

Section 1 Nutrient Composition and Utilization

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Executive Summary - Nutrient Composition and Utilization Soy/Swine Nutrition Program Year 1

- There were two phases of work in this area during 1998-1999. Results from Phase I are reported here; Phase II results will be reported in the next year as projects end.
- The objectives of Phase I work were to
 - measure the variation in the nutrient content of soybean meal processed within a single processing plant during the course of a single harvest season; and
 - to determine the apparent and true amino acid digestibilities in these samples.
- Researchers from five regionally distinct institutions used the same study design for ileal digestibility studies of soybean meal based diets that used:
 - a common source of soybean meal,
 - a locally procured soybean meal from one harvest collected at four different times (days 0, 15, 30 and 45),
 - soy protein concentrate, and
 - casein, low protein diet to estimate endogenous losses of amino acids.
- Results were mixed for the comparisons of apparent and true ileal digestibilities of the amino acids for the soy protein concentrate and the meal based diets. While the Kansas study found the concentrate digestibilities were lower, the Ohio study found the apparent digestibilities were higher, but no difference in true digestibilities. North Carolina and Illinois noted lower apparent digestibility of methionine, probably related to how the concentrate is processed.
- Digestibility of amino acids among diets from Kansas were similar, except for tryptophan, which was lower for the day 30 sample than for samples from other dates. In Illinois, Ohio, and North Carolina, there were no significant differences between samples over time. Overall, apparent and true digestibilities varied little from one collection period to another.
- Results were also mixed for the comparisons of apparent and true ileal digestibilities of the amino acids for the common source and locally procured diets. Kansas found the control meal had higher digestibilities of some amino acids, but Ohio found the control meal had lower digestibilities. Illinois and North Carolina found no significant differences
- These trials suggest there is variation in amino acid digestibilities by regions and/or by processor. The reasons for these variations may be due to genotypes, processing conditions or an interaction between these factors.
- True ileal digestibilities of amino acids in soybean meal and soy protein concentrate are not 100%, providing future opportunities to increase digestibilities and/or decrease endogenous amino acid losses in pigs fed soy products.

Evaluating the Ileal Digestibility of Amino Acids in Soybean Meal from Different Soy Processors. Variation in the Digestibility of Amino Acids in Soybean Meal Collected at a Single Processing Plant in Kansas

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Institution: Kansas State University

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Summary

This report is for the Kansas State University portion of a collaborative research project involving five universities located throughout the United States and Europe. The overall objective was to determine the variation in ileal digestibility of amino acids in soybean meal (SBM) that might be encountered in the United States and Western Europe during single fall harvest season. Scientists at each experiment station collected 100 kg of SBM, at four different times (collections were separated by at least 15 d), from a local soy processing plant. The SBM samples were incorporated into cornstarch-based diets (17% CP) that were fed to 7 crossbred barrows (PIC Line C22 sows x 327 boars) weighing approximately 25 kg. The pigs were fitted with T-cannulas at the distal end of the small intestine and housed in steel metabolism cages to allow collection of ileal digesta during the 49-d experiment. Treatments were: 1) soy protein concentrate (a low anti-nutritional factor control supplied by the Ohio State University); 2) control SBM (supplied by the Ohio State University); 3, 4, 5, and 6) SBM collected in from the Kansas processor. The seventh diet (for the 7 x 7 Latin square design) was a low-protein (4% CP), casein-cornstarch-based formulation to allow estimation of endogenous losses of amino acids. As expected, the soy protein concentrate had greater concentrations of N and amino acids, and lower carbohydrate (NFE) content than the SBM samples. However, proximate components of the SBM samples were similar, as were the analyzed values for the essential amino acids. Apparent and true ileal digestibilities of the amino acids tended to be lower for the soy protein concentrate than for the SBM samples. Digestibility of amino acids among the SBM samples collected in Kansas were similar, except that true digestibility for tryptophan was lower ($P < .05$) for the d-30 SBM sample than for SBM samples collected on the other dates. Thus, it appears that date of collection had little effect on proximate components and amino acid digestibilities of SBM.

Problem Addressed

Soybean meal is a commonly used protein source in diets for pigs because of its high protein content. However, there still is concern about variability in protein content and quality that might result from variation in soybeans throughout the harvest season and inconsistencies in processing conditions at soy crushing plants. This perceived variability in content and quality of protein in commercially prepared soybean meal is of concern especially because of other high quality amino acid sources (e.g., fish meal, canola meal, and miscellaneous animal protein sources) from other countries now competing with SBM produced in the United States.

Swine and poultry producers alike demand a consistent, high quality, and reasonably priced high protein meal rich with highly digestible amino acids. To produce high quality SBM, heat treatment is essential to destroy anti-nutritional factors (e.g., trypsin inhibitors) that can reduce growth performance (Jimenez et al., 1963; Hancock et al., 1990). However, if too much heat is applied to the SBM during processing, decreased nutrient digestibility and animal performance will result (Hancock et al., 1990; Parsons et al., 1992). Thus, an experiment was designed with the objectives: 1) to gain an understanding of the variation encountered in the nutrient content of SBM processed within a single processing plant during the course of a single harvest season; and 2) to determine the apparent and true amino acid digestibilities in these SBM samples.

Approach Used

Four samples (100 kg each) of soybean meal were collected from a soybean processing plant in northeast Kansas (Bunge, Inc., Emporia, KS). The sample collection dates were separated by at least 15 d. A soy protein concentrate control was supplied by The Ohio State University to allow comparison of the SBM treatments to a soy product having the known antinutritional factor (protease inhibitors, oligosaccharides, and antigenic components) removed and(or) inactivated. Also, a SBM control was supplied by the Ohio State University to allow comparison of values derived at the various participating laboratories. All diets (Table 1) were cornstarch-based and formulated to 17% CP, (4.44% CP for the casein diet), .9% Ca, and .75% P. Vitamins and minerals were added to meet or exceed NRC (1998) recommendations. Finally, a cornstarch-casein-based diet was used to allow estimation of endogenous amino acid losses (Table 2) and, thus, calculation of true amino acid digestibilities.

For the experiment, nine barrows (25 kg average initial BW) were fasted for 16 to 20 h (to allow the digestive tract to empty) and surgically fitted with a simple T-cannula approximately 15 cm anterior to the ileocecal juncture. Anesthesia was induced using 5% thiamyl sodium (Boehringer Ingleheim Animal Health, St. Joseph, MO) and maintained with methoxyflurane (Pittman-Moore, Terra Haute, IN) and oxygen. Following surgery, the pigs were moved to steel metabolism crates (.5 m x 1.5 m) in a temperature-controlled (22°C) room. During the 10-d recovery period, the pigs were fed a standard grower diet formulated to 16% CP and to meet or exceed NRC (1998) recommendations for all nutrients. After recovery, the pigs were weighed and randomly assigned treatments. Treatments were: 1) soy protein concentrate; 2) control SBM (supplied by the Ohio State University); 3, 4, 5, and 6) SBM collected from the Kansas processor. The experimental design was a 7 x 7 Latin square (the casein diet serving as the seventh treatment) with pig and period as blocking criteria.

Water was provided ad libitum and feed was provided at 0700 and 1900 h using the equation: daily feed allowance = $BW^{.75} \times .09$. The pigs were weighed at the start and end of each period, and the average weight was used to calculate the food allowance for the next 7-d period. Chromic oxide (.5%) was added to the diets (as an indigestible marker) to allow calculation of apparent digestibility coefficients. The pigs were allowed 5 d for adjustment to diet before 2 d of collecting digesta from 0700 to 1900 h. The ileal digesta was collected in a balloon attached to the end of the cannula as described by Horszczaruk et al. (1972). The balloons were emptied every 20 to 30 min into a plastic jar and frozen. Upon completion of the collection period, the samples were thawed, homogenized, and sub-sampled. The sub-samples were frozen until they could be lyophilized, ground, and analyzed for nutrient content.

The protein sources, diets, and digesta samples were analyzed for concentrations of DM, N, ether extract, crude fiber, ash, and amino acids (AOAC, 1998). Also, as measures of under or over processing, color determinations (Hunter Lab) were made on the SBM samples (McNaughton et al., 1981) and urease activities (AOCS, 1994) were determined.

Digestibility data were analyzed as a Latin square design using the GLM procedure of SAS (1988). The statistical model included the effects of pig, period, and treatment (protein source). Because of the unstructured nature of the SBM collection treatments, means were separated using the LSD procedure (Steele and Torrie, 1980).

Results and Discussion

Dry matter concentrations for the SBM samples (Table 3) were very similar (ranging from 88.5 to 90%). Likewise, other proximate components (i.e., N, ether extract, crude fiber, ash, NFE) and amino acid concentrations were similar among the SBM samples and typical for those of commercially prepared SBM. However, chemical analyses will not detect differences in the adequacy of processing (i.e., over or under processing).

Commercial soybean processors prefer a urease index value between .2 and .02 Δ pH to indicate adequate thermal treatment of SBM (McNaughton et al., 1981). For our experiment, urease indexes ranged from .01 to .03 Δ pH, indicating that heat treatment should be adequate to inactivate the protease inhibitors found in raw soybeans. However, Araba et al. (1990) proposed that urease activity was of no value for detection of over processing. The authors proposed that low levels of urease activity were not always correlated with good growth performance of chicks because low levels of urease activity were not indicative of heat-damaged meal.

McNaughton et al. (1981), using color as an alternative to urease index, observed poor growth performance in broilers when Hunter Lab +a values were out of the range from +3.96 to +5.81. The authors suggested that optimum cooking conditions of SBM were achieved with Hunterlab +a values between 4.5 and 5.5. Other researchers (Vandergrift et al., 1983; Hansen et al., 1987; Chang et al., 1987) reported that Hunter Lab values were useful for predicting the performance of nonruminants as related to overheating of SBM. But these authors suggested slightly greater variation in Hunter Lab was of no nutritional consequence. Our SBM samples had Hunter L values ranging from 61.5 to 71.8, +a value from 4.7 to 5.9, and b values from 31.2 to 38.4. The control SBM (from the Ohio State University) had a Hunter L value of 71.1, +a value of 5.0, and b value of 31.9. Thus, all of the SBM samples used in our experiment were similar in color and typical for commercially prepared SBM.

As for digestibility of nutrients, the soy protein concentrate had lower apparent and true digestibility coefficients for several of the amino acids compared to the SBM treatments (Table 4). This response is difficult to explain because the soy protein concentrates supposedly have most known antinutritional factors found in soybeans (e.g., lectins, protease inhibitors, oligosaccharides, and antigenic constituents) either removed or inactivated with the hot alcohol wash used to manufacture soy concentrates.

Apparent digestibility of DM was greater for the SBM control and the sample collected on d 15 vs. the samples collected on d 0 and 45 ($P < .05$). Apparent digestibility of N was similar among the various SBM samples ($P > .05$) but the SBM control did have greater apparent digestibility of Ile and greater true digestibilities of Ile, Leu, and Val than the SBM collected on d 0 ($P < .05$). Also, the SBM control had greater apparent digestibilities of Ile and Thr and greater true digestibilities of His, Ile, Trp, and Val than the SBM collected on d 30 ($P < .05$). Among the SBM samples collected on d 0, 15, 30, and 45 only one response criterion (true digestibility of Trp for d 0 vs. d 30) was different.

Implications

Soybean meal is considered to be one of the most economical and highest quality protein sources available to the feed/livestock industries. However, for soybean meal to remain competitive and complementary with other feed grade protein sources, a thorough understanding of its potential variability is necessary. Our data indicate that day of processing at a single crushing plant may not be a major source of variability in the nutritional value of soybean meal. However, there were several differences in the apparent and true digestibilities of amino acids among the soybean meal control (from Ohio), the soy protein concentrate, and the soybean meal samples that we collected in Kansas that suggest variation (sometimes considerable) does exist.

Future Directions

Obviously, the data from our experiment need to be pooled and compared with the reports from the other institutions to draw definitive conclusions and suggest future direction for these research activities. However, it does seem that certain conclusions and inferences can be drawn from just our project. The consistencies that we observed in the nutritional value of the soy samples we collected during a 45-d period suggest that 'new harvest' beans from a small region in Kansas are of similar nutritional value. However, this does not indicate the variability that might occur in different seasons and times of year at this crushing plant. It would be of value to know if there are differences in the soybean meal produced in late August (old crop and out of state) vs. late October (new crop and grown locally). Perhaps collection dates of November 1, March 1, and July 1 for three to four years would be more indicative of the variation in end product that might be expected from this processing plant. Also, there is much to be known about the nutritional differences among various soybean genotypes and the interactions among soybean genotypes and processing conditions.

Table 1. Composition of diets (as fed basis)

Item, %	Soy conc.	SBM control	Soybean meals ^c				Casein
			d 0	d 15	d 30	d 45	
Corn starch	46.00	38.10	37.28	37.54	38.31	37.14	61.60
Sucrose	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal	—	35.25	36.07	35.81	35.04	36.21	—
Soy protein concentrate	27.00	—	—	—	—	—	—
Cellulose fiber	—	—	—	—	—	—	5.00
Casein	—	—	—	—	—	—	5.00
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	.35	.35	.35	.35	.35	.35	.40
Dicalcium phosphate	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	.45	.45	.45	.45	.45	.45	.60
Vitamins and minerals ^a	.35	.35	.35	.35	.35	.35	.35
Chromic oxide	.50	.50	.50	.50	.50	.50	.50
Potassium carbonate (55% K)	.35	—	—	—	—	—	1.40
Magnesium oxide (58% Mg)	—	—	—	—	—	—	.15
Calculated analysis							
CP	17.0	17.0	17.0	17.00	17.0	17.0	4.4
Lysine	1.03	1.05	1.05	1.05	1.05	1.05	.37
Ca	.90	.90	.90	.90	.90	.90	.90
P (total)	.75	.75	.75	.75	.75	.75	.61
Analyzed values ^b							
DM, %	91.4	91.4	91.2	91.0	90.8	90.8	91.1
CP, %	18.6	17.8	19.7	19.1	19.2	17.7	6.1
Ether extract, %	2.37	2.80	2.86	2.78	2.72	2.83	1.84
Crude fiber, %	1.05	1.49	1.59	1.44	1.43	2.32	.53
Ash, %	6.75	7.19	6.27	7.21	7.19	6.95	6.36

^aProvided per kilogram of complete diet: 2,000 IU of vitamin A; 300 IU of vitamin D₃; 20 IU of vitamin E; 1.0 mg of vitamin K (menadione); 4 mg of thiamin; 15 mg of niacin; 4 mg of riboflavin; 12 mg of pantothenic acid; 15 ug of vitamin B₁₂; 2 mg of pyridoxine; .1 mg of biotin; .5 mg of folic acid; .60 g of choline; 90 mg of Fe (ferrous sulfate); 5 mg of Mn (manganese oxide); 8 mg of Cu (copper sulfate); .20 mg of I (potassium iodate); .21 mg of Se (sodium selenite), and 90 mg Zn (zinc sulfate).

^dValues are on a DM basis.

^cSoybean meals were acquired from Bungee, Inc., Emporia, KS.

Table 2. Endogenous losses of amino acids in pigs, g/d^a

Period	Indispensable Amino Acids									
	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
1	.52	.24	.50	.72	.58	.12	.41	.62	.14	.59
2	.72	.20	.42	.62	.44	.11	.35	.63	.13	.52
3	.50	.24	.60	.77	.59	.17	.40	.74	.17	.65
4	1.14	.24	.65	.74	.50	.17	.36	.87	.18	.67
5	.54	.23	.60	.77	.49	.15	.38	.74	.10	.58
6	.56	.29	.84	.92	.52	.17	.46	.92	.19	.84
7	.91	.26	.59	.79	.51	.13	.40	.78	.13	.64
Mean	.70	.24	.60	.76	.52	.15	.39	.76	.15	.64

^aValues were obtained by feeding a purified diet with 5% added casein.

Table 3. Chemical analyses of protein sources, % (dry matter basis)

Item	Soy concentrate	SBM Control	Soybean meals ^d				Casein
			d 0	d 15	d 30	d 45	
Proximate components ^a							
DM, %	90.2	90.0	88.8	88.7	88.6	88.5	89.9
N, %	10.9	8.7	9.0	9.0	9.0	9.0	15.7
Ether extract, %	.6	2.5	2.0	1.9	1.7	1.9	.2
Crude fiber, %	3.9	3.4	3.9	3.6	3.7	3.6	.1
Ash, %	7.8	7.2	8.2	8.1	8.3	8.3	3.9
NFE, %	9.9	22.9	18.5	19.0	18.7	18.5	0
Urease index, ΔpH ^b	.03	.03	.03	.01	.03	.03	.06
Hunter L ^c	67.2	71.1	61.5	70.8	71.4	71.8	53.8
A	4.7	5.0	5.9	4.9	4.7	5.0	6.6
b	36.6	31.9	38.4	32.3	32.1	31.2	38.7
Indispensable amino acid, %							
Arg	5.19	3.98	3.97	4.05	4.04	4.03	3.37
His	1.93	1.44	1.58	.54	1.52	1.51	2.70
Ile	3.26	2.41	2.36	2.43	2.50	2.45	4.45
Leu	5.51	4.10	4.20	4.26	4.28	4.25	8.54
Lys	4.52	3.32	3.46	3.52	3.53	3.51	7.11
Met	1.00	.73	.80	.80	.84	.82	2.61
Phe	3.59	2.71	2.93	2.91	2.88	2.87	4.79
Thr	2.83	2.08	2.08	2.07	2.09	2.08	3.91
Trp	.92	.68	.89	.83	.86	.87	1.30
Val	3.49	2.60	2.44	2.54	2.63	2.59	5.83
Total	32.24	24.05	24.71	24.95	25.17	24.98	44.61
Dispensable amino acids, %	33.83	25.18	25.55	26.08	26.34	26.24	47.29

^aAOAC (1990).^bAOCS (1973).^cHunterlab color value (McNaughton et al., 1981).^dSoybean meals were acquired from Bungee, Inc., Emporia, KS.

Table 4. True and apparent digestibilities of amino acids in soybean protein meals^a

Item	Soy conc.	SBM control	Soybean meals ^b				SE
			d 0	d 15	d 30	d 45	
DM digestibility, %	80.6 ^{tu}	81.6 ^t	79.4 ^u	81.6 ^t	79.8 ^{tu}	79.2 ^u	.6
N digestibility, %	76.3 ^u	82.1 ^t	79.3 ^{tu}	82.1 ^t	79.8 ^{tu}	81.1 ^t	1.3
Arg digestibility, %							
Apparent	90	92	91	92	91	92	2.0
True	94 ^u	96 ^t	95 ^{tu}	96 ^t	95 ^{tu}	95 ^{tu}	.6
His digestibility, %							
Apparent	84 ^v	89 ^t	88 ^t	88 ^t	87 ^{tu}	87 ^{tu}	.8
True	88 ^v	93 ^t	91 ^{tu}	92 ^{tu}	90 ^u	91 ^{tu}	.8
Ile digestibility, %							
Apparent	84 ^u	87 ^t	84 ^u	86 ^{tu}	84 ^u	85 ^{tu}	.8
True	89 ^v	92 ^t	90 ^{uv}	91 ^{tu}	90 ^{uv}	90 ^{tuv}	.8
Leu digestibility, %							
Apparent	82 ^v	85 ^{tu}	83 ^{uv}	85 ^{tu}	83 ^{uv}	84 ^{tuv}	.8
True	86 ^v	89 ^t	87 ^{uv}	89 ^{tu}	87 ^{tuv}	88 ^{tuv}	.8
Lys digestibility, %							
Apparent	83 ^v	87 ^{tu}	85 ^{uv}	87 ^{tu}	85 ^{tuv}	87 ^{tu}	1.0
True	86 ^u	91 ^t	88 ^{tu}	90 ^t	89 ^{tu}	90 ^t	1.1
Met digestibility, %							
Apparent	83 ^u	87 ^t	87 ^t	89 ^t	87 ^t	87 ^t	.7
True	88 ^u	92 ^t	91 ^t	93 ^t	91 ^t	92 ^t	.8
Phe digestibility, %							
Apparent	85	87	86	87	86	86	.7
True	88 ^u	90 ^t	89 ^{tu}	90 ^t	89 ^{tu}	89 ^{tu}	.7
Thr digestibility, %							
Apparent	74 ^v	79 ^t	76 ^{tuv}	78 ^{tu}	76 ^{uv}	76 ^{uv}	1.0
True	82 ^v	87 ^t	84 ^{tuv}	86 ^{tu}	84 ^{tuv}	84 ^{uv}	1.1
Trp digestibility, %							
Apparent	81 ^v	85 ^u	86 ^{tu}	88 ^t	84 ^u	87 ^{tu}	1.0
True	86 ^v	90 ^{tu}	90 ^{tu}	92 ^t	88 ^v	90 ^{tu}	1.0
Val digestibility, %							
Apparent	81	85	82	84	82	83	1.0
True	86 ^v	91 ^t	88 ^{uv}	90 ^{tu}	88 ^{uv}	88 ^{uv}	1.0
Total digestibility, %							
Apparent	83	86	85	86	85	85	1.0
True	87	91	89	91	89	90	1.0

^aTrue digestibilities were calculated using average amino acid values for pigs fed a casein-based diet.

^bSoybean meals were acquired from Bungee, Inc., Emporia, KS.

^{tu}^v^w^x^y^z Means in the same row with different superscripts are different (P < .05).

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Digestibility of Soybean Meals Collected at Four Periods from a Soybean Processor (Cargill) in Ohio

Investigators: Don Mahan

Institution: Ohio State University

Report Date: January 31, 2000

Project Start Date: July 1, 1998

Project End Date: December 31, 1999

Funding Level: \$42,000

Objectives

1. To evaluate the ileal digestibility of amino acids of four soybean meal samples collected from the Cargill soybean meal processor in Sidney, OH.
2. To determine the apparent digestibility of Se in the Ohio soybean meals collected from the Ohio Soybean Processor and to analyze the Se content of the soybean meals from the other study collaborators.

Approach Used

Experimental Treatments

<u>No.</u>	<u>General dietary description</u> ^{a b}
1.	48% Soybean meal (Common source) -- negative control--
2.	48% Soybean meal Cargill (Sidney, OH) B collected 9/11/98
3.	48% Soybean meal Cargill (Sidney, OH) B collected 10/2/98
4.	48% Soybean meal Cargill (Sidney, OH) B collected 10/15/98
5.	48% Soybean meal Cargill (Sidney, OH) B collected 10/29/98
6.	Soy Protein Concentrate (single soy source) --positive control
7.	<u>Casein diet (low protein)</u>

^aSee Table 1 for diet compositions.

^bSee Table 2 for amino acid analyses of test ingredients.

Experimental Procedures

Diets and Soybean Meal Procurement

1. A large quantity of dehulled soybean meal and soy protein concentrate was procured by Don Mahan and analyzed for its amino acid (Univ of MO.) and mineral (OARDC, Wooster, OH) contents. These soybean protein sources will be used in the formulation of the negative and

positive control diets (Treatments No. 1, and No. 6) and will be considered the common source that was used between all collaborators. The casein sample was collected from a common supplier and kept on inventory at Wooster, Ohio for later distribution to all investigators. The casein was also analyzed for amino acids by the University of MO.

2. A sample (e.g. 500 lb) of 48% soybean meal was collected at 4 different times from the Sidney, Ohio Cargill soybean meal processing plant. Contact personnel were: Andrea Flowers and Bob Fridley. The four soybean meals were procured at least 14 days and Cargill was only asked the morning of pickup if the day was permissible for them. An approximate 2 lb sample of each of the 48% soybean meals collected were saved for later analyses of carbohydrate and KOH (by Dr. G. Fahey).
3. Calculation of treatment diets was done on the basis of crude protein substitution of the treatment soybean meals as was done for the positive and negative control diets (common sources). Diets were to be formulated to a 17% crude protein level.
4. The diet compositions for all Treatments 1, 6, 7 are presented in Table 1 and was used by all investigators. Each investigator procured their own ingredients except those noted. A common source of vitamins and trace minerals was used by all collaborators and was supplied by Don Mahan (Table 1). Each investigator was to use Dicalcium phosphate, limestone (38% Ca), potassium carbonate (55% K), and magnesium oxide (15% Mg) as the supplemental macro-mineral sources in the appropriate treatment diets.
5. Chromic oxide was included in all diets (.50%) for determining amino acid and Se digestibilities. The Cr analysis was conducted by the University of Mo.
6. Ohio State deleted the Se from their trace mineral mixture for the determination of apparent digestibility of the Se from their soybean meal samples. Other stations did not conduct this aspect of the trial.

Animal Preparation

1. Each station procured the necessary animal protocol use forms from their Animal Use Committee before the project was approved.
2. Crossbred barrow pigs of approximately 25-30 kg body weight were surgically prepared with a simple T-cannula at the distal ileum. Two additional animals were prepared in the event that animals were unable to be used. The pigs not used during the course of the trial were fed the same quantity of the positive control 48% dehulled soybean meal diet as the treatment animals within each replicate.

Experimental Design and Collection Procedure

1. The experiment was a 7 x 7 Latin Square Design with pigs allotted to treatments randomly within each treatment group and rotated in a manner such that the entire set of animals received the 7 treatment diets.

2. Pigs were weighed prior to surgery and at the time of placement into the stainless steel metabolism stalls. Pigs were subsequently fed a constant amount of diet within each replicate period for a 5-day pre-test adaptation period. Meals were fed twice daily at 12-hour intervals (i.e., 0700 and 1900 h) followed by a 2 day collection of digesta. The amount of feed provided during each subsequent period was calculated on the basis of $.090 \text{ kg}^{.75}$ body weight, but equalized for animals within each experimental treatment period. Because it was not possible to weigh the animals the feed intake was provided to the estimated values. The feed intakes provided for each period, and subsequent daily gains for the entire collection period are reported in Table 3.
3. Ileal samples were collected on a timely basis as needed during a 12 hour period (e.g. 0800 to 2000 hr) during each of the 2 day collection periods. Small plastic tubes were attached to the cannula and changed when digesta filled the tube or no longer than 1 hour. Care was taken to ensure that digesta flow was unaffected during the collection period. Samples were immediately placed in a freezer upon removal from the cannula in order to eliminate microbial activity in the digesta. The ileal digesta contents for each pig was pooled for the 2 day period, mixed, and a 200 gram sample sent under dry ice for freeze drying, amino acid, and Cr analyses (Univ of Missouri analytical laboratory).

Analytical Methods

1. The data were analyzed as a 7 X 7 Latin Square design using the GLM method of SAS (1985). Treatment contrasts were
 - a. Negative (common SBM) vs. the Positive (common SPC)
 - b. Negative (common SBM) vs. the 4 SBM (Cargill)
 - c. Period responses (Linear regression)
2. The common soybean meal, the soy protein concentrate, and the casein were analyzed in triplicate for amino acids by the University of MO. These analyses were shared with all investigators. The address of this laboratory is:

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3. The Se analyses were conducted by the AOAC fluorometric method after the samples were wet asked in perchloric and nitric acid. This was done in the swine nutrition laboratory (Ohio State University).

4. Digestibilities were calculated using the following formulas:

$$\text{Apparent Digestibility, \%} = ((M_d * AA_I) / (AA_d * M_I)) * 100$$

M_d = Marker [Cr] concentrate in diet (.50% * 68.4% = .34)

AA_I = Amino acid concentration in diet

AA_d = Amino acid concentration in Ileal digesta

M_I = Marker concentration in Ileal digesta

$$\text{True Digestibility, \%} = ((M_d * [AA_I - AA_e]) / (AA_d * M_I)) * 100$$

M_d = Marker concentrate in diet

AA_I = Amino acid concentration in ileal digesta

AA_d = Amino acid concentration in diet

AA_e = Amino acid concentration in endogenous fraction

M_I = Marker concentration in ileal digesta

Results

1. The apparent digestibilities and true digestibilities are presented in Tables 4 and 5, respectively.
 - a. The Soy protein concentrate diet (positive control) compared with the common soybean meal (negative control) generally had higher apparent digestibilities of most essential amino acids, but there were fewer differences in true digestibilities between these sources.
 - b. The apparent and true digestibilities of the common soybean meal source (negative control) were lower when compared with the four samples collected from the Cargill soy processor (Sidney, OH). This suggests that soy processing can indeed affect the digestibility of soybean meal, and whatever factors were present in the processing of the soybean meals at the Sidney plant enhanced the digestibility of these meals.
 - c. The digestibilities (apparent and true) from the soybean meal samples collected from the Cargill soy processor were uniform from one collection period to the next. This suggests that the processing method used at the Sidney plant was consistent and of good quality.
 - d. When the Cargill soybean meal samples were compared to the positive control (soy protein concentrate), the digestibilities were in general similar to that reported for the Asuperior® soy protein source. This questions the use of soy protein concentrate for grower finisher swine, but also challenges the fact that soybean meal can be processed in such a way that its digestibility can be comparable to the soy protein concentrate source.
2. The effect of period on apparent and true digestibility is reported in Tables 6 and 7, respectively. The results do not indicate that either digestibility (apparent or true) was affected by period. This suggests that the digestibility values can be used without bias or confounding of overall conclusions.

3. The apparent and true digestibilities obtained with the common soybean meal (negative control) and the four soybean meal samples collected from Cargill (Sidney, OH) and compared to that reported in NRC (1998) demonstrated:
 - a. The common source of soybean meal (negative control) compared with the NRC (1998) values was similar in both apparent and true digestibilities (Table 8).
 - b. When the Cargill source was compared with the common source (negative control) and NRC (1998), the Cargill source had higher digestibilities when expressed on an apparent or true digestibility. This suggests that soybean meal processing can greatly influence the quality of the bean meal provided to swine.
4. Selenium apparent digestibilities were high in all samples (Table 4). Although there were significant differences between the negative control and the positive control and the negative control to the four soybean meal samples from the Cargill soy processor, all values can be considered very high. The statistical significance is of minor biological importance.
5. Selenium concentrations in the various soybean meal samples collected from the various collaborators are presented in Table 9. The resulting Se concentrations are consistent with previously reported Se values from soybean meal samples collected from each region. In general, the east coast and the eastern part of the Midwest have areas that are low in Se, whereas the Midwest areas in the western part of the corn belt have higher concentrations. The samples obtained from the Netherlands are variable, which is attributed to the variable sources of soybean meals being imported.

Table 1. Percentage composition experimental diets (as-fed).

Ingredient	Trt. No.	1	2	3	4	5	6	7
		Control SBM (Common Source)	SBM-1	SBM-2	SBM-3	SBM-4	Control (Soy Protein Concent.)	Low protein (Casein)
Corn starch		38.10	39.55	39.55	39.55	39.55	46.00	61.60
Sucrose		20.00	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal (stored reserve)		35.25	-	-	-	-	-	-
Soybean meal (source 1-4)		-	33.80	33.80	33.80	33.80	-	-
Soy Protein Conc.(from DM)		-	-	-	-	-	27.00	-
Solka Floc		-	-	-	-	-	-	5.00
Casein, food grade		-	-	-	-	-	-	5.00
Corn oil		2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt		0.35	0.35	0.35	0.35	0.35	0.35	0.40
Dicalcium phosphate		3.00	3.00	3.00	3.00	3.00	3.00	3.00
Limestone		0.45	0.45	0.45	0.45	0.45	0.45	0.60
Trace mineral (special) ^a		0.05	0.05	0.05	0.05	0.05	0.05	0.05
Chromic oxide		0.50	0.50	0.50	0.50	0.50	0.50	0.50
Potassium carbonate(55%K)		-	-	-	-	-	0.35	1.40
Magnesium oxide (58% Mg)		-	-	-	-	-	-	0.15
Vitamin mix (special) ^b		0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analysis, calculated %								
Crude Protein		17.0	17.0	17.0	17.0	17.0	17.0	
Lysine		1.05	.98	.98	.98	.98	1.03	.37
Ca		.90	.94	.90	.90	.90	.90	.90
P (total)		.75	.78	.75	.75	.75	.75	.61
P (avail)		.61					.61	.61
K		.78	.73	.73	.73	.73	.79	.78
Mg		.11	.11		.11	.11	.12	.12

Table 2. Amino acid and mineral composition of soy proteins (as fed basis)

Nutrient	Soybean Meal (dehulled)	Soy Protein Concentration	Casein
Essential Amino Acids, % ^a			
Arg	3.56	4.68	3.03
His	1.29	1.74	2.43
Iso	2.16	2.94	4.00
Leu	3.67	4.97	7.68
Lys	2.97	4.08	6.39
Met	0.65	0.90	2.35
(Cys)	0.76	1.07	0.30
Phe	2.43	3.24	4.31
(Tyr)	1.70	2.29	4.65
Typ	0.61	0.83	1.17
Thr	1.83	2.55	3.52
Val	2.31	3.15	5.24
Nonessential amino acids, % ^a			
Asp	5.29	7.16	5.70
Ser	2.26	3.11	4.61
Glu	8.59	11.53	18.77
Pro	2.37	3.24	9.44
Gly	1.97	2.68	1.52
Ala	2.07	2.81	2.48
Minerals ^b			
Ca, %	0.20	0.36	-
P, %	0.57	0.75	-
Mg, %	0.23	0.32	-
K, %	0.12	0.20	-
Na, %	0.01	0.03	-
Cu, ppm	12	11	-
Zn, ppm	41	42	-
Fe, ppm	172	109	-
Mn, ppm	24	38	-
Se, ppm ^c	0.26	0.24	-

^a Assays conducted in triplicate (Un of Mo)

^b Assays conducted in triplicate (ICP), OARDC (Wooster, OH)

^c Assays conducted in triplicate (Swine Nutrition Lab, Ohio State Univ.)

Table 3. Experimental Pig Information (Ohio Station)

Test Period: March 23, 1999 to May 14, 1999

Pig Weight, kg

Initial 28.4

Final 78.8

Daily gain, g 826

Feed Intake, g Period

1,300 1

1,480 2

1,680 3

1,880 4

2,080 5

2,300 6

2,500 7

Table 4. Apparent Digestibility of Soybean Meal (48% CP) Samples.

Amino Acid	SBM (common source) (1)	Soy (Protein concent.) (2)	Test Soybean Meals (Ohio)				SEM	P < .xx	
			1	2	3	4		1 vs	1 vs
			(3)	(4)	(5)	(6)		2	3,4,5,6
Arg	92.4	94.6	93.6	94.2	93.9	94.1	.29	.01	.01
His	87.5	89.1	89.2	90.6	89.4	89.2	.61	.08	.01
Iso	83.7	87.2	85.5	87.3	85.4	86.3	.81	.01	.01
Leu	82.4	86.0	84.6	86.2	84.9	84.8	.80	.01	.01
Lys	84.9	88.8	87.1	89.0	88.3	87.8	.63	.01	.01
Met	85.6	87.7	88.5	89.4	89.0	88.1	.81	.08	.01
Cys	77.6	80.0	81.3	82.3	80.5	79.6	1.46	.26	.06
Phe	84.0	87.7	86.2	87.3	86.5	86.5	.68	.01	.01
Tyr	83.7	87.1	86.2	87.4	86.5	86.1	.76	.01	.01
Try	83.2	85.3	88.4	90.5	88.1	86.4	1.50	.34	.01
Thr	76.1	79.3	79.6	81.5	80.4	79.4	1.11	.05	.01
Val	81.7	84.8	83.4	85.7	83.3	83.8	.99	.04	.05
Ala	78.3	82.1	81.4	83.3	82.0	81.4	1.10	.02	.01
Asp	81.3	83.4	84.7	86.5	86.0	85.8	.75	.06	.01
Glu	86.1	88.5	87.8	89.7	88.3	87.5	1.00	.10	.05
Gly	74.1	76.5	78.3	79.4	77.1	77.2	1.69	.34	.05
Pro	83.0	84.0	83.7	85.8	84.5	84.7	.92	.43	.10
Ser	83.4	86.0	84.7	85.9	85.6	84.5	.78	.01	.06
Se	97.8	97.0	96.8	96.2	95.7	97.3	.21	.01	.01

Table 5. True Digestibility of Soybean Meal (48% CP) Samples.

Amino Acid	SBM (common source) (1)	Soy Protein Concen. (2)	Test Soybean Meal				SEM	P < .xx	
			1	2	3	4		1 vs	1 vs
			(3)	(4)	(5)	(6)		2	3,4,5,6
Arg	95.8	97.2	96.5	96.9	96.7	96.9	.22	.01	.01
His	93.0	93.4	94.0	95.2	94.1	93.8	.47	.61	.03
Iso	93.8	94.9	94.5	95.8	94.7	94.9	.56	.17	.08
Leu	89.9	91.7	91.1	92.4	91.4	91.1	.61	.04	.03
Lys	91.3	93.7	92.6	94.2	93.8	93.1	.50	.01	.01
Met	94.0	94.1	95.4	96.3	96.1	95.1	.63	.93	.03
Cys	87.1	87.0	89.4	90.2	89.0	87.7	1.22	.96	.16
Phe	90.3	92.7	91.6	92.5	91.9	91.8	.52	.01	.01
Tyr	93.8	94.9	95.0	95.9	95.4	94.7	.48	.11	.01
Try	90.8	91.2	94.3	96.0	93.9	92.0	1.35	.85	.04
Thr	90.3	90.0	91.7	93.2	92.5	91.3	.76	.77	.04
Val	92.2	92.8	92.7	94.4	92.9	92.7	.72	.57	.21
Ala	89.7	91.0	91.4	92.8	91.9	91.1	.83		.04
Asp	87.8	88.4	90.2	91.8	91.4	91.2	.58		.01
Glu	94.1	94.7	94.5	96.1	95.0	94.1	.82		.38
Gly	89.1	87.9	91.2	91.5	89.8	89.5	1.31		.33
Pro	99.1	96.2	98.2	99.3	98.0	98.2	.76		.42
Ser	98.2	97.2	98.1	98.6	98.6	97.8	.42		.69

Table 6. Period Responses - Apparent Digestibility (Least Square Means)

Amino Acid	Period							SEM	(P < .xx)
	1	2	3	4	5	6	7		
Arg	93.1	93.1	93.0	94.3	94.4	94.4	94.5	.32	.01L
His	88.9	88.4	88.8	90.0	90.3	88.2	89.4	.67	.43L
Iso	85.1	85.4	84.0	86.6	87.8	85.4	86.8	.89	.07L
Leu	84.3	84.4	83.3	86.8	86.5	84.1	85.5	.88	.21L
Lys	87.3	87.4	87.0	88.4	89.1	86.5	87.7	.70	.70L
Met	86.8	87.8	87.0	89.1	89.5	87.5	88.5	.88	.15L
Cys	77.7	78.686	78.8	81.6	82.9	79.9	82.1	1.60	.03L
Phe	86.5	.6	85.7	87.0	87.1	85.4	86.3	.74	.69L
Tyr	85.7	84.9	84.5	87.1	87.5	86.6	87.0	.83	.03L
Try	85.7	86.2	85.4	88.2	88.2	86.7	88.3	1.64	.20L
Thr	78.5	78.4	77.7	80.9	82.1	78.5	79.6	1.21	.25L
Val	82.8	83.8	82.3	84.7	85.8	82.7	84.5	1.08	.28L
Ala	80.6	81.6	79.8	82.4	83.5	80.0	81.9	1.21	.50L
Asp	84.3	84.7	83.5	85.5	86.4	83.3	84.3	.82	.98L
Glu	87.3	87.9	87.8	88.9	89.6	86.7	87.7	1.09	.88L
Gly	75.2	75.0	75.6	78.7	79.4	77.7	78.2	1.84	.08L
Pro	83.7	82.8	82.9	85.1	86.5	84.4	84.4	1.45	.16L
Ser	85.4	84.8	84.2	86.5	87.0	83.3	83.9	.87	.32L

Table 7. Period Responses - True Digestibility (Least Square Means)

Amino Acid	Period							SEM	(P < .xx)
	1	2	3	4	5	6	7		
Arg	96.4	96.8	95.3	97.4	97.1	97.2	96.4	.23	.07L
His	95.0	94.1	92.1	94.8	94.7	94.0	92.7	.52	.11L
Iso	96.8	94.3	92.3	94.6	95.1	94.6	95.6	.61	.91L
Leu	92.4	91.8	88.2	92.2	92.0	91.7	90.5	.66	.57L
Lys	93.8	94.1	91.3	93.6	94.2	93.0	91.8	.56	.09L
Met	95.0	95.9	92.6	96.4	95.9	96.3	94.1	.70	.76L
Cys	88.2	88.9	85.9	90.0	89.7	87.6	88.4	1.33	.80L
Phe	92.0	92.2	89.2	93.2	92.0	93.1	90.9	.58	.73L
Tyr	97.5	94.4	91.8	96.3	94.0	97.9	93.0	.53	.12L
Try	93.3	93.6	88.6	93.4	93.9	95.5	93.1	1.48	.27L
Thr	93.6	92.1	87.8	92.7	92.1	91.7	90.5	.83	.18L
Val	94.5	93.2	90.3	93.7	93.7	92.6	92.7	.79	.42L
Ala	92.2	93.4	87.3	91.6	92.8	91.9	89.9	.91	.36L
Asp	91.1	90.8	88.0	90.9	91.4	89.6	89.1	.64	.16L
Glu	95.7	94.0	93.7	95.1	95.7	94.3	94.9	.90	.94L
Gly	89.3	87.5	84.7	95.1	91.8	93.8	86.7	1.44	.13L
Pro	94.4	92.6	91.8	95.7	101.2	99.9	101.6	.83	.01L
Ser	102.3	95.9	95.0	98.1	97.2	98.7	99.7	.76	.99L

Table 8. Comparison of Apparent and True Digestibilities of Soybean Meal(48% CP) from the Ohio Soybean Processor to NRC Published Sources

Amino Acid	Apparent Digestibilities,%			True Digestibilities,%		
	NRC	This report		NRC	This report	
	(1998)	Common source	Cargill (Ohio)	1998	Common source	Cargill (Ohio)
Arg	90	92	94	94	96	97
His	86	82	90	91	93	94
Iso	84	84	86	89	94	95
Leu	84	82	85	89	90	91
Lys	85	85	88	90	91	93
Met	86	86	89	91	94	96
Cys	79	78	81	87	87	89
Phe	84	84	87	89	90	92
Tyr	85	84	87	90	94	95
Try	81	83	88	90	91	94
Thr	78	76	80	87	90	92
Val	81	82	84	88	92	93

Table 9. Selenium Analyses for various soybean meals ^a

Period of Collection	Station				
	North Carolina	Ohio	Illinois	Kansas	Netherlands
1	.087	.074	.136	.599	.186
2	.078	.103	.170	.577	.345
3	.117	.103	.146	.628	.064
4	.092	.101	.150	.548	.023
Avg.	.092	.095	.151	.588	.155

^a Se results are expressed as mg/kg soybean meal.

Evaluating the Ileal Digestibility of Amino Acids in Soybean Meals from Different Soy Processors

Investigators: Theo van Kempen and Inbae Kim

Institution: North Carolina State University

Report Date: January 31, 2000

Project Start Date: July 1, 1998

Project End Date: December 31, 1999

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Summary

The objective of this experiment was to evaluate the degree of variation in nutritional value of soybean meals processed within a single plant over a 45-day period (locally produced beans), and to standardize procedures for evaluating the quality factors that affect the nutritional value of soybean meal. Seven (plus two spare) barrows were surgically fitted with a simple-T cannula at the distal ileum for collection of ileal digesta. The pigs were fed one of seven experimental diets according to a 7×7 Latin square design. The experimental diets comprised six iso-nitrogenous diets and a low-protein casein diet. Diet SBM OSU contained soybean meal (CP 48%) as a common source provided by Dr. Mahan. Diets SBM 0, 15, 30, and 45 contained soybean meal obtained from the same local soybean processor but processed on different days (0, 15, 30, and 45 d), and diet SPC contained soy-protein concentrate as a control. Diet LPC contained 5 % casein as the only protein source, and was used to estimate endogenous losses of amino acids for correcting ileal amino acids digestibility. Animals were fed twice daily, at 0700 and 1900 h, with equal amounts at each meal. Feeding level was determined on the basis of $90\text{g}/(\text{kg}^{.75} \cdot \text{day})$ body weight.

The standard error of means observed for the digestibility coefficients were typically one percent for the indispensable amino acids. This suggests that the measurements were obtained with good precision. Nevertheless, no differences were observed in the digestibility coefficients for indispensable amino acids for the different soybean meals ($P > .05$). These data suggest that between-batch variation within a limited time frame is a minor issue, presuming that soybean meal is obtained from a single plant and a single region.

Problem Addressed

Soybean meal is the major high-protein ingredient used in swine feeds in the U.S. and many other countries around the world. The nutritional value of soybean meal has received attention in

many studies, but a fundamental understanding of factors that affect variation in nutritional values is missing.

The objective of the here described experiment was 1) to evaluate the degree of variation in nutritional value of soybean meals processed within a single plant over a 45 day period (processing locally produced beans), and 2) to standardize procedures such that future studies can address possible quality factors that may affect the nutritional value of soybean meal.

Approach Used

Animals and Diets

Nine barrows (PIC breed) were obtained from the Swine Education Unit of NCSU at a weight of approximately 22 kg. These animals were surgically fitted with a simple T-cannula at the distal ileum using procedures adapted from Sauer et al. (1983). Following recovery from surgery, the animals were housed in smooth concrete walled pens in the Grinnells facility where they were allowed a two-week adaptation period.

During the adaptation period, animals were 'played with' daily to accustom them to humans. During the adaptation period and during the actual experiment, pens and animals were washed daily. In addition, a zinc-oxide containing diaper crème was applied twice daily around the cannula.

After adaptation, seven animals were arbitrarily chosen to participate in the experiment (the other two were maintained as auxiliary). The selected animals were fed one of seven experimental diets according to a 7×7 Latin square design. At the start of each period, animals were weighed, and based on group average weight, the feeding level was calculated on the basis of $90\text{g}/(\text{kg}^{.75}\cdot\text{day})$ body weight (Table 1). Animals were fed twice daily, at 0700 and 1900 h, with equal amounts at each meal. Water was provided *ad libitum*. Between period 3 and 4, animals were removed from the experiment for a one-week period as the investigators attended a scientific meeting, during which time the animals were fed a commercial grower diet at the same level as in Period 3.

During Period 2, one animal escaped from its pen and consumed feed that was prepared for other animals (this pig was on feed SBM 30). Samples from this pig were, therefore, not analyzed for Period 2. An attempt was made to replace the missing data by feeding the SBM 30 diet to one of the spare animals during Period 6. However, this animal did not consume the total quantity of feed offered, and data from this animal were thus not a suitable substitute.

The experimental diets comprised six isonitrogenous diets and one low-protein casein diet (Table 2). Diet SBM OSU contained soybean meal (CP 48%) from a common source (provided by Don Mahan at Ohio State University) and served as a control. Diets SBM 0, 15, 30, and 45 contained soybean meal obtained from the same local soybean processor but processed on different days (0, 15, 30, and 45 d), and the batches collected were supposed to represent locally produced soybeans.¹ Diet SPC contained soy-protein concentrate as the positive control. Diet LPC contained 5 % casein, and was used to estimate endogenous losses of amino acids for correcting ileal amino acids digestibility. The composition of each of the protein sources is provided in Table 3. Chromic oxide was included in each diet at a level of .5% and used as an indigestible marker for digestibility calculation.

¹ An attempt was made to collect meal corresponding to locally produced soy beans, but as it was impossible to track beans through the plant it can not be guaranteed that beans were indeed locally obtained.

Each experimental period consisted of 7 d, which were 5 d for adaptation and 2 d for ileal digesta collection. During the collection days, digesta were collected over 12 hours, from 0700 and 1900h. The ileal digesta were collected continuously from the T-cannula into an attached Nalgene[®] plastic bottle (125 ml), which prevented loss of sample. The collected ileal digesta were frozen immediately (-20°C). Samples were pooled within barrow and period for analysis.

Chemical and Statistical Analysis

The proximate, chromium, and amino acids analysis of samples were conducted by the Experimental Station Chemical Laboratories, University of Missouri-Columbia, MO. For amino acids analysis, ileal digesta samples were freeze-dried. The determination of energy content of diet and ileal digesta samples was conducted with an oxygen bomb calorimeter (IKA Model 250) at NCSU. For energy determination, the ileal digesta were dried at 60 °C. Both of the proximate and amino acids analyses were conducted according to procedures described by the AOAC (1990).

The endogenous amino acids losses were determined using a low-protein casein (LPC) diet. Also, for the calculation of true ileal amino acid digestibility in line with the 1998 NRC, basal endogenous loss data obtained using a protein-free diet as published by Tran et al. (1999) were used. The calculation equations used are shown in Appendix I.

All data were analyzed using PROC GLM in SAS (1996). Data from one pig were deleted for all periods as results obtained from this animal were considered abnormal during two time-period.

Results and Discussion

The pigs remained healthy and consumed their meals throughout this experiment. The average daily gain observed during the course of this experiment was 570 grams per day, while the feed efficiency was approximately 2.5. These figures are impressive given that the diets were not formulated to provide a well-balanced meal. In addition, as these animals were surgically modified a less than ideal growth was expected (although some degree of compensatory gain may have occurred). These growth data indicate that the animals were in perfect health and well cared for during the course of this experiment, which also shows itself in the low error term observed in the digestibility coefficients.

The soybean meal samples obtained from North Carolina were somewhat higher in protein (4%) and indispensable amino acids (0-14%) than the reference sample obtained from Ohio. The four samples obtained, however, were effectively identical in protein and indispensable amino acids content (differences observed are smaller than the measurement error).

Apparent ileal digestibility coefficients are provided in Table 4. These data are calculated without assigning a portion of the endogenous losses to the non-soybean meal portion of the diet, and are thus, in principle, different than values reported in current CVB tables (1998). For indispensable amino acids, the four soybean meal samples obtained from North Carolina were not different in their apparent digestibility, nor were these samples different from the reference sample obtained from Ohio.

Apparent ileal digestibility coefficients for the LPC diet are provided in Table 5. However, as the protein content of the SPC diet was much lower than that of the other test diets and as apparent digestibilities are dependent on the protein content of the test diet (due to the 'fixed'

basal endogenous losses), these apparent digestibility figures bear little scientific relevance. Remarkably, negative apparent digestibility coefficients were obtained for both cysteine and glycine using the LPC diet.

In Table 6, digestibility coefficients corrected for endogenous excretions as measured with the low protein casein diet are provided (the correction factors used are in Table 8). This method of correcting apparent digestibilities has been suggested as a more biologically relevant method but no internationally recognized standardized diet for measuring LPC endogenous losses has been accepted. Therefore, the results here obtained should not be compared with other experiments except where the same LPC diet was used. As endogenous excretions obtained with diets containing casein and fiber (sulka floc) were higher than those obtained with a protein and fiber-free diet, the corrected digestibility coefficients are higher. Following correction, digestibility coefficients for the five soybean meal samples were not statistically different.

In this experiment, using the LPC diet for determining endogenous losses lead to digestibility coefficients for proline that exceed 100%. This phenomenon has typically been associated with the feeding of protein-free diets, where prolonged exposure to such diets could increase proline excretion. These data suggest that the LPC diet does not escape this abnormality, thus suggesting that it is biologically not more relevant than a protein-free diet.

In Table 7, true/standardized ileal digestibility coefficients are provided calculated in line with the 1998 NRC). Although a protein-free diet is biologically abnormal, endogenous losses obtained with such a diet should be considered more 'basal', in line with the definition (presuming that the diet is devoid of fiber). As no protein and fiber-free diet was used in this experiment, basal endogenous losses reported by Tran et al. (1999) were used for calculations. Using this endogenous correction, no abnormal digestibility coefficients were observed.

The standard error of means observed for the digestibility coefficients were typically one percent for the indispensable amino acids. This suggests that the measurements were obtained with good precision. Nevertheless, no differences were observed in the digestibility coefficients of indispensable amino acids for the different soybean meals ($P > .05$). The apparent ileal energy digestibility of the North Carolina Soybean meal samples tended to be higher (+1.7 to +2.9%, $P = 0.23$ to 0.05) than that of the Ohio reference sample (Table 9). It is expected that this is related to differences in fiber composition of the samples.

The soy-protein concentrate (SPC diet) did have lower LPC-corrected and true digestibility for methionine and threonine than the SBM 0 diet ($P < .05$, Table 6 and 7). These differences are likely linked to the processing of the soy-protein concentrate, which leads to a lowering of sulfur amino acid and threonine (Emmert and Baker, 1995). Also, histidine digestibilities for the SPC diet were lower than the SBM 15 diet ($P < .06$).

Implications

The ileal digestibility of soybean meals obtained at different times from the same processor did not differ ($P > .05$) for the indispensable amino acids, nor were differences observed with the reference sample obtained from Ohio. These data thus suggest that between batch variation within a limited time frame (corresponding to a single harvest from a single geographical region) is a minor issue, presuming that soybean meal is obtained from a single processing plant. Differences were observed in protein and amino acid content between the sample obtained from Ohio and the North Carolina samples, with the North Carolina samples being higher in protein

and amino acids (not analyzed statistically), and a trend for improved energy digestibility. It is expected that these differences relate to differences in processing conditions (fiber return to samples).

Table 1. The initial average BW ($n=7$) and feeding level at each period ¹

<i>Items</i>	Initial average BW (kg \pm SD)	Feeding Level (g per day, as-fed basis)
Period 1	27.7 \pm 2.30	1,087
Period 2	29.6 \pm 2.60	1,143
Period 3	32.7 \pm 2.65	1,231
Period 4	41.5 \pm 1.68	1,470
Period 5	46.0 \pm 1.52	1,590
Period 6	50.8 \pm 1.40	1,713
Period 7	55.9 \pm 1.40	1,841

¹ Animals were taken off the experiment for one week between Period 3 and 4.

Table 2. The formulation of experimental diets (% , as-fed basis) ¹

Items	SBM OSU	SBM 0	SBM 15	SBM 30	SBM 45	SPC	LPC
<i>Ingredients;</i>							
Corn starch ²	38.10	39.41	39.18	39.77	39.48	46.00	61.60
Soybean meal	35.25	33.94	34.17	33.58	33.87	-	-
Soy-protein concentrate ³	-	-	-	-	-	27.00	-
Casein ⁴	-	-	-	-	-	-	5.00
Sucrose ⁵	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Corn oil ⁶	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt ⁷	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Cellulose ⁸	-	-	-	-	-	-	5.00
Limestone	0.45	0.45	0.45	0.45	0.45	0.45	0.60
Dicalcium phosphate	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Potassium carbonate ⁹	-	-	-	-	-	0.35	1.40
Magnesium oxide ¹⁰	-	-	-	-	-	-	0.15
Vitamin premix ¹¹	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Mineral premix ¹²	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Chromic oxide	0.50	0.50	0.50	0.50	0.50	0.50	0.50
<i>Chemical analysis (calculated %);</i>							
Crude protein	17.00	17.00	17.00	17.00	17.00	17.00	-
Lysine	1.05	1.05	1.05	1.05	1.05	1.03	0.37
Ca	0.90	0.90	0.90	0.90	0.90	0.90	0.90
P (total)	0.75	0.75	0.75	0.75	0.75	0.75	0.61
P (avail.)	0.61	0.61	0.61	0.61	0.61	0.61	0.61
K	0.78	0.78	0.78	0.78	0.78	0.79	0.78
Mg	0.11	0.11	0.11	0.11	0.11	0.12	0.12

¹ Diet abbreviations; SBM OSU diet: Ohio State University soybean meal diet, SBM 0 diet: local soybean meal diet (processed d0), SBM 15 diet: local soybean meal diet (processed d15), SBM 30 diet: local soybean meal diet (processed d30), SBM 45 diet: local soybean meal diet (processed d45), SPC diet: soy-protein concentrate diet, and LPC diet: low-protein casein diet.

² Clinton [®] brand, ADM Co., Des Moines, IA.

³ Profine E, Central Soya Co., Decatur, IN.

⁴ Edible Acid Casein, Ecco Casein, Erie, IL.

⁵ Domino [®] Sugar, Tate & Lyle North American Sugars, Inc., New York, NY.

⁶ Food Lion [®] Corn Oil, Food Lion Inc., Salisbury, NC.

⁷ Feed grade salt.

⁸ Solka Floc [®], Fiber Sales & Development Corp., Urbana, OH.

⁹ Potassium carbonate contains 55 % potassium (K) (as-fed basis), Fisher Scientific, Pittsburgh, PA.

¹⁰ Magnesium oxide contains 58 % magnesium (Mg) (as-fed basis), Fisher Scientific, Pittsburgh, PA.

¹¹ Provided per kilogram diet: 2,000 IU vitamin A, 300 IU vitamin D₃, 20 IU vitamin E, 1.0 mg vitamin K (menadione), 4 mg thiamin, 15 mg niacin, 4 mg riboflavin, 12 mg pantothenic acid, 15 µg vitamin B₁₂, 2 mg pyridoxine, 1 mg d-biotin, 5 mg folic acid, and 0.60 g choline.

¹² Provided per kilogram diet: 90 mg Fe (Ferrous sulfate), 5 mg Mn (Manganese oxide), 8 mg Cu (Copper sulfate), 20 mg I (Potassium iodate), 0.21 mg Se (Sodium selenite), and 90 mg Zn (Zinc sulfate).

Table 3. The amino acids composition of the protein ingredients (% , as fed-basis) ¹

Items	SBM OSU	SBM 0	SBM 15	SBM 30	SBM 45	SPC	Casein
Crude protein	48.06	50.09	49.75	50.63	50.19	61.31	87.75
<i>Indispensable amino acids;</i>							
Arginine	3.26	3.76	3.71	3.73	3.73	4.68	3.03
Histidine	1.29	1.35	1.35	1.35	1.34	1.74	2.43
Isoleucine	2.16	2.25	2.17	2.19	2.22	2.94	4.00
Leucine	3.67	3.91	3.90	3.89	3.89	4.97	7.68
Lysine	2.97	3.18	3.17	3.16	3.14	4.08	6.39
Methionine	0.65	0.71	0.71	0.71	0.71	0.90	2.35
Phenylalanine	2.43	2.56	2.55	2.57	2.55	3.24	0.30
Threonine	1.83	1.93	1.96	1.95	1.94	2.55	3.52
Tryptophan	0.61	0.69	0.69	0.71	0.70	0.83	1.17
Valine	2.31	2.36	2.28	2.27	2.32	3.15	5.24
TIAA ²	21.18	22.70	22.49	22.53	22.54	29.08	36.11
<i>Dispensable amino acids;</i>							
Alanine	2.07	2.15	2.14	2.14	2.14	2.81	2.48
Aspartic acid	5.29	5.72	5.76	5.72	5.72	7.16	5.70
Cysteine	0.76	0.80	0.81	0.79	0.82	1.07	0.30
Glutamic acid	8.59	9.42	9.41	9.47	9.42	11.53	18.77
Glycine	1.97	2.07	2.06	2.07	2.07	2.68	1.52
Proline	2.37	1.49	2.47	2.45	2.48	3.24	9.44
Serine	2.26	2.25	2.32	2.30	2.67	3.11	4.61
Tyrosine	1.70	1.79	1.79	1.81	1.78	2.29	4.65
TDAA ²	25.01	25.69	26.76	26.75	27.10	33.89	47.47
TAA ²	46.49	48.33	49.20	49.24	49.20	62.97	87.59

¹ Protein ingredients obtained from, SBM OSU: Ohio State University soybean meal (CP 48%); SBM 0: local soybean meal , processed d0; SBM 15: local, processed d15; SBM 30: local, processed d30; SBM 45: local, processed d45; and SPC: soy-protein concentrate (CP 63%).

² Abbreviations: TIAA, total indispensable amino acids; TDAA, total dispensable amino acids; and TAA, total amino acids.

Table 4. Apparent ileal amino acids digestibilities (%)¹

Items	SBM OSU	SBM 0	SBM 15	SBM 30	SBM 45	SPC
Indispensable amino acids;						
Arginine	93.2±1.0	93.7±1.0	93.8±1.0	93.7±1.0	93.1±1.0	94.0±1.0
Histidine	89.0±1.1	89.7±1.1	90.1±1.1	88.9±1.2	89.0±1.1	88.2±1.1
Isoleucine	87.2±1.6	87.8±1.6	87.6±1.6	86.6±1.8	86.5±1.6	87.4±1.6
Leucine	85.3±1.1	86.5±1.1	86.5±1.1	85.3±1.3	85.3±1.1	85.8±1.1
Lysine	88.6±1.1	89.5±1.1	89.9±1.1	89.1±1.3	88.3±1.1	87.8±1.1
Methionine	88.2±1.1	90.0±1.1	89.6±1.1	88.4±1.2	88.6±1.1	87.3±1.1
Phenylalanine	86.6±1.1	87.4±1.1	87.5±1.1	86.5±1.2	86.2±1.1	87.5±1.1
Threonine	79.6±2.2	81.5±2.2	81.5±2.2	78.7±2.4	79.3±2.2	78.5±2.2
Tryptophan	87.4±2.4	89.5±2.4	89.4±2.4	88.6±2.6	88.4±2.4	85.6±2.4
Valine	85.8 ±1.4	86.1±1.4	85.8±1.4	84.2±1.5	84.5±1.4	85.0±1.4
AIAAD ²	87.1±1.3	88.2±1.3	88.2±1.3	87.0±1.4	86.9±1.3	86.7±1.3
Dispensable amino acids;						
Alanine	82.9±2.7	83.8±2.7	82.9±2.7	81.9±3.0	80.6±2.7	80.5±2.7
Aspartic acid	84.7±1.9	85.7±1.9	86.4±1.9	85.4±2.0	84.4±1.9	81.6±1.9
Cysteine	80.0±6.0	80.2±6.0	80.9±6.0	80.0±6.5	79.1±6.0	74.6±6.0
Glutamic acid	89.2±1.6 ^{ab}	88.7±1.6 ^{ab}	89.7±1.6 ^a	88.8±1.7 ^{ab}	88.1±1.6 ^{ab}	85.0±1.6 ^b
Glycine	78.2±6.5	79.8±6.5	80.2±6.5	78.3±7.1	77.0±6.5	73.1±6.5
Proline	78.2±4.2 ^{ab}	68.5±4.2 ^b	81.6±4.2 ^a	78.8±4.6 ^{ab}	77.3±4.2 ^{ab}	76.2±4.2 ^{ab}
Serine	85.1±1.6	86.3±1.6	86.5±1.6	85.7±1.7	84.7±1.6	86.0±1.6
Tyrosine	86.0±1.1	88.1±1.1	87.2±1.1	86.7±1.2	85.7±1.1	85.8±1.1
ADAAD ²	83.0±2.6	82.6±2.6	84.4±2.6	83.2±2.8	82.1±2.6	80.4±2.6
TAAD ²	86.1±1.4	86.6±1.4	87.2±1.4	86.4±1.6	85.5±1.4	84.4±1.4

^{a, b} Means within a row lacking a common superscript letter differ (P < .05).

¹ Diet abbreviations; SBM OSU diet: Ohio State University soybean meal diet, SBM 0 diet: local soybean meal diet (processed d0), SBM 15 diet: local soybean meal diet (processed d15), SBM 30 diet: local soybean meal diet (processed d30), SBM 45 diet: local soybean meal diet (processed d45), and SPC diet: soy-protein concentrate diet.

² Abbreviations: AIAAD, average indispensable amino acids digestibility; ADAAD, average dispensable amino acids digestibility; and TAAD, total amino acids digestibility.

Table 5. Apparent ileal amino acids digestibilities of the low-protein casein (LPC) diet (%)

Items	LPC diet
<i>Indispensable amino acids;</i>	
Arginine	76.2 ± 1.0
Histidine	84.4 ± 1.1
Isoleucine	74.0 ± 1.6
Leucine	82.2 ± 1.1
Lysine	86.3 ± 1.1
Methionine	87.8 ± 1.1
Phenylalanine	82.7 ± 1.1
Threonine	62.8 ± 2.2
Tryptophan	74.0 ± 2.4
Valine	78.6 ± 1.4
AIAAD¹	78.9 ± 1.3
<i>Dispensable amino acids;</i>	
Alanine	55.4 ± 2.7
Aspartic acid	69.3 ± 1.9
Cysteine	-29.9 ± 6.0
Glutamic acid	81.2 ± 1.6
Glycine	-31.1 ± 6.5
Proline	61.4 ± 4.2
Serine	64.1 ± 1.6
Tyrosine	81.4 ± 1.1
ADAAD¹	44.0 ± 2.6
TAAD¹	73.7 ± 1.4

¹ Abbreviations: AIAAD, average indispensable amino acids digestibility; ADAAD, average dispensable amino acids digestibility; and TAAD, total amino acids digestibility.

Table 6. The ileal amino acids digestibilities (%) corrected for endogenous losses observed using a low-protein casein (LPC) diet ¹

Items	SBM OSU	SBM 0	SBM 15	SBM 30	SBM 45	SPC
<i>Indispensable amino acids;</i>						
Arginine	96.4±.5	96.8±.5	97.0±.5	97.0±.5	96.3±.5	97.2±.5
Histidine	93.0±.7 ^{ab}	93.7±.7 ^{ab}	94.1±.7 ^a	93.7±.8 ^{ab}	93.0±.7 ^{ab}	92.0±.7 ^b
Isoleucine	93.6±.7	94.2±.7	94.2±.7	93.6±.8	93.0±.7	93.5±.7
Leucine	90.3±.8	91.4±.8	91.3±.8	90.9±.8	90.1±.8	90.6±.8
Lysine	92.6±.8	93.3±.8	93.8±.8	93.8±.9	92.2±.8	91.6±.8
Methionine	94.0±1.0 ^{ab}	95.6±1.0 ^a	95.1±1.0 ^{ab}	94.6±1.0 ^{ab}	94.2±1.0 ^{ab}	92.8±1.0 ^b
Phenylalanine	90.7±.7	91.4±.7	91.5±.7	91.3±.8	90.3±.7	91.5±.7
Threonine	89.2±1.1 ^{ab}	90.9±1.1 ^a	90.8±1.1 ^a	89.6±1.2 ^{ab}	88.7±1.1 ^{ab}	87.5±1.1 ^b
Tryptophan	94.2±1.5	95.8±1.5	95.6±1.5	95.1±1.7	94.5±1.5	92.1±1.5
Valine	92.3±.8	92.7±.8	92.6±.8	91.8±.9	91.2±.8	91.2±.8
AIAAD ²	92.6±.8	93.6±.8	93.6±.8	93.1±.8	92.3±.8	92.0±.8
<i>Dispensable amino acids;</i>						
Alanine	90.3±1.5	91.2±1.5	90.3±1.5	89.4±1.7	88.1±1.5	87.6±1.5
Aspartic acid	89.1±1.1 ^a	89.9±1.1 ^a	90.5±1.1 ^a	89.7±1.2 ^a	88.7±1.1 ^{ab}	85.9±1.1 ^b
Cysteine	86.8±1.9 ^a	86.9±1.9 ^a	87.5±1.9 ^a	86.9±2.1 ^a	85.7±1.9 ^{ab}	80.9±1.9 ^b
Glutamic acid	94.7±1.3 ^a	93.9±1.3 ^{ab}	94.8±1.3 ^a	94.0±1.4 ^{ab}	93.3±1.3 ^{ab}	90.3±1.3 ^b
Glycine	92.9±1.6 ^a	94.4±1.6 ^a	94.7±1.6 ^a	93.0±1.8 ^a	91.5±1.6 ^{ab}	87.2±1.6 ^b
<i>Proline</i>	106.6±3.5 ^{ab}	115.2±3.5 ^a	109.6±3.5 ^{ab}	107.5±3.9 ^{ab}	105.4±3.5 ^{ab}	103.3±3.5 ^b
Serine	95.1±.9	96.7±.9	96.6±.9	96.0±.9	95.1±.9	95.5±.9
Tyrosine	93.0±.8 ^{ab}	95.0±.8 ^a	93.8±.8 ^{ab}	93.5±.9 ^{ab}	92.5±.8 ^b	92.5±.8 ^b
ADAAD ²	93.6±1.2 ^{ab}	95.4±1.2 ^a	94.7±1.2 ^a	93.8±1.3 ^{ab}	92.5±1.2 ^{ab}	90.4±1.2 ^b
TAAD ²	93.2±.9 ^{ab}	93.8±.9 ^{ab}	94.1±.9 ^a	93.4±1.0 ^{ab}	92.5±.9 ^{ab}	91.3±.9 ^b

^{a, b} Means within a row lacking a common superscript letter differ (P < .05).

¹ Diet abbreviations; SBM OSU diet: Ohio State University soybean meal diet, SBM 0 diet: local soybean meal diet (processed d0), SBM 15 diet: local soybean meal diet (processed d15), SBM 30 diet: local soybean meal diet (processed d30), SBM 45 diet: local soybean meal diet (processed d45), and SPC diet: soy-protein concentrate diet.

² Abbreviations: AIAAD, average indispensable amino acids digestibility; ADAAD, average dispensable amino acids digestibility; and TAAD, total amino acids digestibility.

Table 7. True ileal amino acids digestibilities (%) calculated as per the 1998 NRC ¹

<i>Items</i>	SBM OSU	SBM 0	SBM 15	SBM 30	SBM 45	SPC
<i>Indispensable amino acids;</i>						
Arginine	95.8±.5	96.3±.5	96.4±.5	96.4±.5	95.8±.5	96.6±.5
Histidine	91.7±.7	92.3±.7	92.7±.7	92.3±.8	91.6±.7	90.7±.7
Isoleucine	90.7±.7	91.3±.7	91.2±.7	90.6±.8	90.0±.7	90.7±.7
Leucine	88.8±.8	90.0±.8	89.9±.8	89.4±.8	88.7±.8	89.2±.8
Lysine	92.1±.8	92.9±.8	93.3±.8	93.3±.9	91.7±.8	91.1±.8
Methionine	91.6±1.0 ^{ab}	93.3±1.0 ^a	92.9±1.0 ^{ab}	92.3±1.0 ^{ab}	91.9±1.0 ^{ab}	90.6±1.0 ^b
Phenylalanine	90.0±.7	90.8±.7	90.8±.7	90.6±.8	89.6±.7	90.8±.7
Threonine	85.6±1.1 ^{ab}	87.3±1.1 ^a	87.2±1.1 ^a	85.9±1.2 ^{ab}	85.1±1.1 ^{ab}	84.0±1.1 ^b
Tryptophan	91.2±1.5	93.1±1.5	92.9±1.5	92.4±1.7	91.8±1.5	89.3±1.5
Valine	90.1±.8	90.5±.8	90.3±.8	89.5±.9	88.9±.8	89.2±.8
AIAAD ²	90.8±.8	91.8±.8	91.8±.8	91.3±.8	90.5±.8	90.2±.8
<i>Dispensable amino acids;</i>						
Alanine	88.1±1.5	89.0±1.5	88.0±1.5	87.2±1.7	85.8±1.5	85.4±1.5
Aspartic acid	87.8±1.1 ^a	88.7±1.1 ^a	89.3±1.1 ^a	88.4±1.2 ^a	87.4±1.1 ^{ab}	84.6±1.1 ^b
Cysteine	85.7±1.9 ^a	85.7±1.9 ^a	86.4±1.9 ^a	85.7±2.1 ^a	84.6±1.9 ^{ab}	79.8±1.9 ^b
Glutamic acid	91.4±1.3 ^a	90.8±1.3 ^{ab}	91.8±1.3 ^a	90.9±1.4 ^{ab}	90.2±1.3 ^{ab}	87.2±1.3 ^b
Glycine	86.2±1.6 ^a	87.7±1.6 ^a	88.1±1.6 ^a	86.4±1.8 ^a	84.9±1.6 ^{ab}	80.8±1.6 ^b
Proline	91.8±3.5	90.8±3.5	94.9±3.5	92.5±3.9	90.7±3.5	89.1±3.5
Serine	89.6±.9	90.9±.9	91.0±.9	90.3±.9	89.3±.9	90.3±.9
Tyrosine	89.7±.8 ^{ab}	91.7±.8 ^a	90.6±.8 ^{ab}	90.2±.9 ^{ab}	89.2±.8 ^b	89.3±.8 ^b
ADAAD ²	88.8±1.2 ^{ab}	89.4±1.2 ^a	90.0±1.2 ^a	88.9±1.3 ^{ab}	87.8±1.2 ^{ab}	85.8±1.2 ^b
TAAD ²	90.2±.9 ^{ab}	90.8±.9 ^{ab}	91.2±.9 ^a	90.5±1.0 ^{ab}	89.5±.9 ^{ab}	88.4±.9 ^b

^{a, b} Means within a row lacking a common superscript letter differ (P < .05).

¹ Diet abbreviations; SBM OSU diet: Ohio State University soybean meal diet, SBM 0 diet: local soybean meal diet (processed d0), SBM 15 diet: local soybean meal diet (processed d15), SBM 30 diet: local soybean meal diet (processed d30), SBM 45 diet: local soybean meal diet (processed d45), and SPC diet: soy-protein concentrate diet.

² Abbreviations: AIAAD, average indispensable amino acids digestibility; ADAAD, average dispensable amino acids digestibility; and TAAD, total amino acids digestibility.

Table 8. Endogenous amino acids loss (g/kg dry matter intake) observed with a low casein diet or using a protein-free diet.

Items	Low-protein casein diet (average \pm SD)	Protein-free diet (Tran et al., 1999)
<i>Indispensable amino acids;</i>		
Arginine	0.437 \pm .141	0.360
Histidine	0.197 \pm .073	0.130
Isoleucine	0.530 \pm .204	0.289
Leucine	0.696 \pm .251	0.494
Lysine	0.448 \pm .186	0.391
Methionine	0.145 \pm .080	0.086
Phenylalanine	0.381 \pm .140	0.319
Threonine	0.674 \pm .088	0.417
Tryptophan	0.158 \pm .074	0.090
Valine	0.576 \pm .214	0.385
<i>Dispensable amino acids;</i>		
Alanine	0.587 \pm .185	0.409
Aspartic acid	0.894 \pm .316	0.627
Cysteine	0.198 \pm .059	0.164
Glutamic acid	1.796 \pm .648	0.740
Glycine	1.112 \pm .317	0.607
<i>Proline</i>	<i>2.571 \pm 1.761</i>	<i>1.227</i>
Serine	0.864 \pm .221	0.385
Tyrosine	0.451 \pm .137	0.234
<i>Total amino acids</i>	12.727 \pm 3.204	7.354

Table 9. The ileal energy digestibilities (%)¹

Items	SBM OSU Diet	SBM 0 diet	SBM 15 diet	SBM 30 diet	SBM 45 diet	SPC diet	LPC diet
Energy Dig. (%)	83.0 ^c	84.4 ^{bc}	84.4 ^{bc}	84.5 ^{bc}	85.4 ^b	86.1 ^b	88.9 ^a
<i>SEM</i>	0.8	0.8	0.8	0.9	0.8	0.8	0.8

^{a, b, c} Means within a row lacking a common superscript letter differ ($P < .05$).

¹ Diet abbreviations; SBM OSU diet: Ohio State University soybean meal diet, SBM 0 diet: local soybean meal diet (processed d0), SBM 15 diet: local soybean meal diet (processed d15), SBM 30 diet: local soybean meal diet (processed d30), SBM 45 diet: local soybean meal diet (processed d45), SPC diet: soy-protein concentrate diet, and LPC diet: low-protein casein diet.

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Appendix

I. Calculation equation for apparent nutrients digestibility

$$\text{App. Dig. (\%)} = 100 - ((\text{CrD}/\text{CrE} * \text{NuE}/\text{NuD}) * 100)$$

Where; App. Dig., apparent nutrients digestibility (%)
CrD, Cr content of diet (%)
CrE, Cr content of excretion (%) (ileal digesta)
NuE, nutrients contents of excretion (%) (ileal digesta)
NuD, nutrients contents of diet (%)

II. Calculation equation for endogenous amino acids losses using LPC diet

$$\text{EAAL (g/kg DMI)} = (100 - \text{LPCAD}) / 100 * (\text{LPCAA} / 100) * 1,000$$

Where; EAAL, endogenous amino acids losses (g per kg dry matter intake)
DMI, dry matter intake (kg)
LPCAD, apparent amino acids digestibility of LPC diet (%)
LPCAA, amino acids contents of LPC diet (DM basis, %)

III. Calculation equation for true amino acids digestibility

$$\text{True Dig. (\%)} = (\text{DiAA} - (\text{NDAA} - \text{EAAL})) / \text{DiAA} * 100$$

cf. $\text{NDAA} = (100 - \text{AD}) / 100 * \text{DiAA}$

$$\text{DiAA} = \text{AA} * 10$$

Where; True Dig., true amino acids digestibility (%)
DiAA, amino acids content of each diet (g per kg diet DM)
AD, apparent amino acids digestibility of each diet (%)
AA, amino acids composition of each diet (%)
NDAA, non-digestible amino acids amount (g per kg diet DM)
EAAL, endogenous amino acids losses (g per kg dry matter intake)
(Standard EAAL *or* values from LPC diet)

Evaluating the Ileal Digestibility of Amino Acids in Soybean Meals from Different Soy Processors.

(This report represents the contribution from this institution)

Investigators: Dr. Vince M. Gabert

Institution: University of Illinois at Urbana-Champaign

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Project Start Date: September 18, 1998

Project End Date: December 31, 1999

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Problem Addressed

Defining the chemical composition of any feedstuff is an important first step in determining its feeding value. Compositions of the same feedstuff can vary because of growing crop conditions. Also, analytical variations from different laboratories can result in tremendous variation in nutrient contents. The reputation of any product is, however, based upon knowledge about its quality and consistency of nutrient content.

The oilseed products contribute other nutrients, but notably the amino acids that when blended with cereal grains have been shown to result in excellent performance when fed to swine. Currently soybean meal has the best-recognized reputation of the oilseeds for its high amino acid quality, but there still remains a large variation in the quality of the product provided. This is becoming of greater concern as other amino acid sources are becoming more competitive and soybeans from other countries are competing with the soy products produced in the U.S.

The resulting performance responses from the meal produced are influenced by the level of the anti-nutritional factors present after processing or from other components added to the meal after processing (Liener, 1981; Anderson and Wolf, 1995). The effect of these and other components in soybean meal (e.g. hulls, etc), and other indigenous nutrients present in soybean meal (e.g. carbohydrates, minerals) on amino acid availability is largely unknown (Gdala et al., 1997).

Heat is used to reduce the level of most anti-nutritional factors, but when the meals are heated excessively there can be a detrimental effects on amino acid availability (Hurrell and Carpenter, 1974; Moughan and Rutherford, 1996). Any factor that would influence the availability of the amino acids should be documented and appropriate steps taken to improve the processing of soy protein. Other nutrients in soybean meal are also undoubtedly important to swine, and they may also interfere with amino acid utilization. Consequently, it is the amino acids that must be protected in the processing of this product if soybean meal is to continue to enjoy its prominence in the feed and livestock industry. Although technology has developed where oil and protein can be readily determined, this does not reflect the availability of amino acids (Batterham et al., 1990).

The determination of amino acid digestibilities in soybean meals is necessary in order to more accurately characterize their nutritional value (Sauer and Ozimek, 1986; Lenis, 1992). Having a greater understanding of what factors affect the nutritional value of soybean meal and understanding ways to improve the meal will enhance its value for swine diets. This will allow more efficient use of soybean meals. When utilization of amino acids and other nutrients are improved there will result a reduced fecal and urinary excretion of N and P, thus reducing environmental pollution (Yi et al., 1996).

The ileal analysis method, in which amino acid digestibilities are determined at the end of the small intestine, is clearly recognized as being superior to the fecal analysis method (Tanksley and Knabe, 1984; Sauer and Ozimek, 1986). When the ileal analysis method is used the modifying effects of bacterial metabolism on amino acids in the cecum and large intestine are avoided, as there is no absorption of amino acids from the hindgut (Zebrowska, 1973). Therefore the ileal analysis method is more sensitive and provides a more representative reflection of amino acid uptake (Sauer and Ozimek, 1986; Fan et al., 1994). Dietary amino acid intake and balance may also influence the apparent ileal amino acid digestibilities (Fan et al., 1994). Dietary intake of amino acids needs to be high enough in order to minimize the contribution of endogenous amino acids compared to dietary amino acids in ileal digesta collected from the distal ileum (Fan et al., 1994).

To obtain true digestibilities, estimates of the endogenous contributions of amino acids are necessary to determine the extent to which protein in soybean meal (amino acids) has not been digested (Gabert et al., 1997; Nyachoti et al., 1997). Sources of endogenous amino acids include digestive secretions such as mucin, pancreatic enzymes, bile and sloughed epithelial cells. These confound protein (amino acid) digestion and prevent the determination of true amino acid digestibility (Gabert et al., 1997; Nyachoti et al., 1997). Although true digestibilities are clearly the way dietary amino acid requirements will be presented in the future, there are several intestinal and indigenous factors that may influence the apparent absorption of amino acids. When determined correctly, apparent digestibilities will approach and will reflect true digestibilities (Fan et al., 1994). In this experiment our goal was to determine the differences between soy processors and commonly used soybean meal products in apparent and true amino acid digestibility.

Approach Used

Animals and Diets

All experimental procedures were approved by the University of Illinois Laboratory Animal Care and Advisory Committee. Eight barrows (line 326 sire x C22 dams; PIC, Franklin, KY) were obtained from the University of Illinois swine herd. The animals were housed individually in metabolism crates in a temperature-controlled room. The pigs were surgically fitted with a simple-T cannula at the distal ileum using procedures adapted from Sauer et al. (1983).

After recovery from surgery, the barrows were fed one of seven experimental diets according to a 7 x 7 Latin square design. They were fed twice daily, at 0800 and 2000 h, with equal amounts at each meal. The barrows were fed 1.38, 1.53, 1.68, 1.83, 1.98, 2.13, and 2.28 kg/d in periods 1-7 of the trial. Initial feeding level was determined on the basis of .90 kg^{0.75} body

weight, and feeding level was increased 150 g each experimental period. Water was provided ad libitum from a low-pressure drinking nipple.

Six isonitrogenous diets, and one low-protein casein diet, were used in the experiment (Table 1). Diet SBM OSU contained soybean meal from a common source, and served as a negative control. Diets SBM 0, 14, 33, and 50 contained soybean meal obtained from the same soybean processor on different days (0, 14, 33 and 50 d). Samples of soybean meal were obtained in this manner to determine the variability in soybean meal quality from the same processor. Diet SPC contained soy protein concentrate, and served as a positive control diet. Diet Casein contained 5% casein, and was used to estimate endogenous secretions of amino acids. This approach was taken to supply some amino acids to the animal to attempt to maintain a more physiological state as opposed to feeding a protein-free diet. When a protein-free diet is fed, the animal is in a catabolic state, and digestive secretions are reduced (Skilton et al., 1988; Brannon, 1990); Butts et al., 1991). Amino acid and crude protein compositions of the protein ingredients are shown in Table 2. Chromic oxide was included in each diet at a level of .5% and used as an inert marker for digestibility determinations. The soybean meals used in this study were not ground prior to incorporation into the experimental diets. Following mixing, the diets were screened through a 0.5 mm screen in order to improve the incorporation of corn oil into the diets.

Each experimental consisted of 7 d. The barrows were allowed to adapt to each experimental diet for 5 d, and ileal digesta were collected on the final 2 d. Digesta were collected over 12 h, from 0800 and 2000h, on each of the two days of collection. Digesta were frozen (-10°C) immediately after collection. Samples were pooled within barrow and period for analysis.

Chemical and Statistical Analysis

Samples of the protein sources and freeze-dried digesta were pooled and ground in liquid nitrogen. The dry matter contents of the diets were determined to calculate endogenous amino flow and true digestibilities. Empty 50 mL glass beakers that had been in a 105°C oven overnight were weighed immediately after removal from the oven. Samples of diets were weighed into the beakers, and the beakers plus sample were placed in the oven overnight. The next day each beaker and sample were weighed, and dry matter was calculated. Analyses of nitrogen and amino acids in protein sources and digesta, and analysis of chromium in digesta, were conducted by the Experiment Station Chemical Laboratories, University of Missouri, Columbia. Analyses of amino acids and nitrogen were conducted according to procedures described by the AOAC (1990). Chromic oxide in digesta was calculated using the chromium values and stoichiometry. Endogenous output of amino acids was calculated in each experimental period from the pig fed the casein diet. The following formula was used: $EO = ((100 - AD) / 100) * IDM$ where EO is endogenous output on a g/kg dry matter intake basis; AD is apparent digestibility of an amino acid or crude protein; and IDM is dry matter intake of an amino acid or of crude protein from the Casein diet. True digestibility was calculated with the following formula: $TD = (IDM - ((100 - AD) / 100) * IDM - EO) / IDM$ where TD is true digestibility; IDM is dry matter intake of amino acid or crude protein; AD is apparent digestibility; and EO is endogenous output of amino acid or crude protein from the same period. Endogenous losses were used for each period and not pooled over the entire experiment because endogenous losses change with body weight for pigs that weigh under 60 kg (Stein, 1998). The data was analyzed using PROC GLM of SAS (1990). The apparent and true ileal digestibility coefficients of the experimental diets were compared using the Student-Newman-Keuls multiple range test (Ott, 1993).

Results

The pigs remained healthy and consumed their meals throughout the experiment. At the conclusion of the trial, the pigs were used for other experiments, and remained in good health throughout all of these trials.

The following endogenous outputs of crude protein and amino acids were calculated (mean \pm sample standard deviation; g/kg dry matter intake): crude protein, 18.92 ± 2.70 ; ASP, $1.02 \pm .07$; GLU, $1.94 \pm .15$; SER, $.97 \pm .12$; GLY, $1.30 \pm .33$; HIS, $.24 \pm .03$; THR, $.74 \pm .08$; ALA, $.70 \pm .08$; ARG, $.63 \pm .18$; PRO, 3.90 ± 2.31 ; TYR, $.42 \pm .08$; VAL, $.66 \pm .05$; ISO, $.59 \pm .10$; LEU, $.75 \pm .06$; PHE, $.41 \pm .07$; LYS, $.59 \pm .07$; MET, $.15 \pm .02$; CYS, $.24 \pm .02$; TRP, $.17 \pm .04$. These estimates are within the range of values reported in the literature (de Lange et al., 1989b; Gabert et al., 1997; Lien et al., 1997). Apparent and true ileal amino acid digestibility coefficients are shown in Table 3 and 4.

Discussion and Implications

Apparent and true amino acid digestibility were not affected ($P > .05$) by source of soybean meal (Diets SBM OSU through SBM 50). The apparent digestibility of methionine, and the true digestibility of methionine and cysteine, were lower ($P < .05$) for Diet SPC than the diets with soybean meal. This probably relates to the chemical alteration of sulfur amino acids during processing of soybean meal to soy protein concentrate (Emmert and Baker, 1995), which reduced their digestibilities in the present study. The apparent and true digestibilities of histidine were lower ($P < .05$) for Diet SPC than the diets containing soybean meal. The reason for this is unknown, but may relate to chemical alterations caused by processing soybean meal to soy protein concentrate. Many of the apparent amino acid digestibility coefficients were lower ($P < .05$) for Diet Casein than the other diets, which was expected (Fan et al., 1994) considering the low protein intake of pigs fed the Casein diet. The true digestibility coefficients of proline were over 100%. The use of an endogenous diet with low-protein may result in the mobilization of glutamine from muscle, which can be metabolized into glutamate (for use by enterocytes), ammonia, citrulline and proline – this has been speculated to cause an overestimation of endogenous proline, and thus, high true digestibility of proline (de Lange et al., 1989b). However, a net secretion of proline in the intestinal lumen has been shown using several approaches, such as the isotope-dilution technique and the use of enzymatically hydrolyzed casein, to estimate endogenous outputs (e.g., Butts et al., 1993; Lien et al., 1997). Therefore, this may be a normal physiological occurrence. Further research on the endogenous output of proline is necessary to more accurately determine the true digestibility of proline. Other true digestibility coefficients are within the normal ranges reported in the literature (e.g., Fan et al., 1995).

Soybean meal obtained at different times from the same processor did not differ ($P < .05$) in both apparent and true ileal amino acid digestibilities. Therefore, the ileal digestible supply of amino acids is not affected by processing batch. The use of a low protein-casein diet for the estimation of endogenous amino acid secretions works well for all amino acids except proline, the endogenous output of which is overestimated. However, this may be a normal physiological condition.

Future Directions

Future studies should be conducted with soybean meal and soy protein sources to determine how components (carbohydrates, etc.) present in soybeans and soy products affect the digestibility of amino acids. Even though the findings of the present study indicate that processing batch does not affect the ileal digestible supply of amino acids, further research is necessary because of the development and use of new processing conditions, soybean varieties, feeding techniques, etc. The findings of the present study also indicate that the true ileal digestibilities of amino acids in soybean meal and soy protein concentrate are not 100%. Therefore, further research to attempt to increase true amino acid digestibilities and/or decrease endogenous amino acid losses in pigs fed soy products could result in an increased efficiency of amino acid use.

Table 1. Formulation (%) of the experimental diets (as-fed basis)

Ingredient	Diet						
	SBM OSU	SBM 0	SBM 14	SBM 33	SBM 50	SPC	Casein
Corn starch ^a	38.10	39.92	39.10	38.40	39.15	45.90	61.60
Soybean meal	35.25	33.43	34.25	34.95	34.20		
Soy protein concentrate ^b						27.10	
Casein ^c							5.00
Sucrose ^d	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Sodium chloride ^e	.35	.35	.35	.35	.35	.35	.40
Cellulose ^f							5.00
Dicalcium phosphate	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Calcium carbonate	.45	.45	.45	.45	.45	.45	.60
Vitamin premix ^g	.30	.30	.30	.30	.30	.30	.30
Trace mineral premix ^h	.05	.05	.05	.05	.05	.05	.05
Potassium carbonate ⁱ						.35	1.40
Magnesium oxide ^j							.15
Chromic oxide	.50	.50	.50	.50	.50	.50	.50

^aClinton[®] Brand, Archer Daniels Midland Company, Effingham, IL

^bProfine E, Central Soya, Decatur, IN

^cEdible Acid Casein, Ecco Casein, Erie, IL

^dDomino[®] Sugar, Tate & Lyle North American Sugars, Inc., New York, NY

^eMeijer[®] Free Flowing Salt, non-iodized, Meijer, Inc., Grand Rapids, MI

^fSolka Floc[®], Fiber Sales & Development Corp., Urbana, OH

^gProvided the following (per kg of diet): vitamin A, 2,000 IU; vitamin D₃, 300 IU; vitamin E, 20 IU; vitamin K (menadione), 1.0 mg; thiamine, 4 mg; niacin, 15 mg; riboflavin, 4 mg; pantothenic acid, 12 mg; vitamin B₁₂, 15 µg; pyridoxine, 2 mg; d-biotin, .1 mg; folic acid, .5 mg; and choline .60 g.

^hProvided the following (per kg of diet): ferrous sulfate, 90 mg; manganese oxide, 5 mg; copper sulfate, 8 mg; potassium iodate, .20 mg; sodium selenite, .21 mg; and zinc sulfate, 90 mg.

ⁱFisher Scientific, 55% potassium, Pittsburgh, PA

^jFisher Scientific, 58% magnesium, Pittsburgh, PA

Table 2. Composition (%) of the protein ingredients (as-fed basis)

Item	SBM OSU ^a	SBM 0 ^b	SBM 14 ^b	SBM 33 ^b	SBM 50 ^b	SPC ^c	Casein ^d
Crude protein ^e	48.06	49.75	49.31	48.56	49.19	61.31	87.75
Amino acids							
Indispensable							
Arginine	3.55	3.67	3.67	3.61	3.65	4.44	3.35
Histidine	1.34	1.39	1.39	1.37	1.39	1.72	2.75
Isoleucine	2.05	2.15	2.13	2.03	2.06	2.62	4.44
Leucine	3.67	3.67	3.79	3.76	3.75	4.75	8.90
Lysine	3.00	3.12	3.12	3.07	3.10	3.94	7.41
Methionine	.74	.76	.78	.76	.72	.92	2.70
Phenylalanine	2.43	2.51	2.51	2.47	2.49	3.11	4.81
Threonine	1.77	1.84	1.85	1.84	1.86	2.36	3.80
Tryptophan	.75	.68	.72	.75	.73	.82	1.24
Valine	2.23	2.30	2.29	2.21	2.21	2.80	5.93
Dispensable							
Alanine	2.13	2.22	2.20	2.19	2.21	2.84	3.13
Aspartic acid	5.17	5.40	5.39	5.32	5.42	6.77	6.48
Cysteine	.67	.73	.73	.72	.74	.91	.44
Glutamic acid	8.62	8.91	8.98	8.82	8.94	11.13	19.87
Glycine	1.95	2.03	2.03	2.00	2.03	2.53	1.69
Proline	2.29	2.38	2.38	2.35	2.38	3.01	9.56
Serine	2.02	2.07	2.14	2.10	2.14	2.64	4.20
Tyrosine	1.69	1.76	1.76	1.73	1.75	2.16	5.13

^aCommon source of soybean meal obtained from Dr. Don Mahan, Ohio State University

^bSoybean meal obtained from the same processor on days 0, 14, 33 and 50

^cSoy protein concentrate

^dUsed in low-protein casein diet to estimate endogenous amino acid secretions

^eNitrogen multiplied by 6.25

Table 3. Apparent ileal digestibilities (%) of crude protein and amino acids in the experimental diets

Item	Diets						Casein	SEM ^a
	SBM OSU	SBM 0	SBM 14	SBM 33	SBM 50	SPC		
Crude protein	76.0 ^b	76.0 ^b	76.2 ^b	75.7 ^b	74.8 ^b	74.2 ^b	60.4 ^c	1.14
Amino acids								
Indispensable								
Arginine	88.9 ^b	88.7 ^b	88.8 ^b	89.0 ^b	88.1 ^b	88.2 ^b	65.2 ^c	1.42
Histidine	84.2 ^b	84.2 ^b	84.1 ^b	84.6 ^b	84.0 ^b	81.5 ^c	83.9 ^b	.61
Isoleucine	81.5 ^b	80.7 ^b	80.3 ^b	81.2 ^b	79.4 ^b	79.4 ^b	75.8 ^c	.80
Leucine	80.5 ^c	79.9 ^c	80.3 ^c	80.9 ^c	79.3 ^c	79.6 ^c	84.6 ^b	.75
Lysine	81.5 ^{bc}	82.3 ^{bc}	81.8 ^{bc}	81.7 ^{bc}	80.6 ^c	80.6 ^c	85.4 ^b	.99
Methionine	84.5 ^c	84.7 ^c	84.7 ^c	85.3 ^c	83.4 ^c	81.1 ^d	90.1 ^b	.75
Phenylalanine	82.2 ^b	81.8 ^b	82.0 ^b	82.2 ^b	81.1 ^b	82.2 ^b	84.4 ^b	.78
Threonine	71.8 ^b	70.5 ^b	71.1 ^b	72.4 ^b	70.8 ^b	69.7 ^b	64.1 ^c	.97
Tryptophan	85.2 ^b	81.0 ^{bc}	82.7 ^{bc}	83.1 ^{bc}	82.0 ^{bc}	79.5 ^c	74.9 ^d	1.09
Valine	78.7 ^{bc}	77.7 ^{bc}	77.9 ^{bc}	78.4 ^{bc}	76.1 ^{bc}	75.3 ^c	79.6 ^b	.85
Dispensable								
Alanine	76.0 ^b	76.0 ^b	75.6 ^b	76.6 ^b	74.9 ^b	74.4 ^b	58.8 ^c	1.12
Aspartic acid	79.2 ^b	78.1 ^b	78.6 ^b	79.6 ^b	77.7 ^b	76.2 ^b	71.0 ^c	.84
Cysteine	67.9 ^b	67.6 ^b	67.0 ^b	67.4 ^b	66.3 ^b	59.8 ^b	.3 ^c	1.95
Glutamic acid	83.9 ^b	84.0 ^b	83.6 ^b	84.3 ^b	82.6 ^b	80.6 ^b	82.1 ^b	.95
Glycine	69.0 ^b	69.1 ^b	68.7 ^b	68.8 ^b	66.1 ^b	61.5 ^b	-40.6 ^c	5.13
Proline	75.0 ^b	73.6 ^b	76.6 ^b	73.6 ^b	73.5 ^b	62.7 ^b	25.2 ^c	6.21
Serine	77.8 ^b	76.1 ^b	77.5 ^b	78.6 ^b	77.5 ^b	76.6 ^b	57.6 ^c	.83
Tyrosine	82.4 ^{bc}	82.5 ^{bc}	82.7 ^{bc}	82.4 ^{bc}	81.6 ^c	82.2 ^{bc}	85.0 ^b	.68

^aStandard error of the mean (n=7)

^{b,c,d}Means in the same row with different superscript letters differ ($P < .05$)

Table 4. True ileal digestibilities (%) of crude protein and amino acids in the experimental diets

Item	Diet						SEM ^a
	SBM OSU	SBM 0	SBM 14	SBM 33	SBM 50	SPC	
Crude protein	86.3 ^b	86.5 ^b	86.4 ^b	85.9 ^b	85.1 ^b	84.7 ^b	.82
Amino acids							
Indispensable							
Arginine	93.6 ^b	93.5 ^b	93.4 ^b	93.6 ^b	93.8 ^b	93.0 ^b	.49
Histidine	88.8 ^b	89.0 ^b	88.7 ^b	89.2 ^b	88.6 ^b	86.2 ^c	.64
Isoleucine	88.9 ^b	88.1 ^b	87.7 ^b	88.8 ^b	87.0 ^b	87.0 ^b	.81
Leucine	85.8 ^b	85.3 ^b	85.6 ^b	86.1 ^b	84.7 ^b	84.9 ^b	.73
Lysine	86.6 ^b	87.4 ^b	86.9 ^b	86.7 ^b	85.7 ^b	85.6 ^b	1.04
Methionine	89.7 ^b	89.9 ^b	89.7 ^b	90.3 ^b	88.8 ^{bc}	86.5 ^c	.80
Phenylalanine	86.6 ^b	86.2 ^b	86.3 ^b	86.5 ^b	85.5 ^b	86.7 ^b	.64
Threonine	82.7 ^b	81.6 ^b	81.9 ^b	83.0 ^b	81.6 ^b	80.3 ^b	1.01
Tryptophan	91.1 ^b	87.8 ^{bc}	88.9 ^{bc}	89.1 ^{bc}	88.1 ^{bc}	86.5 ^c	.94
Valine	86.4 ^b	85.6 ^b	85.6 ^b	86.2 ^b	84.1 ^b	83.3 ^b	.92
Dispensable							
Alanine	84.6 ^b	84.7 ^b	84.2 ^b	85.0 ^b	83.4 ^b	82.8 ^b	1.07
Aspartic acid	84.4 ^b	83.3 ^b	83.7 ^b	84.7 ^b	82.8 ^b	81.3 ^b	.90
Cysteine	77.2 ^b	76.5 ^{bc}	75.8 ^{bc}	76.2 ^{bc}	75.0 ^{bc}	68.7 ^c	1.94
Glutamic acid	89.7 ^b	90.0 ^b	89.4 ^b	90.1 ^b	88.4 ^b	86.5 ^b	.99
Glycine	86.2 ^b	86.7 ^b	85.8 ^b	85.8 ^b	83.2 ^b	78.8 ^c	1.33
Proline	119.3 ^b	118.5 ^b	120.5 ^b	117.2 ^b	117.4 ^b	106.5 ^c	2.57
Serine	90.3 ^b	89.0 ^b	89.7 ^b	90.7 ^b	89.6 ^b	89.1 ^b	.75
Tyrosine	88.8 ^b	89.0 ^b	89.1 ^b	88.8 ^b	88.0 ^b	88.7 ^b	.59

^aStandard error of the mean (n=7)

^{b,c}Means in the same row with different superscript letters differ ($P < .05$)

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Ileal Digestibility of Different Batches of Soyabean Meal

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Summary

As a part of the research program on the variability of the nutritional value of soybean meal for pigs, an ileal digestibility experiment has been conducted. Seven experimental diets were involved, including three reference diets and four diets with four different batches of soybean meal of Dutch origin. The batches were obtained from the same production plant with intervals of two weeks. Seven PTVC cannulated pigs with an initial body weight of 65 ± 3 kg were used in a Latin square design.

Currently, the experimental diets and ileal digesta samples are being analyzed chemically in the US. These data will be used, together with the results obtained by the other partners involved in this part of the research program, to draw conclusions on the variability of the nutritional value of soybean meal for pigs.

Approach Used

In the experiment, seven experimental diets were tested in a Latin square design with seven animals and seven experimental periods.

The following experimental diets were tested :

Group	Diet
1	Control diet with reference soy bean meal
2	Test diet with Dutch soy bean meal production 18-Feb-99, batch A
3	Test diet with Dutch soy bean meal production 05-Mar-99, batch B
4	Test diet with Dutch soy bean meal production 19-Mar-99, batch C
5	Test diet with Dutch soy bean meal production 06-Apr-99, batch D
6	Control diet with reference soy protein concentrate (SPC)
7	Control diet with a low protein content

The batches soybean meal were obtained from the same soy bean oil processing plant at two weeks intervals.

The analyzed crude protein contents of the four batches of soy bean meal (A-D) are presented in Table 1.

The composition of the experimental diets is presented in Table 2.

The diets were mixed and pelleted without addition of steam (diameter pellets 2.5 mm). Animals were fed twice daily with intervals of 12 hours using an automatic feeding device. Water was available ad libitum to the animals via drinking nipples.

Nine PTVC cannulated animals (van Leeuwen et al., 1991) with an initial body weight of 65 ± 3 kg were used. Seven animals were allocated randomly to the seven experimental diets, the two reserve animals were fed diet 5.

After allocation, the animals were changed over gradually to the experimental diets over a period of three days. After five days on the full experimental diets, ileal digesta was collected on two consecutive days for 12 hours per day, starting at the morning feeding and ending at the evening feeding. Digesta was collected in plastic bags, attached to the cannula, which were changed every hour. The content was weighed and stored in the freezer immediately.

After the collection period, part of the chyme was freeze dried and milled over a 1 mm screen. After each collection period, the animals were changed over to another experimental diet during two meals in one day. A survey of the allocation is presented in Table 3.

After each collection period, the animals were weighed and the amount of feed supplied was adjusted, using the mean body weight of all 9 animals. Per day, all animals were fed an equal amount corresponding to 90 grams per kg metabolic weight ($\text{kg}^{0.75}$).

Results

In general, the experiment went well. During the first four collection periods, no problems with health, appetite or faeces consistency were observed. During the fifth period (P5), animal nr. 451 (group 1) and nr. 457 (group 5), suffered from ileal diarrhoea. From animal 457, no digesta was collected during this period, from animal 451, digesta of only one day was collected in this period. In period P6, one of the reserve animals (nr. 420) was fed the diet of group 5 and ileal digesta was collected. In the last period (P7), animal nr. 434 (group 4) lost his cannula and was therefore replaced in the experimental schedule by animal number 420. From animal nr. 479 (group 5), chyme could only be collected on one day in this period, since no more feed was available.

Results of body weight, feed intake and collected amounts of chyme are presented in Tables 3-7. Digesta samples have been freeze dried in Wageningen and have been sent to the US for further analysis.

Discussion and Implications

The diets and ileal digesta samples are currently being analyzed in the US. Based on the analytical data, the apparent ileal digestibility of the experimental diets and the different batches of soy bean meal can be calculated. These data will be used, together with the results obtained by

the other partners involved in this part of the research program, to draw conclusions on the variability of the nutritional value of soybean meal for pigs.

Future Directions

It will be important to evaluate which chemical and physical factors in soybean meal the variability in digestibility is related.

Table 1. Analysed crude protein contents of the batches soy bean meal (g.kg⁻¹)

Batch	CP content
Batch A 18-feb 99	471.0
Batch B 05-mar 99	485.3
Batch C 19-mar 99	491.4
Batch D 06-apr 99	493.6

Table 2. Composition of the experimental diets (g.kg⁻¹)

Ingredient	Diet						
	1	2	3	4	5	6	7
Soy bean meal ref.*	352.5	-	-	-	-	-	-
Soy bean meal 18-feb	-	361.0	-	-	-	-	-
Soy bean meal 05-mar	-	-	351.0	-	-	-	-
Soy bean meal 19-mar	-	-	-	346.0	-	-	-
Soy bean meal 06-apr	-	-	-	-	344.0	-	-
Soy Protein Concentrate *	-	-	-	-	-	270.0	-
Casein	-	-	-	-	-	-	50.0
Corn starch	381.0	372.5	382.5	387.5	389.5	460.0	616.0
Sugar (dextrose)	200.0	200.0	200.0	200.0	200.0	200.0	200.0
Cellulose (Arbocel B800)	-	-	-	-	-	-	50.0
Maize oil	20.0	20.0	20.0	20.0	20.0	20.0	20.0
NaCl	3.5	3.5	3.5	3.5	3.5	3.5	4.0
Dicalciumphosphate	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Limestone	4.5	4.5	4.5	4.5	4.5	4.5	6.0
Cr ₂ O ₃	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Potassium Carbonate	-	-	-	-	-	3.5	14.0
Magnesium oxide	-	-	-	-	-	-	1.5
Vitamin premix*	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Trace elements premix*	0.5	0.5	0.5	0.5	0.5	0.5	0.5

* supplied by Dr. Mahan

Table 3. Distribution of animals over treatments

Animal ID	P1	P2	P3	P4	P5	P6	P7
435	1	7	6	5	4	3	2
457	2	1	7	6		4	3
434	3	2	1	7	6	5	
479	4	3	2	1	7	6	5
468	5R	5R	5R	5R	5R	5R	5R
420	5R	5R	5R	5R	5R	5	4
451	5	4	3	2	1	7	6
405	6	5	4	3	2	1	7
469	7	6	5	4	3	2	1

Table 4. Body weight of animals at digesta collection (kg)

Between And	- P1	P1 P2	P2 P3	P3 P4	P4 P5	P5 P6	P6 P7	P7 -
435	69,1	78,6	84,3	92,5	100,0	106,2	115,2	121,7
457	63,4	74,0	79,4	86,5	94,5	102,1	107,6	116,6
434	67,4	75,8	81,6	88,3	94,3	102,3	109,2	114,0
479	63,3	72,3	78,8	85,9	90,1	98,5	104,8	112,5
468	60,1	71,0	78,5	85,2	91,4	98,5	106,5	114,8
420	67,6	77,3	84,8	91,9	98,8	106,3	114,0	119,5
451	61,1	69,2	75,6	81,9	87,3	92,1	98,7	106,1
405	68,8	78,0	86,4	95,2	103,1	108,8	112,6	119,6
469	65,3	72,8	80,5	88,0	95,3	100,0	107,5	115,2
Mean*	65,1	74,3	81,1	88,4	95,0	101,6	108,5	115,6
SD*	3,3	3,3	3,5	4,2	5,0	5,1	5,1	4,6

Table 5. Feed intake in gram per day

Animal ID	P1	P2	P3	P4	P5	P6	P7
435	2100	2280	2430	2590	2740	2880	3000
457	2100	2280	2430	2590		2880	3000
434	2100	2280	2430	2590	2740	2880	
479	2100	2280	2430	2590	2740	2880	3000
468							
420						2880	3000
451	2100	2280	2430	2590	2740	2880	3000
405	2100	2280	2430	2590	2740	2880	3000
469	2100	2280	2430	2590	2740	2880	3000

Table 6. Flow of ileal digesta per animal in 2x12 hours (g)

Animal ID	P1	P2	P3	P4	P5	P6	P7
435	2675	1243	2180	2857	3642	3571	4453
457	2427	2685	1226	2450		3142	3780
434	2103	3306	2400	1340	2520	2731	
479	1956	3029	2843	3137	1504	3415	2006
468							
420						3245	2977
451	2529	3897	3529	3949	1505 *	2106	4220
405	2344	2835	2786	3202	3332	3434	1683
469	1256	2486	2159	3500	4454	4038	4797

* only digesta collected during 1x12h

Table 7. Mean chyme flow per experimental group per period (g/12h)

Group	P1	P2	P3	P4	P5	P6	P7	mean
1	1338	1343	1200	1569	1505	1717	2399	1581
2	1214	1653	1422	1975	1666	2019	2227	1739
3	1052	1515	1765	1601	2227	1786	1890	1691
4	978	1949	1393	1750	1821	1571	1489	1564
5	1265	1418	1080	1429		1366	2006	1455
						1623		
6	1172	1243	1090	1225	1260	1708	2110	1401
7	628	622	613	670	752	1053	842	740