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Evaluation of ruminal degradability and lysine bioavailability of four soybean meal products (2006)

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EVALUATION OF RUMINAL DEGRADABILITY AND LYSINE BIOAVAILABILITY OF FOUR SOYBEAN MEAL PRODUCTS

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Summary

Evaluations of four soybean meal (SBM) products were conducted. The products were: solvent SBM (SSBM), expeller SBM (ESBM), lignosulfonate-treated SBM (LSBM), and SSBM treated with 0.05% Baker's yeast and toasted at 212ºF (YSBM). *In situ* ruminal degradations of YSBM and LSBM were slower than those of SSBM or ESBM; thus, ruminally undegraded protein contents of YSBM and LSBM were greater than those of SSBM or ESBM. The ruminally undegraded protein of all SBM products had similar small intestine digestibility when assessed by susceptibility to enzymatic digestion *in vitro*. Available lysine contents, estimated chemically or using standard chick growth assay, were less for YSBM and LSBM than for SSBM or ESBM, suggesting deleterious effects of processing on lysine availability in those products.

(Key Words: Availability, Protein, Soybean Meal.)

Introduction

Soybean meal (SBM) is a supplemental protein commonly used as a supplement for dairy cattle. Soybean products are characterized by high palatability and well-balanced and available amino acid contents. But extensive ruminal degradability of SBM limits its utilization by ruminants as a source of ruminally undegraded protein. Various methods have been used to treat soybean products to alter their ruminal degradability, and thereby increase their escape protein content, but "overprotection" can impair protein quality of SBM by altering the nutritional availability of amino acids, particularly that of lysine. This study was conducted to compare the ruminal degradability, intestinal digestibility, and lysine bioavailability of 4 SBM products.

Procedures

We evaluated the ruminal degradability, intestinal digestibility, and lysine bioavailability of solvent SBM (SSBM), expeller SBM (ESBM), lignosulfonate-treated SBM (LSBM), and SSBM treated with 0.05% Baker's yeast (*Saccharomyces cerevisiae*) and steeped for 10 minutes at 86ºF before toasting at 212ºF (YSBM; Table 1). The SSBM and YSBM were from the same source, but ESBM and LSBM were commercial products.

In Situ Protein Degradability. Two ruminally cannulated Jersey steers fed a typical dairy diet were used. To estimate *in situ* protein degradability, 1.5 to 2.0 grams of ground samples of the 4 SBM products were weighed in duplicate for each incubation time (0, 2, 4, 8, 16, 24, and 48 hours) into polyester bags, which were heat-sealed, presoaked in cold tap water, and placed into the ventral sac of the rumen at different time points. Bags were then simultaneously removed from the rumen and washed with cold water in a commercial washing machine with 1 minute of delicate agitation and 2 minutes of spin per rinse for 5 cycles. Bags were then dried and analyzed for residual nitrogen content.

Protein fractions (A, B, and C) and degradation rate of fraction B (k_B) were estimated by using the model:

$$\text{Residual nitrogen} = (B \times e^{(-kB \times t)}) + C$$

where B is the slowly degraded protein fraction, C is the completely undegradable protein fraction, t is incubation time, and k_B is the degradation rate of fraction B. Fraction A, the instantly degraded protein fraction, was calculated by difference, $A = 1 - B - C$.

Intestinal Digestibility of Ruminally Undegraded Protein. Digestibility of ruminally undegraded protein was determined by a 3-step procedure. Samples were incubated in the rumen of fistulated steers for 16 hours. Residues in the bags after ruminal incubation were then subjected to digestion with pepsin and pancreatin *in vitro*. Intestinally digestible protein was calculated as that solubilized by the enzymes. Digestible protein in the SBM products was calculated as ruminally undegraded protein content multiplied by the intestinal digestibility of the ruminally undegraded protein.

Lysine Bioavailability by Chick Growth Assay. Broiler chicks (n = 480, 1-day old) were used in a chick-growth assay to compare the relative bioavailability of lysine in the 4 SBM products. Chicks were housed in temperature-regulated starter batteries, in 48 pens with 10 chicks per pen. Birds had free access to feed and water. At the conclusion of the study (9 days), each pen of birds was weighed to calculate weight gains, and unconsumed feed was weighed to allow calculation of feed intake.

Chicks were fed one of 12 diets based on corn and SBM. Four of the treatments, for which data are not presented, were used to verify that performance of chicks in our model was most limited by the supply of lysine. The SSBM diet contained 26% SSBM, and the remaining treatments were formulated to be isonitrogenous by varying the amount of corn starch added to diets. Treatments included the 4 SBM sources and residuals from the four SBM sources after 12-hours of *in situ* ruminal incubation. We evaluated the *in situ* residues to determine if the ruminal incubation, which would be experienced if the SBM sources were fed to cattle, altered lysine availability.

Ruminal residuals were obtained by using ruminally cannulated steers consuming a typical dairy cow diet. About 200 grams of the SBM sources were weighed into polyester bags, heat-sealed, and placed in the ventral sac of the rumen of a steer. After 12 hours of incubation, bags were removed and washed in cold water, and bag residues were freeze-dried before being used in the chick diets.

Lysine Availability by Assay of Chemically Available Lysine. Available lysine contents of SBM products were estimated by using a chemical availability assay. Chemically available lysine in the original SBM and residues after 12 hours of ruminal incubation were colorimetrically measured according to the 1-fluoro-2, 4-dinitrobenzene procedure. Available lysine is defined as units whose side-chains are free and can react with 1-fluoro-2,4-dinitrobenzene. Lysine units whose side-chains are bound to other groups will not react with 1-fluoro-2,4-dinitrobenzene and are considered to be nutritionally unavailable.

Results and Discussion

In Situ Protein Degradability. Data for *in situ* CP degradation for the SBM products are presented in Table 2. Although not statistically different, likely due to small number of replications (two per incubation time per steer), differences among SBM products in sizes of the protein fractions and degradation

rates are observable. The YSBM and the LSBM had greater contents of ruminally undegraded protein than did SSBM or ESBM, predominantly as a result of a slower degradation rate (k_B) for YSBM and a larger fraction C for LSBM.

Our measured value for ruminally undegraded protein for LSBM (78%) was similar to expectations, whereas that for ESBM (51%) was less than expected and that for SSBM (42%) was greater. Few published values are available to compare with our measure for YSBM (75%).

Intestinal Digestibility of Ruminally Undegraded Protein. Intestinal digestibilities of ruminally undegraded protein from SBM products are presented in Table 3. There were no differences among SBM products for intestinal digestibility of ruminally undegraded protein, which averaged 82%. Because there was more ruminally undegraded protein in YSBM and LSBM than in SSBM and ESBM, the proportions of ingredient protein that were available post-ruminally were greater for YSBM (66%) and LSBM (64%) than for SSBM (39%) or ESBM (48%).

Data from lysine availability studies described in the next section indicate that the lack of differences among SBM sources in intestinal digestion, as evaluated by the 3-step procedure, is not completely correct, at least for lysine availability.

Lysine Bioavailability by Chick Growth Assay. Results of data not shown demonstrated that chick performance was limited by lysine supply and, thus, that our study provided a comparison of the relative lysine bioavailabilities in the SBM products.

When original SBM products were tested (Table 4), SSBM and ESBM resulted in similar chick performance (feed intake, daily gain, gain:feed), but they yielded better performance than YSBM and LSBM, indicating that lysine was more available for growth in SSBM and ESBM than in YSBM and LSBM. Feeding YSBM resulted in worse performance than feeding LSBM, suggesting that lysine was less available for growth in YSBM than in LSBM. This might be, in part, due to "over protection" of YSBM during processing, which might have led to deleterious effects on lysine availability.

Feeding *in situ* residues of SSBM, ESBM, or LSBM resulted in similar performance (feed intake, daily gains, and feed efficiency), but performance was better than that from feeding *in situ* residues of YSBM. If a prediction of performance was based on total lysine content only (Table 4), it would be expected that feeding *in situ* residues of LSBM would result in worse chick performance than feeding SSBM or ESBM, simply because LSBM (5.8% of CP) had less total lysine content than did SSBM (6.7% of CP) or ESBM (7.0% of CP).

For each SBM product, we tested the original SBM, as well as SBM that was previously incubated *in situ* for 12 hours, to 1) simulate what actually occurred when SBM was fed to cattle and 2) investigate if the comparisons among different SBM products using the original SBM were comparable to those using *in situ* residues. Using *in situ* residues for SSBM or ESBM yielded less feed intake and slower gains, but more efficient gains, compared with using the original SSBM and ESBM. This could be due to depressed feed intake as a result of poor palatability of the *in situ* residues.

In general, using ruminal *in situ* residues or original SBM in the chick growth assay yielded similar ranking of SBM products in terms of lysine availability, except for LSBM, which led to worse performance than SSBM

or ESBM when the original SBM products were compared, but equal performance when the *in situ* residues were compared. It is possible that some of the unavailable lysine in LSBM became available to the chicks after 12 hours of ruminal incubation. Our data indicates that lysine availability in SBM products can be impacted by ruminal incubation.

Lysine Availability by Assay of Chemically Available Lysine. Chemically available lysine (% of crude protein; Table 4) was greater for original SSBM (5.5%) and ESBM (5.3%) than for YSBM (4.1%) or LSBM (4.3%). Chemically available lysine contents (% of crude protein) for *in situ* residues of SSBM (5.2%), ESBM (5.3%), and LSBM (5.1%) were similar to each other (Table 4), but greater than that in YSBM (3.9%), which agrees with chick performance data.

Chemically available lysine contents in the *in situ* residues were almost identical to the original SBM for the same product, except for LSBM. It is possible that some of the unavailable lysine in the original LSBM became available after ruminal incubation, resulting in greater content of available lysine (5.1 vs. 4.3%).

Conclusions. Treating SBM with lignosulfonate or yeast, followed by heating to induce non-enzymatic browning, was successful in protecting LSBM and YSBM from ruminal degradation, without affecting their intestinal digestibility as measured by susceptibility to enzymatic digestion. Processing of YSBM and LSBM, however, seemed to decrease lysine bioavailability as measured either by the chick growth assay or by a chemically available lysine procedure.

Table 1. Nutrient Composition of Soybean Meal Products

	Soybean Meal (SBM) Product[1]			
Nutrient	SSBM	YSBM	ESBM	LSBM
	---------- % of dry matter ----------			
Neutral detergent fiber	13.5	31.8	12.9	22.7
Acid detergent fiber	7.6	8.1	8.6	10.5
Ether extract	2.9	2.9	8.0	2.7
Crude protein	55.8	55.9	47.9	51.2
	---------- % of crude protein ----------			
Arginine	6.8	6.3	7.0	6.3
Histidine	2.6	2.4	2.8	2.6
Isoleucine	5.3	5.5	5.1	5.3
Leucine	7.8	7.6	7.7	7.7
Lysine	7.6	6.2	7.6	6.7
Methionine	0.9	1.1	0.8	1.0
Phenylalanine	5.4	5.3	5.1	5.3
Threonine	3.9	4.0	3.8	3.8
Tyrosine	3.4	3.5	3.1	3.4
Valine	4.9	4.9	5.0	4.8
	---------- % of total nitrogen ----------			
Neutral detergent insoluble nitrogen	11.5	42.1	8.0	29.0
Acid detergent insoluble nitrogen	5.7	6.4	4.2	9.9

[1]SSBM = solvent SBM, ESBM = expeller SBM, LSBM = lignosulfonate-treated SBM, and YSBM = SSBM treated with 0.05% baker's yeast and steeped for 10 minutes at 86ºF before toasting at 212ºF.

Table 2. In Situ Protein Degradation Kinetics of Soybean Meal Products

	Soybean Meal (SBM) Product[1]				
Item	SSBM	YSBM	ESBM	LSBM	SEM
Fraction, %					
A[2]	21	11	25	7	7
B[3]	78	89	70	61	22
C[4]	0	0	4	31	18
K_B, %/hour[5]	3.8	1.1	2.6	2.0	0.9
Ruminally undegraded protein, %[6]	42[b]	75[a]	51[b]	78[a]	2.1

[1]SSBM = solvent SBM, ESBM = expeller SBM, LSBM = lignosulfonate-treated SBM, and YSBM = SSBM treated with 0.05% baker's yeast and steeped for 10 minutes at 86ºF before toasting at 212ºF.

[2]Instantly degraded N.

[3]Slowly degraded protein fraction.

[4]Completely undegradable protein fraction.

[5]Degradation rate of fraction B.

[6]Estimated using the fractions and rate for each SBM for an incubation time of 16 hours.

[a, b] Values having different superscript letters within row differ ($P<0.05$).

Table 3. Intestinal Digestibility of Ruminally Undegraded Protein of Soybean Meal Products

	Soybean Meal (SBM) Product[1]				
Item	SSBM	YSBM	ESBM	LSBM	SEM
Ruminally undegraded protein, %[2]	48[c]	83[a]	55[b]	81[a]	1.5
Intestinal digestibility, % of ruminally undegraded protein	82	80	86	78	2.0
Intestinal availability, % of ingredient crude protein[3]	39[c]	66[a]	48[b]	64[a]	1.9

[1]SSBM = solvent SBM, ESBM = expeller SBM, LSBM = lignosulfonate-treated SBM, and YSBM = SSBM treated with 0.05% baker's yeast and steeped for 10 minutes at 86ºF before toasting at 212ºF.

[2]Ruminally undegradable protein on the basis of 16-hour *in situ* ruminal incubation.

[3]Ruminally undegraded protein × intestinal digestibility.

[a, b, c]Values having different superscript letters within row differ, $P \leq 0.05$.

Table 4. Total and Chemically Available Lysine and Performance of Chicks Fed Original Soybean Meal Products or *In Situ* Residues of Soybean Meal Products[1]

	Original Soybean Meal (SBM) Product				
Item	SSBM	YSBM	ESBM	LSBM	SEM
Total lysine in SBM, % of crude protein	7.6	6.2	7.6	6.7	
Chemically available lysine in SBM, % of crude protein	5.5	4.1	5.3	4.3	
Dry matter intake, grams/day	18.3[a]	11.4[c]	17.9[a]	15.1[b]	0.40
Daily gain, grams/day	14.8[a]	7.9[c]	14.6[a]	11.5[b]	0.34
Gain:Feed	0.81[a]	0.70[c]	0.81[a]	0.76[b]	0.01
	12-h *In Situ* Residue of SBM Product				
	SSBM	YSBM	ESBM	LSBM	
Total lysine in SBM, % of crude protein	6.7	4.9	7.0	5.8	
Chemically available lysine in SBM, % of crude protein	5.2	3.9	5.3	5.1	
Dry matter intake, grams/day	14.72[a,z]	10.68[b]	15.04[a,z]	14.56[a]	0.40
Daily gain, grams/day	12.53[a,z]	7.60[b]	12.95[a,z]	12.23[a]	0.34
Gain:Feed	0.852[a,z]	0.711[b]	0.861[a,z]	0.840[a,z]	0.01

[1]SSBM = solvent SBM, ESBM = expeller SBM, LSBM = lignosulfonate-treated SBM, and YSBM = SSBM treated with 0.05% baker's yeast and steeped for 10 minutes at 86ºF before toasting at 212ºF. The SSBM diet contained 26% SSBM, and the other diets were formulated to be isonitrogenous by removing all of the SSBM, adding an isonitrogenous amount of the alternative SBM, and adjusting the amount of corn starch.

[a, b, c]Values having different superscript letters within row differ ($P<0.05$).

[z]Values differ from original of the same SBM product ($P<0.05$).