ROASTING AND EXTRUDING AFFECT ILEAL DIGESTIBILITY OF NUTRIENTS FROM SOYBEANS IN GROWING AND FINISHING PIGS

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Summary

Eight crossbred barrows (initial body wt of 90 lb and 180 lb for four growing and four finishing pigs, respectively) were fitted with T-cannulas at the distal ileum and used in 36-d metabolism experiments (4 × 4 Latin squares) to determine the effects of roasting and extruding full-fat soybeans on nutrient utilization. Treatments were 1) soybean meal, 2) roasted soybeans, 3) extruded soybeans, and 4) soybeans extruded with an extrusion enhancer (sodium sulfite). The soybean meal and soybeans were mill-run. The control diet was cornstarch-based, with .9% lysine, .65% Ca, and .55% P for the growing pigs and .75% lysine, .55% Ca, and .45% P for the finishing pigs. For the growing pigs, apparent total tract digestibilities of DM and GE were greater for soybean meal than full-fat soy products. However, ileal digestibilities of DM, GE, N, and amino acids generally were greatest for extruded soybeans and lowest for roasted soybeans, with soybean meal intermediate. Differences at the terminal ileum were more pronounced than for the total tract, thus indicating that hind-gut fermentation is likely to mask many of the true nutritional differences in feedstuffs. For finishing pigs, total tract digestibilities of DM and GE were greater for soybean meal than for the full-fat soy products because of the relatively low digestibility coefficients for roasted soybeans. Ileal digestibilities of DM, GE, and N were greater for the extruded soybeans and extruded soybeans with sodium sulfite than for the roasted soybeans. Availabilities of the indispensable amino acids measured at the terminal ileum were greatest for extruded soybeans, intermediate for soybean meal, and lowest for roasted soybeans. In conclusion, nutrient digestibilities and availabilities of indispensable amino acids tended to be greatest in extruded soybeans, intermediate in soybean meal, and lowest in roasted soybeans for growing and finishing pigs.

(Key Words: Pig, Soybean, Extrude, Roast, Sodium Sulfite, Ileum, Digestibility.)

Introduction

During the past 6 years, we have reported growth performance for pigs fed extruded soybeans that was equal to, or greater than, growth performance of pigs fed soybean meal. However, the performance of pigs fed roasted soybeans often has been less than that of pigs fed soybean meal and extruded soybeans. Thus, the objectives of the experiments reported herein were to determine if the greater nutritional value of extruded soybeans can be explained partially by greater nutrient availabilities (e.g., greater ileal digestibilities of amino acids). Also, we wished to evaluate differences in nutrient availability in pigs of different ages (i.e., growing vs finishing) and to generate nutrient availability values for the soybean preparations we have been using in growth assays.

Procedures

The soybean meal and full-fat soybeans used in these experiments were mill-run. For the roasting and extrusion treatments, processing conditions were those deemed usual for soybeans (i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 260°F in a Roast-A-Tron® roaster vs a throughput of approximately 1,500 lb/h

and an average barrel temperature of 290°F in an Insta-Pro® dry-extruder). Treatments were 1) soybean meal, 2) roasted soybeans, 3) extruded soybeans, and 4) soybeans extruded with an extrusion enhancer (sodium sulfite). Sodium sulfite is suggested to aid in the breaking of disulfide bonds that hold proteins in their biologically active configurations. Thus, it should ensure very low activities for trypsin inhibitors and other antinutritional factors that limit the utilization of soybean proteins. The soybean meal and full-fat soybeans preparations were incorporated into cornstarch-based diets formulated to .9% lysine, .65% Ca, and .55% P for the growing pigs and .75% lysine, .55% Ca, and .45% P for the finishing pigs (Table 1). Chromic oxide (.25%) was added to the diets as an indigestible marker.

Eight crossbred barrows (four growing and four finishing with average initial body wt of 90 and 180 lb, respectively) were surgically fitted with T-cannulas approximately 15 cm anterior to the ileo-cecal junction. The pigs were deprived of feed for 16 to 20 h prior to surgery and allowed a 14-d recuperation period before initiation of the experiments. The experimental designs were 4 × 4 Latin squares with pig and period as blocking criteria. Each period included 4 d of adjustment to diet, 3 d of total feces and urine collection, and 2 d (12 h/d) of ileal digesta collection. The pigs were limit-fed (.05 × body $wt^{.9}$) with two meals daily (7:00 a.m. and 7:00 p.m.). Feed was offered as a wetted mash. Water was available for ad libitum consumption between feedings. Feces and urine were collected twice daily during the 3 d of feces and urine collection. The urine was acidified during collection by 100 mL of 10% HCl in the collection vessel. Total urine volumes were recorded, and 5% was saved and frozen each day for later analyses. Ileal digesta were collected during the 12-h period between the morning and evening feeding for the last 2 d of each collection period. Feed, feces, and ileal digesta were analyzed for DM, N, and GE concentrations. Amino acid analyses were accomplished after hydrolysis for 24 h with 6N HCl. Chromium concentrations were determined by atomic absorption spectrometry. All data were analyzed using the orthogonal comparisons: 1) soybean meal vs other treatments; 2) roasted soybeans vs extruded soybeans; and 3) extruded soybeans vs soybeans extruded with sodium sulfite.

Results and Discussion

The chemical compositions of the soybean meal and full-fat soybean preparations are given in Table 2. Chemical analyses were similar to those anticipated and, as expected with their greater fat content, the full-fat soy products had greater GE. Crude protein and amino acid concentrations generally were greater for soybean meal than the full-fat soy products.

For the growing pigs, digestibilities of DM ($P<.05$) and GE ($P<.01$) for the total tract were greater for soybean meal vs the full-fat soy products (Table 3) because of the relatively low digestibilities for roasted soybeans. Digestibilities of DM, GE, and N at the terminal ileum were greater for pigs fed extruded soybeans than for pigs fed roasted soybeans ($P<.10$). For N digestibility, differences between small intestine and total tract averaged 13.3% for soybean meal, 22.0% for roasted soybeans, 12.2% for extruded soybeans, and 9.2% for soybeans extruded with sodium sulfite. Nutrients disappearing in the large intestine would be used largely for microbial activity and are of little benefit to the host animal. Apparent digestibilities of amino acid at the terminal ileum followed the same patterns as N digestibility (Table 4). Availabilities for nine indispensable amino acids measured at the terminal ileum averaged 80.3% for soybean meal, 62.6% for roasted soybeans, 81.7% for extruded soybeans, and 84.8% for soybeans extruded with sodium sulfite.

For the finishing pigs, digestibilities of DM ($P<.05$) and GE ($P<.001$) for the total tract were greater for soybean meal than for the full-fat soy products because of the relatively low digestibilities for roasted soybeans (Table 5). Ileal digestibilities for DM, GE, and N were greater ($P<.01$) for the extruded soybeans than for the roasted soybeans.

Apparent amino acid digestibilities measured at the terminal small intestine are given in Table 6. Availabilities for nine indispensable amino acids measured at the terminal ileum averaged 83.4% for soybean meal, 72.2% for roasted soybeans, 84.1% for extruded soybeans, and 87.8% for soybeans extruded with sodium sulfite. The availability of lysine was greatest in soybeans extruded with sodium sulfite (88.9%) and lowest in roasted soybeans (71.2%) with soybean meal intermediate (83.3%).

In conclusion, digestibilities of nutrients were lower at the terminal ileum than in the feces, and much of the treatment effect was lost with total tract determination. Thus, results based on the fecal analysis method may provide erroneous interpretations of the effects of heat treatment on full-fat soybeans. Ileal digestibilities of DM, GE, N, and various amino acids tended to be greatest for soybeans extruded with sodium sulfite and lowest for roasted soybeans. These trends were true for both growing and finishing pigs. Finally, our results demonstrate that future NRC values should indicate the type of processing used to generate full-fat soybean products to avoid overestimation of amino acid availabilities in roasted products and underestimation of amino acid availabilities for extruded products.

Table 1. Diet Composition, %

	Growing pigs[a]		Finishing pigs[b]	
Ingredient	Soybean meal	Soybeans	Soybean meal	Soybeans
Cornstarch	62.84	53.53	68.22	61.02
Soybean meal	29.08	--	24.11	--
Soybeans	--	40.43	--	33.33
Soybean oil	1.00	--	1.00	--
Cellulose fiber	4.00	3.00	4.00	3.00
Dicalcium phosphate	1.97	1.64	1.54	1.28
Limestone	.21	.50	.23	.47
Salt	.25	.25	.25	.25
KSU vitamin premix	.25	.25	.25	.25
KSU mineral premix	.15	.15	.15	.15
Chromic oxide[c]	.25	.25	.25	.25
Total	100.00	100.00	100.00	100.00

[a]All grower diets were formulated to .9% lysine, .65% Ca, and .55% P and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988).
[b]All finisher diets were formulated to .75% lysine, .55% Ca, and .45% P and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988).
[c]Used as an indigestible marker.

Table 2. Chemical Composition of Soybean Meal, Roasted Soybeans, Extruded Soybeans, and Soybeans Extruded with Sodium Sulfite[a]

		Soybeans		
Item	Soybean meal	Roasted	Extruded	Sodium sulfite
CP, %	43.5	34.0	35.1	33.6
Gross energy, kcal/lb	1,884	2,242	2,246	2,199
Indispensable amino acids, %				
Arginine	3.1	2.6	3.0	2.9
Histidine	1.1	1.0	1.0	1.0
Isoleucine	1.7	1.7	1.7	1.6
Leucine	3.0	2.9	2.9	2.8
Lysine	2.8	2.2	2.2	2.2
Methionine	.5	.5	.5	.5
Phenylalanine	1.8	1.7	1.8	1.7
Threonine	1.7	1.5	1.6	1.5
Valine	1.8	1.7	1.8	1.7
Dispensable amino acids, %				
Alanine	1.7	1.7	1.7	1.7
Aspartate	4.6	4.3	4.5	4.4
Glutamate	7.5	6.4	7.4	7.2
Glycine	2.0	1.7	1.9	1.8
Serine	2.3	2.1	2.3	2.2
Tyrosine	1.3	1.3	1.3	1.2

[a]Corrected to 90% DM.

Table 3. Apparent Nutrient Digestibilities in Growing Pigs

Item	Soybean meal	Soybeans: Roasted	Soybeans: Extruded	Soybeans: Sodium sulfite	CV
DM digestibility, %					
Small intestine[c]	75.7	71.5	75.6	80.1	7.9
Total tract[ae]	92.7	88.9	91.3	92.7	1.6
Difference	17.0	17.4	15.7	12.7	36.5
GE digestibility, %					
Small intestine[d]	76.5	70.1	78.1	81.2	7.9
Total tract[bf]	93.4	86.5	90.8	92.5	2.3
Difference	16.9	16.3	12.7	11.3	41.1
N digestibility, %					
Small intestine[f]	76.3	62.2	77.6	81.5	5.7
Total tract[f]	89.6	84.2	89.8	90.7	2.3
Difference[f]	13.3	22.0	12.2	9.2	27.1

[ab]SBM vs other treatments (P < .05 and .01, respectively).
[cdef]Roasted vs extruded (P < .10, .05, .01, and .001, respectively).

Table 4. Apparent Ileal Amino Acid Digestibilities in Growing Pigs, %

Item	Soybean meal	Soybeans: Roasted	Soybeans: Extruded	Soybeans: Sodium sulfite	CV
Indispensable amino acids					
Arginine[ac]	87.6	72.7	88.7	90.3	4.3
Histidine[bc]	82.7	63.3	83.6	87.6	5.1
Isoleucine[bc]	79.2	59.4	80.1	83.4	5.2
Leucine[c]	78.8	61.3	80.2	84.2	5.6
Lysine[c]	82.6	67.1	86.2	88.5	4.8
Methionine[bc]	80.9	63.9	82.7	84.1	4.5
Phenylalanine[c]	80.9	62.2	83.4	86.1	5.0
Threonine[c]	74.1	58.4	74.5	78.9	7.4
Valine[ac]	75.9	55.3	75.6	80.2	7.3
Total dispensable amino acids[c]	77.7	60.0	80.3	83.2	6.4

[ab]SBM vs other treatments (P < .10 and .05, respectively).
[c]Roasted vs extruded (P < .001).

Table 5. Apparent Nutrient Digestibilities in Finishing Pigs

Item	Soybean meal	Soybeans			CV
		Roasted	Extruded	Sodium sulfite	
DM digestibility, %					
Small intestine[e]	85.4	80.4	84.6	85.7	2.8
Total tract[bf]	92.6	87.9	92.7	93.0	1.2
Difference	7.2	7.6	8.1	7.4	33.4
GE digestibility, %					
Small intestine[af]	86.2	78.4	85.6	86.6	2.9
Total tract[cf]	93.2	84.9	92.7	93.0	1.3
Difference	6.9	6.5	7.1	6.4	40.4
N digestibility, %					
Small intestine[f]	80.7	69.2	83.9	85.6	7.3
Total tract[f]	87.6	79.6	89.7	89.0	3.9
Difference[d]	6.7	10.4	5.8	3.4	88.2

[abc]SBM vs other treatments (P<.10, .05, and .001, respectively).
[def]Roasted vs extruded (P<.10, .01, and .001, respectively).

Table 6. Apparent Ileal Amino Acid Digestibilities in Finishing Pigs, %

Item	Soybean meal	Soybeans			CV
		Roasted	Extruded	Sodium sulfite	
Indispensable amino acids					
Arginine[a]	88.2	76.7	88.5	91.6	5.6
Histidine[a]	84.3	72.7	85.3	88.7	6.3
Isoleucine[a]	84.9	71.9	84.4	87.1	5.9
Leucine[a]	84.4	71.7	84.4	87.3	6.6
Lysine[a]	83.3	71.2	84.7	88.9	6.6
Methionine[a]	83.9	75.5	85.2	89.4	5.6
Phenylalanine[a]	85.2	72.0	85.0	88.8	6.5
Threonine[a]	76.0	68.1	78.3	83.6	7.4
Valine[a]	80.8	69.6	80.8	84.7	6.9
Total dispensable amino acids[a]	78.6	69.0	79.9	85.7	7.6

[a]Roasted vs extruded (P<.001).