Extrusion Processing of Low-Inhibitor Soybeans Improves Growth Performance of Early-Weaned Pigs

I. H. Kim*, J. D. Hancock, D. B. Jones and P. G. Reddy[1]
Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS 66506-0201, USA

ABSTRACT : Two experiments were conducted to determine the effects of roasting and extrusion on nutritional value of conventional and low-inhibitor soybeans for nursery-age pigs. In Exp. 1, 100 weanling pigs (7.5 kg average initial BW) were used in a 35-d growth assay to determine the effects of processing method (roasting in a Roast-A-Tron™ roaster vs extrusion in an Insta-Pro™ extruder) on the nutritional value of Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor. Treatments were 48% soybean meal with added soybean oil, +K roasted, +K extruded, -K roasted and -K extruded. All diets were formulated to contain 3.5 Mcal DE/kg, with 0.92% lysine for d 0 to 14 and 0.76% lysine for d 14 to 35 of the experiment. The lysine concentrations were 80% of NRC (1988) recommendations to accentuate difference in response to protein quality and lysine availability. For d 0 to 14, pigs fed extruded soybeans (+K and -K) had greater ADG ($p<0.001$), ADFI ($p<0.09$) and gain/feed ($p<0.01$) than pigs fed roasted soybeans. For d 14 to 35 and overall, the same effects were noted, i.e., pigs fed extruded soybeans had greater ADG, ADFI and gain/feed than pigs fed roasted soybeans ($p<0.03$). Also, pigs fed -K soybeans were more efficient ($p<0.008$) than pigs fed +K soybeans. In Exp. 2, 150 weanling pigs (7.0 kg average initial BW) were used in a 35-d growth assay. All diets were formulated to contain 3.5 Mcal DE/kg, with 1.25% lysine for d 0 to 14 and 1.10% lysine for d 14 to 35 of the experiment. The lysine concentrations were formulated to be in excess of NRC recommendation to determine if differences in nutritional value of the soybean preparations could be detected in protein-adequate diets. For d 0 to 14 ($p<0.06$), 14 to 35 ($p<0.03$) and 0 to 35 ($p<0.02$), pigs fed extruded soybeans had greater ADG and gain/feed than pigs fed roasted soybeans. Apparent digestibilities of DM, N and GE were greater for diets with extruded soybeans than diets with roasted soybeans, and diets with soybean meal and soybean oil were intermediate. The response to extrusion processing was greater with -K than +K soybeans, with pigs fed extruded -K soybeans having the greatest growth performance and nutrient digestibilities and lowest skin-fold thickness of any treatment. In conclusion, extrusion yielded a full-fat soy product of greater nutritional value than roasting. Also, selection against genetic expression of the Kunitz trypsin inhibitor improved nutritional value of the resulting soybean preparations. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1251-1257*)

Key Words : Weanling Pigs, Soybeans, Extrusion, Roasting, Trypsin Inhibitor, Immunology

INTRODUCTION

Soybean meal is the most commonly used source of supplemental protein in diets for nonruminants because of its excellent amino acid profile and dependable supply. Whole soybean products also are commonly used because the oil content of whole soybeans increases the energy density of the diet. However, raw soybeans contain several antinutritional factors, in particular protease inhibitors, which depress growth rate and decrease efficiency of nutrient utilization when fed to swine (Yen et al., 1977). Fortunately, most of the antinutritional factors found in soybeans (at least those in biologically significant concentrations) are heat labile. Indeed, the nutritional superiority of boiled soybeans vs raw soybeans for rats was recognized by more than 75 years ago (Osborne and Mendel, 1917). In an attempt to further improve the nutritional value of heated soybean products or even to decrease the need for heat treatment, plant breeders have identified and developed soybean genotypes with minimal trypsin inhibitor activity (Hymowitz, 1984).

In various feeding experiments, these low-inhibitor soybeans were superior protein source to conventional soybeans for chicks (Burnham, 1995), nursery pigs (Hancock et al., 1989; Kim et al., 1999a) and growing-finishing pigs (Cook et al., 1988; Giesemann et al., 1989; Hancock et al., 1991). In each of these experiments, heat treatment was required to achieve full nutritional value of the soybean preparations. Also, the attempt was made to ensure that the response to different forms of heat treatment was consistent for conventional and low-inhibitor soybeans.

Thus, the objective of the research reported herein was to determine the effects of roasting and extrusion on nutritional value of conventional and low-inhibitor soybeans for nursery-age pigs.

* Corresponding Author: I. H. Kim. Department of Animal Science, Dankook University, Cheonan, Korea. Tel: 82-417-550-1818, Fax: 82-417-553-1618.
[1] School of Veterinary Medicine, Tuskegee University, Alabama, USA.
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Table 1. Composition of diets for Exp. 1 (as-fed basis), %[a]

	d 0 to 14			d 14 to 25		
	Soybean meal	+K roasted	-K roasted	Soybean meal	+K roasted	-K roasted
Ingredient						
Soybean meal	20.27	-	-	17.62	-	-
Soybean oil	2.50	-	-	2.44	-	-
Whole soybeans[b]	-	24.55	24.85	-	22.00	22.25
Cornstarch	2.21	0.30	-	2.11	0.24	-
Corn	51.38	51.38	51.38	68.85	68.85	68.85
Dried whey	20.00	20.00	20.00	5.00	5.00	5.00
MCP	1.78	1.68	1.68	1.70	1.60	1.59
Limestone	0.86	0.89	0.89	0.98	1.01	1.01
Salt	0.20	0.20	0.20	0.30	0.30	0.30
Vit.-Min. Mix.[c]	0.40	0.40	0.40	0.40	0.40	0.40
Cooper sulfate	0.10	0.10	0.10	0.10	0.10	0.10
Antibiotic[d]	0.50	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a] Soybean treatments, cornstarch, monocalcium phosphate, and limestone were adjusted so that all diets supplied 0.92% lysine, 3.50 Mcal DE/kg, 0.90% Ca and 0.80% P for d 0 to 14 and 0.76% lysine, 3.49 Mcal DE/kg, 0.80% Ca and 0.70% P for d 14 to 35.

[b] Extruded soybeans were added to replace the roasted soybeans on a CP basis (analyzed values).

[c] Provided the following per kilogram of complete diet: 5,512 IU of vitamin A; 551 IU of vitamin D_3; 22 IU of vitamin E; 2.2 mg of vitamin K (as menadione bisulfite complex); 5.5 mg of riboflavin; 30.3 mg of niacin; 13.8 mg of pantothenic acid (as d-calcium pantothenate); 27.6 μg of vitamin B_{12}.; 551 mg of choline; 100 mg of Mn; 100 mg of Fe; 100 mg of Zn; 40 mg of Ca; 10 mg of Cu; 1.0 mg of Co; 3.0 mg of I; and 0.30 mg of Se.

[d] Provided the following per kilogram of complete diet: 110 mg of chlortetracycline; 110 mg of sulfathiazole; and 55 mg of penicillin.

MATERIALS AND METHODS

1. Experiment 1

Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor were either roasted or extruded and incorporated into corn-based diets with 20% dried whey (table 1). The roasting and extrusion treatments were those deemed usual for soybean processing, i.e., a throughput of approximately 454 kg/h and an average exit temperature of 118℃ in a Roast-A-Tron™ (Blount, IN) roaster vs a throughput of approximately 680 kg/h and an average barrel temperature of 143℃ in an Insta-Pro™ (Triple F, IA) dry-extruder.

One hundred crossbred (Yorkshire×Duroc Hampshire×Chester White rotational cross) pigs (21 d of age and 7.5 kg average BW) were weaned and allotted to pens on the basis of weight, sex and ancestry. Treatments were 1) 48% soybean meal with added soybean oil, 2) +K roasted, 3) +K extruded, 4) -K roasted and 5) -K extruded. All diets were formulated to contain 0.92% lysine, 3.5 Mcal DE/kg, 0.90% Ca and 0.80% P for d 0 to 14 and 0.76% lysine, 3.5 Mcal DE/kg, 0.80% Ca and 0.70% P for d 14 to 35. The diets were fed in meal form and formulated to be slightly deficient in lysine to ensure that differences in protein quality and lysine availability would be detected.

The pigs were housed (four pigs per pen and five pens per treatment) in an environmentally controlled nursery equipped with a woven-wire floor. Each pen (1.2 m×1.5 m) had a self-feeder and nipple waterer so feed and water could be consumed ad libitum. Room temperature was 32, 31, 28, 26 and 22℃ for wk 1 to 5, respectively. On d 14 of the experiment, fecal samples were collected from three pigs per pen by rectal massage, pooled within pen, dried and ground. Laboratory analyses of feed and feces included DM and N (AOAC, 1990) and Cr concentrations were determined using by atomic absorption (Model No. 1475, Varian Techtron, Springvale, Australia) spectrophotometry (Williams et al., 1962). Apparent DM and N digestibilities were determined using the indirect ratio method with Cr as the indigestible marker. Trypsin inhibitor concentrations were determined by the procedure of Hamerstrand et al. (1981). Finally, the biological activity of glycinin and β-conglycinin were determined using the procedure of P. G. Reddy (personal communication, Tuskegee Univ.).

Data were analyzed as a randomized complete block design using the GLM procedure of SAS (1988), with pen as the experimental unit. Response

Table 2. Composition of diets for Exp. 2 (as-fed basis), %[a]

	d 0 to 14			d 14 to 25		
	Soybean meal	+K roasted	-K roasted	Soybean meal	+K roasted	-K roasted
Ingredient						
Soybean meal	31.05	-	-	29.43	-	-
Soybean oil	2.92	-	-	2.84	-	-
Whole soybeans[b]	-	38.74	37.25	-	36.72	35.31
Cornstarch	4.84	-	1.44	4.52	-	1.41
Corn	37.36	37.36	37.36	54.00	54.00	54.00
Dried whey	20.00	20.00	20.00	5.00	5.00	5.00
MCP	1.64	1.46	1.54	2.01	1.84	1.88
Limestone	0.69	0.94	0.91	0.85	1.09	1.05
Salt	0.20	0.20	0.20	0.30	0.30	0.30
Vit.-Min. Mix.[c]	0.45	0.45	0.45	0.45	0.45	0.45
Cooper sulfate	0.10	0.10	0.10	0.10	0.10	0.10
Antibiotic[d]	0.50	0.50	0.50	0.50	0.50	0.50
Chromic oxide	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a] Soybean treatments, cornstarch, monocalcium phosphate and limestone were adjusted so that all diets supplied 1.25% lysine, 3.53 Mcal DE/kg, 0.90% Ca and 0.80% P for d 0 to 14 and 1.10% lysine, 3.55 Mcal DE/kg, 0.90% Ca and 0.80% P for d 14 to 35.

[b] Extruded soybeans were added to replace the roasted soybeans on a CP basis (analyzed values).

[c] Provided the following per kilogram of complete diet: 5,512 IU of vitamin A; 551 IU of vitamin D_3; 22 IU of vitamin E; 2.2 mg of vitamin K (as menadione bisulfite complex); 5.5 mg of riboflavin; 30.3 mg of niacin; 13.8 mg of pantothenic acid (as d-calcium pantothenate); 27.6 μg of vitamin B_{12}.; 551 mg of choline; 150 mg of Mn; 150 mg of Fe; 150 mg of Zn; 60 mg of Ca; 15 mg of Cu; 1.5 mg of Co; 4.5 mg of I; and 0.30 mg of Se.

[d] Provided the following per kilogram of complete diet: 110 mg of chlortetracycline; 110 mg of sulfathiazole; and 55 mg of penicillin.

criteria were ADG, ADFI, gain/feed and apparent digestibilities of DM and N. The orthogonal contrasts used to separate treatment means were; 1) soybean meal vs extruded and roasted soybeans; 2) extruded vs roasted soybeans; 3) -K vs +K soybeans; and 4) -K vs +K × extruded vs roasted soybeans.

2. Experiment 2

One hundred fifty crossbred (Yorkshire × Duroc × Hampshire × Chester White rotational cross) pigs (21 d of age and 7.0 kg average BW) were weaned and allotted to pens on the basis of weight, sex and ancestry. Soybean treatments were the same as in Exp. 1, except the diets were formulated to determine the effects of roasting and extruding +K and -K soybeans when fed in protein-adequate diets (i.e., 110 to 115% of NRC recommended lysine concentration). All diets were formulated to contain 1.25% lysine for d 0 to 14 and 1.10% lysine for d 14 to 35. The diets were fed in meal form and formulated to be in excess of NRC (1988) recommendations for all nutrients to ensure that differences in growth performance would not be due to difference in concentration of a limiting amino acids.

The pigs were housed (five pigs per pen and six pens per treatment) and managed as in Exp. 1. Laboratory analyses for trypsin inhibitor concentration, glycinin activity and β-conglycinin activity of the soybean preparations and DM, N and Cr concentrations in the diets and fecal samples were as described for Exp. 1. Additionally, GE concentrations of the diets and fecal samples were determined by bomb calorimetry to allow calculation of DE concentrations in the diets. On d 6 of the experiment, purified soybean protein (1 mg/mL) and physiologic saline were injected intradermally (0.5 mL) into the skin of the flank (twelve pigs/treatment). Skin-fold thickness was measured 24 h later using a constant pressure dial micrometer (Blecha et al., 1983). Results were expressed as the increase in skin-fold thickness on d 7 compared to that from an injection of saline.

The data were analyzed as a randomized complete block design using the GLM procedure of SAS (1988). Response criteria were ADG, ADFI, gain/feed, apparent digestibilities of DM, N and GE and skin-fold thickness. Orthogonal contrasts used to separate treatment means were: 1) soybean meal vs extruded and roasted soybeans; 2) extruded vs roasted soybeans; 3) -K vs +K soybeans; and 4) -K vs +K × extruded vs roasted soybeans.

RESULTS AND DISCUSSION

1. Experiment 1

Chemical composition of the soybean preparations is given in table 3. Dry matter content was similar among the soybean preparations. The protein content of the soybean meal was higher (49%) than that of the roasted and extruded soybeans (37 to 40%), with all values similar to those expected (NRC, 1988). Trypsin inhibitor activities were lower for the -K soybeans than for the +K soybeans, with values of 1.3 and 2.0 mg/g. This was expected because the Kunitz inhibitor accounts for approximately half of the total trypsin inhibitor activity in raw soybean seeds. Soybean antigenic activity (i.e., glycinin and β-conglycinin activity) was reduced by extrusion processing compared to roasting and soybean meal. The nutritional value of soybeans is limited by various antinutritional factors such as trypsin inhibitors (Rackis et al., 1975; Anderson et al., 1979), hemagglutinin (Liener and Pallansch, 1952) and lectins (Liener, 1976; Ronnenkamp, 1977).

Fortunately, these antinutritional factors are typically heat labile and full-fat soybean preparations can be processed for use in animal feeding in several ways including boiling, steaming, autoclaving, roasting and extrusion (Lepley, 1983; Nelson et al., 1987; Cera et al., 1990; Hancock et al., 1990a, 1990b; Kim et al., 1995, 1999a, 1999b). Hancock et al. (1990a) suggested that heat treatment played the dominant role in reducing trypsin inhibitor activity of raw soyflakes. Herkelman et al. (1992) indicated that trypsin inhibitor activity of low-trypsin-inhibitor soybeans was about one-half that of the raw conventional soybeans and that heated, conventional soybeans contained more trypsin inhibitor activity than the heated, low-trypsin-inhibitor soybeans.

Performance of nursery pigs fed the soybean preparations is given in table 4. For d 0 to 14, pigs fed extruded soybeans ate 15% more feed (386 vs 337 g/d), grew 29% faster (299 vs 232 g/d) and were 13% more efficient (gain/feed of 776 vs 687) than pigs fed roasted soybeans ($p<0.09$). Similar responses were observed from d 14 to 35, so that overall, pigs fed the extruded soybeans ate 13% more feed (808 vs 718 g/d), gained 21% faster (470 vs 389 g/d) and were 8% more efficient (gain/feed of 582 vs 542) than pigs fed roasted soybeans ($p<0.005$). Our data are in agreement with those of Faber and Zimmerman (1973), who indicated that performance of pigs fed diets with extruder-processed soybeans was superior to that of pigs fed diets with infrared roasted soybean. The improved performance of pigs fed the extruded soybeans compared to roasted soybeans corresponds with the 6% improvement in DM digestibility and 6% improvement in N digestibility for diets with the extruded soybeans ($p<0.007$). It is unlikely that the differences for extrusion processing can be attributed to trypsin inhibitor content, because all of the values were acceptably low (i.e., 2.2 or less). Thus, the improvements in nutrient digestibility and performance of pigs fed the extruded soybeans may have resulted from the increased susceptibility to enzyme hydrolysis that is associated with the disruption and structural changes in soybean proteins that are normally attributed to extrusion processing. Also, disruption of the soybean proteins reduced their antigenicity (i.e., reduced glycinin and β-conglycinin activities) which could have contributed to improved gut function and nutrient digestibility. These data are in agreement with those of Kim et al. (1999b), who indicated increased ileal digestibilities of DM, GE, N and amino acids

Table 3. Effect of roasting and extrusion on chemical composition of conventional (+K) and low-inhibitor (-K) soybeans

	Soybean meal	+K		-K	
		Roasted	Extruded	Roasted	Extruded
Experiment 1					
DM, %	92.2	92.7	93.7	93.7	93.5
CP, %	49.4	37.4	38.9	37.8	40.1
Trypsin inhibitor, mg/g[a]	0.5	2.2	1.8	1.1	1.4
Glycinin activity, $\log_2$[b]	>10[c]	>10	4	>10	3
β- conglycinin activity, $\log_2$[b]	>10	>10	7	>10	>10
Experiment 2					
DM, %	92.6	94.7	94.4	94.0	95.2
CP, %	48.9	38.1	44.1	38.9	45.8
Trypsin inhibitor, mg/g[a]	1.0	2.1	2.1	2.8	1.1
Glycinin activity, $\log_2$[b]	11	11	4	11	3
β- conglycinin activity, $\log_2$[b]	11	11	4	11	3

[a] Hamerstrand et al. (1981); [b] P. G. Reddy, personal communication; [c] Activity was too high to quantitate.

when pigs were fed extruded soybeans compared to roasted soybeans. Marty and Chavez (1995) reported that apparent ileal crude protein and amino acid digestibilities for pigs fed extruded soybeans were greater than for pigs fed roasted soybeans.

From d 14 to 35, pigs fed the -K soybeans grew 8% faster (559 vs 518 g/d) and were 7% more efficient (gain/feed of 541 vs 506) than pigs fed the +K soybeans ($p<0.08$). For the overall period (d 0 to 35), pigs fed low-trypsin inhibitor soybeans (-K) had 7% greater gain/feed ($p<0.008$) than pigs fed conventional soybean (+K). Cook et al. (1988) indicated that ADG and gain/feed in finishing pigs fed low Kunitz trypsin inhibitor soybeans were higher than for pigs fed high Kunitz trypsin inhibitor soybeans, but in that experiment the soybeans were not heat treated. In our experiment, apparent digestibilities of DM and N were also improved for -K soybeans compared to +K soybeans (i.e., 86.9 vs 82.9% and 84.7 vs 82.0% for DM and N, respectively). Also, the improved nutrition value of the -K soybeans was consistent when roasted or extruded, as indicated by a lack of interaction between soybean type and processing method for any of the response criteria. Thus, even when roasted or extruded, the -K soybeans were of greater nutritional value that +K soybeans. This suggests some other factor(s) than simply trypsin inhibitor differences that is contributing to differences in nutritional value.

2. Experiment 2

DM concentrations were similar among all soybean preparations and protein concentrations were similar to those expected for soybean meal and full-fat soybean products (table 3). Trypsin inhibitor activities were acceptably low, ranging from 1.0 to 2.8 mg/g. Antigenic potential (i.e., glycinin and β-conglycinin activity) of extruded soybeans was less than half that of roasted soybeans and soybean meal.

Pigs fed roasted and extruded soybeans had greater ADG ($p<0.005$) from d 14 to 35 and greater ADFI for d 14 to 35 ($p<0.004$) and overall (d 0 to 35, $p<0.03$) compared to pigs fed soybean meal and soybean oil (table 5). The diet with soybean meal and soybean oil had greater digestibilities of DM ($p<0.03$), N ($p<0.04$) and GE ($p<0.04$) than diets with roasted and extruded soybeans, but these differences were because of the low digestibilities for diets with roasted soybeans. Our data agree with Hanke et al. (1972) who reported that both dry roasted and extruded soybeans appeared to be satisfactory substitutes for soybean meal as sources of supplemental protein for growing pigs.

For d 0 to 14 ($p<0.06$), pigs fed extruded soybeans gained 22% faster (264 vs 216 g/d) and were 31% more efficient (gain/feed of 671 vs 514) than pigs fed roasted soybeans. Similar responses were observed for d 14 to 35 ($p<0.03$), so that overall ($p<0.02$), pigs fed extruded soybeans had 14% greater

Table 4. Performance of nursery pigs fed conventional (+K) or low-inhibitor (-K) soybeans either roasted or extruded (Exp. 1)[a]

	Soybean meal	+K		-K			Contrsts[b]			
		Roasted	Extruded	Roasted	Extruded	SE	1	2	3	4
d 0 to 14										
ADG, g	272	228	298	235	300	7	NS[c]	NS	0.001	NS
ADFI, g	372	338	394	336	377	12	NS	NS	0.09	NS
Gain/feed, g/kg	731	675	756	699	796	14	NS	NS	0.01	NS
d 0 to 14										
ADG, g	536	486	550	500	618	10	NS	0.08	0.001	NS
ADFI, g	1,022	994	1,053	944	1,121	16	NS	NS	0.001	NS
Gain/feed, g/kg	525	489	522	530	551	5	NS	0.007	0.03	NS
d 0 to 14										
ADG, g	430	383	449	394	491	8	NS	NS	0.001	NS
ADFI, g	763	736	790	699	825	13	NS	NS	0.005	NS
Gain/feed, g/kg	564	520	568	564	595	5	NS	0.008	0.002	NS
Apparent digestability (d 14), %										
DM	85.6	80.5	85.3	84.5	89.3	0.7	NS	NS	0.007	NS
N	82.0	80.5	83.5	81.7	81.7	0.5	NS	NS	0.001	NS

[a] A total of 100 weaning pig (average initial BW of 7.5 kg) were fed in a 35-d growth assay (four pigs/pen and six pens/treatment).

[b] Contrasts: 1) soybean meal vs other treatments; 2) -K vs +K; 3) extruded vs roasted; and 4) -K vs +K × extruded vs roasted.

[c] NS = not significant ($p>0.10$).

ADG (420 vs 370 g/d) and were 22% more efficient (gain/feed of 615 vs 504). Digestibilities of DM, N and GE were increased by 9, 13 and 12% when soybeans were extruded vs roasted ($p<0.001$).

An objective of this experiment was to determine if other factors than amino acid content and availability might have contributed to the greater nutritional value of extruded soybeans noted in Exp. 1. In the present experiment, extrusion processing improved growth performance and nutrient digestibility in pigs fed +K and -K soybeans. Additionally, antigenic potential (ELISA determination, log2) was reduced from 11 for roasted soybeans to 3.5 for extruded soybeans. Skin-fold thickness was affected in a similar manner, with a mean of 1.07 mm for roasted soybeans and 0.73 mm for extruded soybeans ($p<0.07$) and was less for pigs given the -K vs +K ($p<0.09$) genotypes. These differences in growth performance and skin-fold thickness infer that residual anti-nutritional factors (e.g., antigencity) contribute to reduced nutritional value of roasted soybeans and soybean meal. According to Li et al. (1991) decreased growth performance should correlate with increased skin-fold thickness. However, this does not rule out the possibility that a delayed-type hypersensitivity response did occur, as described by Newby et al. (1984).

Improved nutritional value of -K vs +K soybeans was apparent primarily when they were extruded and not when roasted. Indeed, pigs fed extruded -K soybeans had numerically the greatest growth performance and nutrient digestibilities of any treatment. These responses were not anticipated for pigs fed protein-adequate diets and did not result from differences in palatability, because pigs fed +K roasted soybeans had the greatest ADFI throughout the experiment. Trypsin inhibitors have been reported to induce allergic responses in humans but have not been implicated as major antigenic factors in livestock. Whether the reduced skin-fold thickness for pigs fed -K soybeans resulted from absence of the Kunitz trypsin inhibitor or some interaction between the glycinin and β-conglycinin of these soybeans with heat processing is not apparent.

IMPLICATIONS

These data suggest that extrusion processing yielded soybean preparations of greater nutritional value than roasting and -K soybeans were greater nutritional value than +K soybeans when roasted or extruded. Furthermore, when pigs were fed protein limiting or protein-adequate diets, extruded -K soybeans were the greatest nutritional value, roasted

Table 5. Performance of nursery pigs fed conventional (+K) or low-inhibitor (-K) soybeans either roasted or extruded (Exp. 2)[a]

	Soybean meal	+K		-K			Contrsts[b]			
		Roasted	Extruded	Roasted	Extruded	SE	1	2	3	4
d 0 to 14										
ADG, g	263	241	250	191	277	11	NS[c]	NS	0.001	NS
ADFI, g	418	468	381	372	404	10	NS	NS	0.09	0.02
Gain/feed, g/kg	629	515	656	513	686	20	NS	NS	0.01	NS
d 0 to 14										
ADG, g	422	481	495	468	554	10	0.005	NS	0.06	NS
ADFI, g	772	981	835	908	922	17	0.004	NS	NS	0.05
Gain/feed, g/kg	547	490	593	515	601	7	NS	NS	0.001	NS
d 0 to 14										
ADG, g	359	384	398	356	442	9	NS	NS	0.02	0.08
ADFI, g	631	776	654	695	713	13	0.03	NS	0.09	0.03
Gain/feed, g/kg	569	495	609	512	620	6	NS	NS	0.001	NS
Apparent digestability (d 14), %										
DM	82.2	75.0	81.7	77.1	83.3	0.5	0.03	NS	0.001	NS
N	78.6	71.3	79.5	69.9	80.6	0.6	0.04	NS	0.001	NS
GE	81.0	72.2	81.2	73.8	82.9	0.6	0.04	NS	0.001	NS
Skinfold thickness, mm	0.78	1.28	0.82	0.85	0.63	0.11	NS	0.09	0.07	NS

[a] A total of 150 weaning pig (average initial BW of 7.0 kg) were fed in a 35-d growth assay (five pigs/pen and six pens/treatment).

[b] Contrasts: 1) soybean meal vs other treatments; 2) -K vs +K; 3) extruded vs roasted; and 4) -K vs +K × extruded vs roasted.

[c] NS = not significant ($p>0.10$).

soybeans were the lowest nutritional value and soybean meal was intermediate.

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