soybeans (Table 2). Trypsin inhibitor activities were lower for the -K soybeans than for the +K soybeans, but urease activities were similar among the soybean preparation. Soybean antigenic activity (i.e., for glycinin and β-conglycinin) was less for the heat-treated soybeans compared to soybean meal.

For Exp. 1, pigs fed extruded soybeans had longer villi ($P<.05$) than pigs fed roasted soybeans, but no differences occurred in crypt depth or antisoy titers among pigs fed the various soy products (Table 3). The greater villus height for pigs fed extruded soybeans would tend to increase absorptive surface area and possibly indicates improved functional status of the small intestine for those pigs compared to pigs fed roasted soybeans.

Digestibilities of DM and N (Table 4) were not different for soybean meal compared to the other treatments (P>.11). However, digestibility of GE from soybean meal tended to be greater (P<.10) than for the full-fat soy products because of the relatively low digestibilities for roasted soybeans. The full-fat soy products supported greater daily retention of N (P<.01) and had 218 kcal/lb more ME than soybean meal. The higher ME would be expected because of the fat content of the full-fat soybean preparation.

The -K soybeans had greater digestibility of N and BV than the +K soybeans (P<.05). Also, percentage N retention, daily retention of ME, and ME of the soy products themselves were greater (P<. 05) for -K compared to +K soybeans.

Extrusion improved nearly all of the response criteria, with 39% greater daily N retention and 490 kcal/lb more ME in the soy products with extrusion processing compared to roasting.

For Exp. 2, digestibilities of DM, N, and GE were greater (P<.05) for soybean meal compared to the full-fat soybean preparations (Table 5). As in Exp. 1, these differences were due to the relatively low digestibilities for the roasted soybeans. The full-fat soy products had 205 kcal/lb more ME than soybean meal (P<.001), as might be expected because of their greater fat content (18.8 vs .9%).

Digestibilities of DM, N, and GE were greater for pigs fed -K soybeans compared to pigs fed +K soybeans (P<.001). Also, the -K soybeans supported greater percentage N retention (P<.01) and percentage ME (P<.05) compared to +K soybeans.

Extrusion improved apparent digestibilities of DM, N, and GE by 11, 8, and 18% compared to roasting (P<.001). Responses for other measurements of nutritional value (i.e., N utilization and ME value) were similar to those for digestibility, with consistently greater utilization of nutrients from extruded soybeans compared to roasted soybeans.

In conclusion, the roasted and extruded soybean preparations were utilized well by the pigs in our experiments. However, as in previous growth assays completed here at KSU, -K soybeans tended to be of greater nutritional value than +K soybeans, and extrusion processing resulted in marked improvements in nutritional value compared to roasting. Finally, our results indicate that the NRC value of 1,644 kcal/lb for full-fat soy products should be revised to indicate the type of processing used. Using our data for conventional (+K) soybeans, NRC overestimates ME of roasted products by 348 kcal/lb in 10-lb pigs and by 50 kcal/lb in 20-lb pigs. In contrast, the ME value of extruded soybeans is underestimated by 293 kcal/lb in 10-lb pigs and 358 kcal/lb in 20-lb pigs.

Table 2. Chemical Composition of Experimental Ingredients (Exp. 1 and 2)[a]

		+ K		- K	
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded
CP, %	45.1	35.8	36.1	36.5	35.8
Gross energy, kcal/lb	1,798	2,200	2,136	2,182	2,144
Indispensable amino acid, %					
Arginine	3.4	2.5	2.5	2.6	2.5
Histidine	1.2	1.0	0.9	1.0	1.0
Isoleucine	2.1	1.6	1.5	1.6	1.7
Leucine	3.7	2.7	2.7	2.7	2.8
Lysine	3.0	2.1	2.1	2.2	2.1
Methionine	0.7	0.5	0.5	0.5	0.5
Phenylalanine	2.4	1.7	1.7	1.9	1.8
Threonine	1.8	1.4	1.4	1.4	1.4
Tryptophan	0.7	0.5	0.5	0.4	0.5
Valine	2.2	1.7	1.7	1.8	1.7
Dispensable amino acid, %					
Alanine	2.0	1.6	1.5	1.6	1.6
Aspartate	5.4	4.0	4.0	4.1	4.0
Cystine	0.8	0.6	0.6	0.6	0.6
Glutamate	8.4	6.0	5.9	6.3	6.2
Glycine	1.9	1.5	1.4	1.6	1.5
Proline	2.5	1.9	1.9	2.1	1.9
Serine	2.3	1.7	1.6	1.8	1.6
Tyrosine	1.7	1.3	1.2	1.3	1.3
Trypsin inhibitor, mg/g	0.9	3.2	2.6	1.3	1.3
Urease activity, Δ pH	0.02	0.12	0.01	0.07	0.01
Glycinin activity, $\log_2$	6	5	4	2	2
β-conglycinin activity, $\log_2$	4	4	2	1	1

[a]Corrected to 90% DM.

Table 3. Intestinal Morphology and Serum Antisoy Titers for Nursery Pigs (10 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 1)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
Villus height, μm[b]	376	354	403	376	413	15.9
Crypt depth, μm	372	356	351	345	336	17.0
Anti-soy titers, $\log_2$	7.0	6.7	6.6	6.5	6.2	18.9

[a]A total of 50 weanling pigs (one pig/pen and ten pens/treatment) was fed from an average initial body wt of 10.4 lb.

[b]Roasted soybeans vs extruded soybeans ($P < .05$).

Table 4. Apparent Nutrient Utilization for Nursery Pigs (10 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 1)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
ADG, lb	.43	.32	.39	.42	.45	37.3
Apparent digestibility, %						
DM[h]	82.3	75.4	80.8	76.3	84.3	6.7
N[dh]	82.6	75.0	81.3	78.5	86.1	7.0
GE[bg]	78.3	70.8	82.8	71.8	83.7	8.3
Biological value, %[de]	63.1	53.8	65.4	67.7	69.9	18.5
N retention, %[df]	47.4	44.6	53.2	53.6	60.4	21.6
N retention, g/d[c]	3.7	3.3	5.4	4.4	5.3	31.1
ME, %[h]	71.0	63.0	78.3	68.1	79.3	8.6
ME retention, kcal/d[dh]	369	347	533	418	549	26.8
ME, kcal/lb[cdi]	1,424	1,296	1,937	1,499	1,837	12.4

[a]A total of 50 weanling pigs (one pig/pen and ten pens/treatment) was fed from an average initial body wt of 10.4 lb.
[bc]SBM vs other treatments ($P < .10$ and .05, respectively).
[d]-K soybeans vs +K soybeans ($P < .05$).
[efgh]Roasted soybeans vs extruded soybeans ($P < .10$, .05, .01, and .001, respectively).
[i]-K vs +K × roasted vs extruded soybeans ($P < .05$).

Table 5. Apparent Nutrient Utilization for Nursery Pigs (20 lb) Fed Conventional (+K) or Low-Trypsin Inhibitor (-K) Soybeans either Roasted or Extruded (Exp. 2)[a]

		+ K		- K		
Item	Soybean meal	Roasted	Extruded	Roasted	Extruded	CV
ADG, lb[i]	.79	.49	.75	.62	.84	31.7
Apparent digestibility, %						
DM[cgi]	83.2	71.6	81.0	78.1	84.7	4.7
N[bgjk]	86.8	75.6	85.3	84.1	86.4	4.4
GE[cgj]	83.6	68.1	82.8	75.5	86.6	5.5
Biological value, %	73.7	73.5	74.1	75.3	80.9	10.5
N retention, %[fh]	63.9	56.0	64.1	63.2	69.0	11.7
N retention, g/d[b]	16.5	12.4	13.4	13.5	15.0	19.1
ME, %[bej]	81.5	66.2	81.4	73.7	84.7	8.6
ME retention, kcal/d[f]	1,261	1,290	1,480	1,325	1,547	26.8
ME, kcal/lb[djk]	1,618	1,594	2,002	1,759	1,937	12.4

[a]A total of 40 pigs (one pig/pen and eight pens/treatment) was fed from an average initial body wt of 21.4 lb.
[bcd]SBM vs other treatments ($P < .05$, .01, and .001, respectively).
[efg]-K soybeans vs +K soybeans ($P < .05$, .01, and .001, respectively).
[hij]Roasted soybeans vs extruded soybeans ($P < .05$, .01, and .001, respectively).
[k]-K vs +K × roasted vs extruded soybeans ($P < .01$).