EFFECT OF HEAT TREATMENT ON THE NUTRITIONAL VALUE OF LOW-INHIBITOR SOYBEANS FOR NURSERY, GROWING, AND FINISHING PIGS

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Summary

Two hundred forty nursery pigs (12.8 lb initial wt) were used in a 28-d growth assay to determine the nutritional value of Williams 82 soybeans with (+K) and without (−K) gene expression for the Kunitz trypsin inhibitor. Treatments were soybean type (+K and −K) and heat treatment (none, half-roasting, and full-roasting time), in a factorial arrangement. The soybeans were heated in a Roast-a-Tron roaster, ground, and added to corn-dried whey diets formulated to be limiting in lysine (.88%). Pigs fed diets with −K soybeans gained 21% faster and were 13% more efficient than pigs fed diets with +K soybeans. As heat treatment was increased to full-roasting, rate and efficiency of gain increased. The +K soybeans were of lower nutritional value than the −K soybeans when fed raw or half-roasted, but the two soybean types were of similar nutritional value when fully roasted. Two additional experiments (66 individually fed pigs each) were conducted using growing and finishing pigs. The soybeans were added to corn-based diets formulated to contain .60 and .48% lysine for the growing and finishing phases, respectively. Growing pigs fed diets with the −K soybeans gained 10% faster, were 10% more efficient, and had 13% lower fat depth at the last rib than pigs fed the +K soybeans. Finishing pigs fed diets with the −K soybeans were more efficient and had lower fat depths than pigs fed the +K soybeans. Considering all three growth phases, the low-inhibitor (−K) soybeans were of greater nutritional value than the conventional (+K) soybeans, with the greatest difference observed when the soybeans were fed raw. The nutritional value of both soybean types (+K and −K) was optimized with full-roasting. The half-roasting treatment was not sufficient to optimize the nutritional value of the low-inhibitor soybeans.

(Key Words: Low-Inhibitor Soybeans, Kunitz Trypsin Inhibitor, Raw Soybeans, Roasting, Pig.)

Introduction

Raw soybean seeds contain many constituents that limit their nutritional value for swine. The major anti-nutritional constituent found in raw soybean seeds is a group of small proteins collectively called trypsin inhibitors. Heat treatment is usually used to inactivate the trypsin inhibitors and any other anti-nutritional factors; thus, soybean meal is toasted, and whole soybean seeds are roasted or extruded before feeding to pigs. Two negative effects of using heat treatment in soybean processing are the added cost (75¢ to $1.00 per bushel for roasting) and the potential loss of protein quality, if the heat treatment is insufficient or excessive.

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In an attempt to reduce processing costs and increase nutritional value, soybeans (Williams 82 variety) have been developed that lack gene expression for the Kunitz trypsin inhibitors. These inhibitors are responsible for one-half of the total trypsin inhibitor activity of raw soybeans. Three experiments were conducted, in a cooperative effort between Kansas State University and the University of Nebraska, to evaluate the nutritional value of soybeans lacking the Kunitz trypsin inhibitor when fed to nursery, growing, and finishing pigs.

Experimental Procedures

Williams 82 soybeans with (+K) and without (−K) gene expression for the Kunitz trypsin inhibitor were fed raw, half-roasted, and fully roasted. The full-roasted treatment was that deemed usual for soybeans processed in a Roast-A-Tron roaster (i.e., throughput of approximately 1000 lb per h and an avg exit temperature of 295°F). The half-roasted treatment was accomplished by doubling the throughput of the roaster (i.e., approximately 2000 lb per h). The soybeans were ground through a hammermill equipped with a 3/16 in. screen before being added to the experimental diets.

Experiment 1 was a nursery experiment conducted at Kansas State University. In experiment 1, 240 weanling pigs (3 to 4 wk of age and 12.8 lb initial wt) were used in a 28-d growth assay. Feed and water were supplied ad libitum, and weight gains and feed intakes were measured weekly. The soybean preparations were added to a corn-based diet (with 20% dried whey) formulated to contain .88% lysine (Table 1). By formulating the diets to be deficient in lysine content, any differences in lysine availability would be accentuated.

Table 1. Diet Composition for the Nursery Experiment

Ingredient	Amount, %
Soybean treatment[a]	23.47 to 25.60
Corn starch[a]	.08 to 2.17
Corn	51.17
Dried whey	20.00
Monocalcium phosphate[a]	1.23 to 1.28
Limestone[a]	.81 to .82
Salt	.10
Vitamins and minerals	.40
Copper sulfate	.08
CSP·250	.50
Santoquin	.03
Total	100.00

[a]Soybean treatment, corn starch, monocalcium phosphate and limestone adjusted so that all diets contained .88% lysine, .8% calcium and .7% phosphorus.

Experiments 2 and 3 were growing-finishing experiments conducted at the University of Nebraska. A detailed description of those experiments can be found in the 1990 Nebraska Swine Report. Briefly, in experiment 2, 66 pigs (30 gilts and 36 barrows) were individually fed from 49 to 104 lb (growing phase). In experiment 3, 66 pigs (24 gilts and 42 barrows) were individually fed from 112 to 227 lb (finishing phase). The same soybean treatments that were used in the nursery experiment were added to simple corn-based diets formulated to contain .60 and .48% lysine for the growing and finishing phases, respectively.

At the end of the growing and finishing experiments, the pigs were scanned ultrasonically for fat depth at the last rib.

Results and Discussion

Attempts to improve the nutritional value of crops have sometimes been thwarted by reduced yields of the "improved" varieties. A good example of that problem was the reduced yield of the early varieties of high-lysine corn in comparison to conventional corn hybrids. Yield and chemical composition were determined on +K and −K soybeans harvested in the fall of 1987 and 1988 (Table 2). Yield was not reduced by genetic manipulation to remove the Kunitz trypsin inhibitor. Measurements of dry matter, crude protein, fat, and lysine content were also very similar for the +K and −K soybeans. However, the −K soybeans had about one-half of the trypsin inhibitor content of the +K soybeans.

Table 2. Yield and Chemical Composition of Conventional (+K) and Low-inhibitor (-K) Soybeans

Item	1987 harvest		1988 harvest	
	+K	−K	+K	−K
Yield, bushels/acre	33.6	35.4	32.9	33.0
Dry matter, %	90.1	90.4	--	--
Protein, %	36.0	36.8	37.1	37.4
Fat, %	20.0	20.9	--	--
Lysine, %	2.38	2.32	2.47	2.43
Trypsin inhibitor, mg/g	24.1	13.3	--	--

The effects of roasting treatment on chemical composition of the soybeans is given in Table 3. Dry matter percentage increased slightly as roasting time was increased to full-roast. The dry flame used in the roasting process tended to dry the soybeans. Protein percentage of the soybeans increased as roasting time was increased, but lysine percentage was slightly reduced for the full-roast treatment. The loss of total lysine probably indicates the beginning of heat damage to the proteins. Trypsin inhibitor content was markedly affected by roasting time, with a reduction to 7.0 mg per g soybean seed as roasting time of the +K soybeans was increased to full-roast. Although the −K soybeans were lower in trypsin inhibitor content initially, they also had a reduction in trypsin inhibitor content as roasting time was increased to full-roast (.6 mg/g).

Performance of nursery pigs fed the soybean preparations is given in Table 4. Pigs fed the −K soybeans gained 21% faster ($P<.001$) than pigs fed the +K soybeans (.70 vs .58 lb/d). Pigs fed the −K soybeans consumed more 11% feed (1.47 vs 1.10 lb/d) and were 13% more efficient (F/G of 2.14 vs 2.46). However, the majority of these differences were achieved when the soybeans were fed raw or half-roasted; performance of pigs fed the +K and −K soybeans

Table 3. Effects of Roasting on Conventional (+K) and Low-inhibitor (-K) Soybeans

	+K heat treatment			−K heat treatment		
Item	None	Half-roast	Full-roast	None	Half-roast	Full-roast
Dry matter, %	90.1	91.4	93.2	90.4	92.0	92.8
Protein, %	36.0	36.9	37.7	36.8	37.1	37.7
Lysine, %	2.38	2.40	2.30	2.32	2.25	2.16
Trypsin inhibitor, mg/g	24.1	18.5	7.0	13.3	5.3	.6

Table 4. Performance of Nursery Pigs Fed Conventional (+K) and Low-inhibitor (-K) Soybeans[a]

	+K heat treatment			−K heat treatment			
Item	None	Half-roast	Full-roast	None	Half-roast	Full-roast	CV
ADG, lb[b]	.39	.45	.90	.52	.67	.91	5.1
ADFI, lb[c]	1.11	1.18	1.70	1.23	1.43	1.74	6.2
F/G[d]	2.86	2.63	1.89	2.38	2.13	1.92	3.5

[a]Eight pigs per pen, five pens per treatment (data collected at Kansas State University).
[b]Soybean type × quadratic effect of roasting time ($P<.001$); soybean type × linear effect of roasting time ($P<.003$); quadratic effect of roasting time ($P<.001$); linear effect of roasting time ($P<.001$); effect of soybean type ($P<.001$).
[c]Soybean type × quadratic effect of roasting time ($P<.04$); quadratic effect of roasting time ($P<.003$); linear effect of roasting time ($P<.001$); effect of soybean type ($P<.003$).
[d]Soybean type × quadratic effect of roasting time ($P<.003$); soybean type × linear effect of roasting time ($P<.001$); quadratic effect of roasting time ($P<.006$); linear effect of roasting time ($P<.001$); effect of soybean type ($P<.001$).

was similar when the soybeans were fully roasted. Full-roasting was necessary to optimize the utilization of +K and −K soybeans.

Performance of growing and finishing pigs fed the soybean treatments is given in Table 5. Growing pigs fed the −K soybeans grew 10% faster (1.20 vs 1.09 lb/d), had F/G that was 10% lower (2.96 vs 3.27), and had 12% less fat thickness at the last rib (.36 vs .41 in.) than pigs fed +K soybeans. As observed in the nursery experiment, the majority of these differences resulted when raw and half-roasted soybeans were fed.

Finishing pigs responded in a similar manner to nursery and growing pigs, i.e., pigs fed −K soybeans grew faster and were more efficient than pigs fed +K soybeans, and as roasting time was increased, growth performance increased. The F/G of pigs fed half-roasted −K soybeans was not different from the F/G of pigs fed the full-roasted +K soybeans, but rate of gain was still depressed for finishing pigs fed half-roasted −K soybeans vs finishing pigs fed full-roasted +K soybeans.

Table 5. Performance of Growing and Finishing Pigs Fed Conventional (+K) and Low-inhibitor (-K) Soybeans[a]

	+K heat treatment			−K heat treatment			
Item	None	Half-roast	Full-roast	None	Half-roast	Full-roast	CV
Growing phase							
ADG, lb[b]	.89	.97	1.40	1.16	1.12	1.32	17.1
ADFI, lb[c]	3.29	3.26	3.93	3.60	3.35	3.64	14.4
F/G[d]	3.66	3.37	2.79	3.11	3.00	2.76	10.0
Last rib fat, in.[e]	.47	.45	.31	.38	.40	.30	23.9
Finishing phase							
ADG, lb[f]	1.54	1.70	1.75	1.68	1.66	1.86	11.6
ADFI, lb[g]	5.93	6.27	6.20	6.25	5.81	6.06	9.4
F/G[h]	3.85	3.70	3.53	3.71	3.50	3.24	5.7
Last rib fat, in.[i]	.96	.99	1.00	.92	.94	.79	19.5

[a]Eleven individually-fed pigs per treatment (data collected at the University of Nebraska).
[b]Soybean type × linear effect of roasting time (P<.004); quadratic effect of roasting time (P<.005); linear effect of roasting time (P<.001).
[c]Soybean type × linear effect of roasting time (P<.05); quadratic effect of roasting time (P<.03); linear effect of roasting time (P<.04).
[d]Soybean type × linear effect of roasting time (P<.04); linear effect of roasting time (P<.001).
[e]Linear effect of roasting time (P<.06).
[f]Linear effect of roasting time (P<.001).
[g]Soybean type × quadratic effect of roasting time (P<.07).
[h]Soybean type × linear effect of roasting time (P<.10); linear effect of roasting time (P<.001).
[i]No treatment effect (P>.18).

Considering all growth phases (nursery, growing, and finishing), older pigs were better able to tolerate the anti-nutritional properties of raw soybeans. Feeding soybeans lacking gene expression for the Kunitz trypsin inhibitors did improve the growth performance of pigs. However, half-roasting was not sufficient to optimize the nutritional value of +K or −K soybeans. Further experiments are in progress to identify methods and levels of heat treatment that will allow producers to take full advantage of the nutritional value of −K soybeans.