AMINO ACID AND ENERGY DIGESTIBILITIES IN SOYBEAN, COTTONSEED, AND MEAT AND BONE MEALS DETERMINED AT THE END OF THE SMALL INTESTINE AND OVER THE TOTAL TRACT IN GROWING PIGS

BY

Robert Watson Jones

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T. D. Tanksley, Jr.

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ABSTRACT

AMINO ACID AND ENERGY DIGESTIBILITY IN SOYBEAN, COTTONSEED, AND MEAT AND BONE MEALS DETERMINED AT THE END OF THE SMALL INTESTINE AND OVER THE TOTAL TRACT IN GROWING PIGS

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Robert W. Jones, B.S. Texas A&M University

University Undergraduate Fellows Program Advisor: T. D. Tanksley, Jr.

Nutrient digestibilities in three high-protein feedstuffs used for swine feeding were determined. An effort was made to obtain meals that were representative of those available to pork producers and feed manufacturers in Texas. The three meals were: 44% CP solvent-processed soybean meal (SBM), 41% CP direct solvent-processed cottonseed meal (CSM) and 50% CP meat and bone meal (M&B).

Six crossbred barrows (22.7 kg initial body weight) were surgically fitted with simple T-cannulas at the end of the small intestine and used in a replicated 3x3 Latin Square design to determine the digestibility of dry matter, ash, energy, nitrogen and amino acids at the end of the small intestine and over the total digesttive tract for the three high-protein meals. Nitrogen and amino acid content of the meals were determined prior to beginning the test and the values were used in formulating diets. Cornstarch-based diets were formulated to contain .60% dietary lysine; .25% chromic oxide was included as an indigestible marker.

Nitrogen and amino acid digestibilities determined at the end of the small intestine and over the total tract tended to be highest for SBM, lowest for M&B, with CSM intermediate but closer to SBM. At the end of the small intestine, digestibilities for nitrogen and the average of the ten essential amino acids were 79.3 and 82.8% for SBM, 79.0 and 79.6% for CSM and 66.0 and 67.1% for M&B. Digestibilities for lysine and tryptophan (the two most limiting amino acids in grain-soybean meal diets) in SBM, CSM and M&B, respectively, were: 85.6, 80.9%; 69.8, 77.6%; 67.4, 49.7%. Digestibility coefficients determined over the total digestive tract followed the same pattern but values for nitrogen and the average of the essential amino acids tended to be higher and more uniform than ileal values (86.7 and 86.9%, SBM; 81.8 and 80.9%, CSM, 76.7 and 74.2%, M&B.

CSM had a lower ($P<.05$) energy digestibility (81.7%) than SBM (90.8%) and M&B (89.4%) which probably resulted from its higher fiber content (10.3%) compared to SBM (3.2%) and M&B (3.3%). Metabolizable energy values (kcal/g) were highest for SBM (3.83) followed by M&B (3.68) and CSM (3.50). In contrast to nitrogen and energy digestibilities which ranged from 66.0 to 83.5% at the terminal ileum among the three meals, ash digestibilities were much lower (25.4 to 33.1%). A much larger percentage of the ash disappeared in the lower gut (36.3 to 50.5%) than for nitrogen (2.8 to 10.8%) and energy (3.8 to 6.5%).

These data suggest that the apparent availability of amino acids determined at the end of the small intestine give a better measure of the amount actually available to the pig than those determined over the total digestive tract.

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The author also wishes to thank and dedicate this thesis to his parents, Mr. and Mrs. George G. Jones. Their love and sacrifice is truly unending.

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CHAPTER I

INTRODUCTION

Soybean meal is the most widely used protein supplement in swine diets today primarily because of its excellent amino acid profile and availability. However, as pork producers strive to decrease feed costs, possible substitutions of soybean meal with more economical, lower-quality protein feedstuffs are receiving attention. Cottonseed and meat and bone meal are two of the most common lower-quality protein feedstuffs used in formulating swine diets.

Traditionally, swine diets were formulated on a crude protein basis. Today, swine diets are widely formulated on a total amino acid basis, which has enabled diets to be formulated more precisely. However, not all of the amino acids in a feedstuff are digestible by the pig because of incomplete protein hydrolysis resulting from inaccessability of the protein or proteolytic enzymes, inhibition of enzymes, or inhibiting of amino acid absorption. Formulation of diets on a digestible amino acid basis may provide a better amino acid balance and should more precisely meet the pig's needs.

Many techniques are available to the swine nutritionist to determine the digestibility of amino acids. Of the *in vitro* and *in vivo* techniques, the most widely-used method has been the fecal index method. However, recent studies have shown that there are serious limitations to the fecal index values due to the microbial modification of nitrogenous compounds and energy in the large intestine. These com-

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The citations on the following pages follow the style and format of the Journal of Animal Science.

pounds which are modifed to ammonia or amines and absorbed across the large intestine wall, have been shown to be of little or no value to the pig for protein synthesis. Because of this inadequacy, several workers have used pigs cannulated at the end of the small intestine (terminal ileum) so that digesta can be collected to obtain amino acid digestibilities before entering the large intestine. Data indicates that high-protein feedstuffs used in swine diets differ widely, not only in amino acid composition but also in digestibility of amino acids.

This study was designed to determine the digestibility of amino acids and energy at the end of the small intestine and over the total tract in three commercially available high-protein feedstuffs: a 44% CP solvent-processed soybean meal (SBM), a 41% CP direct solvent-processed cottonseed meal (CSM), and a 50% CP meat and bone meal (M&B). These values will then be used to determine the value and practicality of using ileal amino acid digestibility values in formulating practical swine rations.

CHAPTER II

REVIEW OF LITERATURE

In Vitro Methods for Determining Amino Acid Digestibility in Feedstuffs

Scientists have attempted to develop an accurate method for determining amino acid digestibility for many years. *In vitro* (within glass) methods have an advanatge over *in vivo* (within the living body) methods in that long and expensive animal work is not required. However, *in vitro* methods are generally narrow in their scope of application and give relative rather than quantitative values as it is nearly impossible to duplicate the action of the digestive tract in the pig. Three *in vitro* methods that have been used to determine amino acid digestibility include chemical determination, enzymatic digestion and microbial growth.

Chemical Determination. The most common method utilizes the reaction of 1-flouro-2:4-dinitrobenzene (FDNB) with the ε-amino group of lysine to determine lysine availability in animal protein feeds (Carpenter and Ellinger, 1955; Carpenter, 1960). Meade (1972) criticized this method because of the destruction of ε-DNP lysine during prolonged hydrolysis (16 to 17 hr), the deleterious effect of carbohydrate that is present in many feedstuffs and the necessity of applying variable and large correction factors in the final calculation of lysine availability.

Kakade and Liener (1969) reacted 2,4,6-trinitrobenzene-sulfonic acid (TNBS) with ε-amino groups of lysine to form ε-TNP lysine which is measured colorimetrically. The TNBS method has a shorter (1 hr) hydrolysis than the FDNB method; however, correction factors, larger and more variable than the Carpenter method, may be needed according to Meade (1972).

Enzymatic Digestion. In order to simulate the biological digestion by enzymatic hydrolysis *in vitro*, several proteases (trypsin, erepsin, pepsin, pancreatin) have been tested (Evans and Butts, 1948; Akeson and Stahman, 1964). Furuya *et al.*(1979) used swine intestinal fluid to determine digestibility of dry matter and crude protein in four commercial swine diets and found a high correlation between the *in vitro* values and *in vivo* values determined by fecal collection using an indigestible marker.

Complex digestion procedures with two or more successive enzymes and more recently, the utilization of powerful microbial enzymes, have been successful (Erbersdobler, 1976). However, Erbersdobler noted that despite these advances, these values are questionable because it seems impossible to duplicate the concerted action of the digestive enzymes.

Microbial Growth. Riesen *et al.* (1947) utilized a microbiological assay to determine the digestibility of raw, properly cooked and overcooked SBM. A vigorous proteolytic enzyme, *Streptococcus zymogenes* (NCDO 592), was first investigated by Ford (1960). Ford (1962) later modified his procedure to evaluate the availabilities of methionine, leucine, isoleucine, arginine, tryptophan, histidine and valine from fish and whale meat meals. Fernel and Rosen (1956) demonstrated the usefulness of *Tetrahymena pyriformis W* in evaluation of protein quality but did not demonstrate availability of individual amino acids. Even though microbial growth methods do not normally require enzymatic hydrolysis, the method would have to be useful for a large number of the essential amino acids and the accuracy of amino acid availability values would have to be determined (Erbersdobler, 1972).

In Vivo Methods for Determining Amino Acid Digestibility in Feedstuffs

In vivo methods for determining amino acid digestibility are considered to be more accurate for swine diet formulations since these methods more closely represent the pig's digestive capabilities than *in vitro* methods. However, these determinations are time consuming and expensive. Common *in vivo* determinations include carcass analysis, growth response, blood plasma free amino acids, fecal index and ileal digestibility of amino acids.

Carcass Analysis. Analyzing the entire carcass for amino acid content is straightforward and accurate. Williams *et al.* (1954) estimated the amino acid requirement of the rat, chick and pig from whole carcass amino acid content. The author found that the relatively similar requirements among species and the close agreement of the calculated values to those determined by nutritional studies support the conclusion that the carcass analysis procedure is a valid method for evaluating the growth requirements for most essential amino acids. Grau (1947) used this analysis to estimate the phenylalanine and tyrosine retention in chicks. The carcass analysis method may be applicable to small animals but has limited application with large animals because of the high cost.

Growth Response. Several workers have attempted to determine the digestibility of amino acids in various feedstuffs in chicks (Osterhart *et al.*, 1959; Metke and Scott, 1970) and rats (Gupta and Elvehjem, 1957; Despance *et al.*, 1959; Gupta *et al.*, 1958). Growth assays are not highly specific because the results are influenced by many factors such as diet protein content, amino acid imbalance, energy source, and protein-energy ratio in the diet (Zebrowska, 1978).

Blood Plasma Free Amino Acids. Puchal *et al.* (1962) reported different plasma amino acid patterns in young pigs that were fed skim milk, soybean meal, fish meal, cottonseed meal and meat meal. Rerat *et al.* (1979) described a new method for determining nutrient absorption utilizing the portal vein and peripheral vessels in pigs. The greatest advantage of this technique is that it allows the estimation of the chronology of nutrient appearance in the circulating fluids of the body (Rerat *et al.*, 1979). However, the technique requires expensive and sophisticated equipment and due to the proliferation of tissue around the blood vessels the collection period is fairly short.

Fecal Index. Kuiken and Lyman (1948) developed the fecal-analysis method in which they attempted to account for the disappearance of amino acids from the digestive tract as well as to correct for amino acids of metabolic origin in the feces. The availability of amino acids for the pig has been determined in a wide variety of feedstuffs using the fecal index method (Dammers, 1964; Poppe *et al.*, 1970; Poppe, 1976). However, the fecal index method's accuracy has been criticized because of the modification of nitrogenous compounds in the large intestine due to the action of the microflora in the hind gut.

Several workers have demonstrated that large amounts of protein peptides and free amino acids passing into the large intestine are degraded there (Zebrowska, 1975; Zebrowska and Buraczewski, 1977). Infusion experiments (Zebrowska, 1975; Sauer, 1976; Just *et al.*, 1979) have shown that the protein or amino acids disappearing from the hind gut provide essentially no value to the pig since the nitrogen is absorbed as amines or ammonia and excreted in the urine. Therefore, apparent digestibility of protein and individual amino acids determined by the fecal index method appears to overestimate the digestibility of amino acids in the small intestine.

Ileal Digestibilities of Amino Acids. Because of the limitations of the fecal index methods, several workers have attempted to sample digesta from the end of the small intestine (terminal ileum) before it enters the large intestine. This sampling of ileal digesta through simple T-cannulas or re-entrant cannulas has been successfully attempted by several Polish, Canadian and European scientists including Zebrowska (1973), Ivan and Small (1976) and Zebrowska and Buraczewski (1977). In all studies ileal digestibility values for most amino acids in feed-stuffs were lower than digestibilities measured over the total tract. Zebrowska and Buraczewski (1977) found that the differences between ileal and fecal digestibilities were very small when a casein (a very high-quality protein) diet was fed. They postulated that the difference between ileal and fecal digestibilities is a function of the quality of the protein: the higher quality proteins are extensively digested in the small intestine while lower quality proteins are less digested in the small intestine, therefore they provide more substrate to the hind gut microflora for further digestion.

Digestibility of Amino Acids in Three High-Protein Feedstuffs

Soybean Meal. It has been known since the report of Hayward *et al*. (1935) that heating soybean meal improved its nutritive value.

Ingram *et al.* (1949) showed the depressing effects of excessive heat during soybean meal processing on amino acid digestibility and correlated the amino acid digestibility to chick weight gains. Tanksley *et al.* (1978) reported the ileal digestibility of lysine in a 44% CP soybean meal to be 88.5% compared to 89.1% determined over the total tract. Carson and Bayley (1970) also reported an 88.0% digestibility for lysine in a 49% CP soybean meal using the fecal index method.

Cottonseed Meal. Kuiken (1952) reported a 64.5% and 71% lysine digestibility for a screwpress-processed cottonseed meal and a hexane extruded degossypolized cottonseed meal, respectively, using the fecal index method. Tanksley *et al.* (1978) found lysine to be 61.7 and 64.0% digestible in a direct solvent-processed and screwpress-processed cottonseed meal at the terminal ileum and 57.9 and 61.0% digestible, respectively, when measured over the entire tract.

Meat and Bone Meal. Stockland and Meade (1970) and Stockland *et al.* (1970) reported qualitative differences in availability of amino acids from meat and bone meals to the laboratory rat and growing pig as determined by plasma free amino acids. Their samples came from different starting material which may have affected the amino acid availability according to Meade (1972). The author also stated that additional studies are essential to determine availability of amino acids from meat and bone meals, particularly as influenced by starting material (fallen animals *vs* packing house viscera). In a 50% CP blended meat and bone product, Tanksley and Knabe (1979) found lysine to be 60.5% digestible at the terminal ileum and 68.4% digestible over the total tract.

CHAPTER III

OBJECTIVES

1. To determine the digestibility of energy, nitrogen and amino acids in soybean, cottonseed and meat and bone meals at the end of the small intestine and over the total digestive tract.

2. To determine nitrogen balance and metabolizable energy values for soybean, cottonseed and meat and bone meals.

CHAPTER IV

EXPERIMENTAL PROCEDURE

A 3x3 Latin Square designed trial conducted in duplicate, was used to to determine the digestibility of energy, nitrogen and amino acids, nitrogen balance and metabolizable energy values of SBM, CSM and M&B. After the CSM and M&B were received, a representative sample of each was obtained by probing each sack. A sample of the soybean meal was obtained as it was unloaded into the storage bin. The samples were analyzed for nitrogen and amino acid content prior to formulating diets. CSM and M&B were then thoroughly mixed and placed in plastic-lined bags before mixing the diets. All diets were formulated to contain .60% dietary lysine and a minimum of .70% calcium and .55% phosphorus. Steamed bone meal was added to the SBM diet to standardize the source of calcium and phosphorus insofar as possible. Corn oil was added to the SBM diet (2.0%) and to the CSM diet (1.0%) to reduce dustiness and improve the mixing and handling qualities of the diets. Chromic oxide (.25%) was added to all diets as an indigestible marker. Chemical composition of the three high-protein meals and steamed bone meal are given in Table 1 and percentage composition of the experimental diets is given in Table 2.

Six crossbred barrows (22.7 kg initial body weight) were surgically fitted with simple T-cannulas approximately 15 cm cranial to the ileocecal junction according to the procedure of Horszczaruk *et al.* (1972). Long-lasting penicillin was administered to each pig during surgery and 3 days postsurgery to reduce chances of infection. Following surgery, pigs were maintained individually in 1.2 x 1.8 m glas-

TABLE 1. CHEMICAL AND AMINO ACID COMPOSITION OF HIGH PROTEIN MEALS AND STEAMED BONE MEAL[a]

Criterion	High-protein meals			Steamed bone meal
	Soybean[b]	Cottonseed[c]	Meat&Bone[d]	
Chemical analyses				
Moisture, %	9.39	6.77	7.91	3.28
Protein (Nx6.25), %	44.58	40.84	47.50	16.40
Crude fiber, %	3.20	10.30	3.30	-----
Ash, %	6.18	5.92	24.26	75.16
Calcium, %	.34	.23	7.26	23.85
Phosphorus, %	.75	.88	3.50	11.65
Gross energy, kcal/g	4.90	5.03	4.64	1.20
Essential amino acids, %				
Arginine	3.32	4.50	2.84	1.07
Histidine	1.20	1.02	.98	.08
Isoleucine	1.84	1.17	1.16	.21
Leucine	3.11	2.14	3.18	.48
Lysine	2.73	1.61	2.57	.49
Methionine	.63	.62	.71	.10
Phenylalanine	2.09	2.03	1.81	.30
Threonine	1.63	1.16	1.58	.28
Tryptophan	.45	.42	.23	.00
Valine	3.08	2.60	3.52	.54
Non-essential amino acids, %				
Alanine	1.84	1.40	3.38	1.14
Aspartic acid	5.59	3.79	4.11	1.01
Glutamic acid	8.37	7.55	5.69	1.52
Glycine	1.56	1.36	4.96	2.46
Proline	2.28	1.43	3.94	1.69
Serine	2.11	1.53	1.79	.41
Tyrosine	1.58	1.15	1.14	.13

[a]As-fed basis. Means represent duplicate or triplicate analyses.

[b]Solvent extracted 44% soybean meal obtained from Wendland Farm Products, Temple, Texas.

[c]Direct solvent extracted 41% cottonseed meal obtained from Anderson, Clayton & Company, Thorndale, Texas.

[d]Fifty percent meat&bone meal obtained from Swift & Company Animal By-Product Department, San Antonio, Texas.

TABLE 2. PERCENTAGE COMPOSITION OF DIETS[a]

	High-protein meals		
Ingredient	Soybean[b]	Cottonseed[c]	Meat&Bone[d]
Corn starch	65.90	53.12	68.00
Soybean meal[b]	22.56	-----	-----
Cottonseed meal[c]	-----	37.26	-----
Meat&bone meal[d]	-----	-----	25.00
Cellulose	5.00	5.00	5.00
Corn oil	2.00	1.00	-----
Sodium phosphate, dibasic	1.00	1.00	1.00
Steamed bone meal	1.84	-----	-----
Ground limestone	.70	1.62	-----
Salt	.35	.35	.35
Trace mineral premix[e]	.15	.15	.15
Vitamin premix[f]	.25	.25	.25
Chromic oxide	.25	.25	.23
Total	100.00	100.00	100.00

[a]As-fed basis. All diets contained .60% lysine.

[b]Solvent extracted 44% soybean meal obtained from Wendland Farm Products, Temple, Texas.

[c]Direct solvent extracted 41% cottonseed meal obtained from Anderson, Clayton & Co., Thorndale, Texas.

[d]Fifty percent meat&bone meal obtained from Swift & Company Animal By-Product Department, San Antonio, Texas.

[e]Provided the following mineral levels, ppm: Cu, 10; Fe, 100; I, .60; Mn, 50; Zn, 100; and Se, .10.

[f]Provided the following per lb of diet: vitamin A, 2,000 IU; vitamin D, 250 IU; vitamin E, 5 IU; vitamin K, 2 mg; riboflavin, 2 mg; d-calcium pantohenate, 7.5 mg; niacin, 7.5 mg; choline chloride, 50 mg; and vitamin B_{12} 7.5 μ.

bord-sided pens for a 14-day convalescence period. Pigs were offered 50 g of a 16% CP sorghum-soybean grower diet 12 hr after surgery. The amount fed was increased 25 g per feeding until the pigs reached an intake of 750 g/day. Feeding was done twice daily at 12 hr intervals (0600 and 1800).

Following this period, pigs were moved to modified stainless steel metabolism crates (Baker *et al.*, 1967) in an environmentally-controlled building. Pigs were randomly allotted to the three experimental diets within a 3x3 Latin Square design which provided six observations for each meal. The feed was fed as a moist mash by mixing the feed with water (.55:1, water:feed) immediately prior to feeding. After the feed was consumed, additional water was offered to provide 2 liters of water per kg of feed. All pigs were offered the same amount of feed which approached *ad libitum* intake.

Three experimental periods of 14 days consisted of a 5-day feed adjustment period, followed by a 4-day total fecal and urine collection. Ferric oxide was used as a visible marker to determine the beginning and end of the fecal collection period. Fecal collection was followed by 3 days of continuous 12 hr ileal collection (0600 to 1800 hr).

Ileal digesta collection was accomplished by attaching a 5 cm diameter polyethylene tubing to the cannula and placing the distal end in a glass container surrounded by crushed ice. Collection was continuously monitored to insure proper digesta flow through the approximately 1.5 m long collection tube. At the end of each 12 hr ileal collection period, the digesta was thoroughly mixed and a 200 g sample removed and frozen. The remaining digesta was warmed to approximately 38°C and returned to the pig through the collection tube. Ileal samples from the three days were frozen, lypholized and ground through a 1 mm screen (Wiley mill) and air equilibrated for a minimum of 48 hr before chemical analysis.

Fecal collections were handled in a similar manner. Feces were collected twice daily, stored in plastic bags and frozen. At the end of the collection period, feces were thawed, thoroughly mixed and sampled. The samples were frozen, lypholized and ground through a 1 mm screen and allowed a 48 hr equilibration period (Cohen and Tanksley, 1973).

Diets, digesta and feces were analyzed for moisture, nitrogen (AOAC, 1975) and gross energy by adiabatic bomb calorimetry. Chromic oxide was analyzed by the procedure of Kimura and Miller (1957). Amino acid analyses (except cystine and tryptophan) were accomplished by ion-exchange chromotography (Beckman 120C Amino Acid Analyzer) following acid hydrolysis (6 N HCl for 24 hr under flushing with N_2) similar to the procedure of Spackman *et al.* (1958). Tryptophan was quantified similar to the procedure recommended by Kohler and Palter (1967).

Nitrogen balance and digestibilities determined over the total tract were calculated from both total fecal and urine collections and using the indigestible marker. Nutrient digestibilities at both the end of the small intestine and over the total tract were determined by the relative concentrations of chromic oxide.

The following equation (Crampton and Harris, 1969) was used to calculate nutrient digestibilities based on the indigestible marker, chromic oxide:

$$\text{Percentage apparent digestibility} = (1 - \frac{\text{MixNo}}{\text{MoxNi}}) \times 100$$

where:

Mi = percent marker in feed

Mo = percent marker in ileal digesta or feces

Ni = percent nutrient in feed

No = percent nutrient in ileal digesta or feces

The data were statistically analyzed as a replicated 3x3 Latin Square to determine significant differences in nutrient digestibilities and nitrogen balance among the three high-protein feedstuffs. A split-plot design was used for comparison of digestibility coefficients obtained at the end of the small intestine and over the total tract. The GLM procedure developed by Barr *et al.* (1976) was used for compilation of all analyses of variance. Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used as a means separation procedure when significant differences were found in the analysis of variance procedure

CHAPTER V

RESULTS AND DISCUSSION

Composition of Diets. Chemical and amino acid composition of the diets are shown in Table 3. Diets were formulated to contain .67% lysine (dry-matter basis). Analyzed levels for the SBM, CSM and M&B diets (.71, .65 and .67%, respectively) indicate that the diets were mixed well and the amino acid analyses of the high-protein meals were correct. Due to the low lysine content of CSM (1.61%), the protein level in the CSM diet (16.58%) was high compared to M&B (13.28%) and SBM (12.28%). Most importantly, tryptophan content in the M&B diet was very low (.05%) compared to SBM (.12%) and CSM (.17%).

Pig Performance. Surgery was completed successfully on seven pigs. The cannulation procedure was considered successful since there was little leakage around the fistulae and digesta was successfully collected from all pigs. Fourteen days postsurgery, pigs were consuming 750 g of a 16% CP sorghum-soybean meal diet per day.

Feed intake, daily gain and gain:feed ratios for each pig during each experimental period and over the entire test are shown in Table 4. Growing-finishing pigs in the feedlot are normally expected to consume approximately 5% of their body weight/day. Average daily feed intake, expressed as a percentage of body weight, was approximately 3.3% for period 1, 3.6% for period 2, and 4.2% for period 3 which indicates that feed intake ranged from 66 to 82% of that expected when pigs are fed *ad libitum.* Although there were some differences between individual pigs, weight gains and feed efficiencies on the corn starch-based diets were generally good.

TABLE 3. CHEMICAL AND AMINO ACID COMPOSITION OF DIETS CONTAINING SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS[a]

	High-protein meals		
Criterion	Soybean[b]	Cottonseed[c]	Meat&Bone[d]
Chemical analyses			
Moisture, %	10.88	9.88	10.73
Protein (N x 6.25), %	12.28	16.58	13.38
Ash, %	5.17	5.09	7.87
Gross energy, kcal/g	4.33	4.43	4.23
Essential amino acids, %			
Arginine	.84	1.78	.79
Histidine	.30	.41	.26
Isoleucine	.52	.48	.32
Leucine	.86	.88	.88
Lysine	.71	.65	.67
Methionine	.20	.26	.21
Phenylalanine	.56	.81	.50
Threonine	.42	.47	.41
Tryptophan	.12	.17	.05
Valine	.85	1.06	.94
Non-essential amino acids, %			
Alanine	.47	.55	.85
Aspartic acid	1.42	1.53	1.07
Glutamic acid	2.14	3.08	1.50
Glycine	.47	.56	1.32
Proline	.60	.56	.95
Serine	.53	.61	.48
Tyrosine	.40	.44	.29

[a]Dry-matter basis. All means represent duplicate or tryplicate analyses.

[b]Solvent extracted 44% soybean meal obtained from Wendland Farm Products, Temple, Texas.

[c]Direct solvent extracted 41% cottonseed meal obtained from Anderson Clayton & Company, Thorndale, Texas.

[d]Fifty percent meat&bone meal obtained from Swift & Company Animal By-Product Department, San Antonio, Texas.

TABLE 4. PIG PERFORMANCE BY PERIOD AND OVER THE ENTIRE TEST[a]

Pig No.	1	2	3	4	5	6
PERIOD 1						
DIET	SBM	SBM	M&B	M&B	CSM	CSM
Starting wt, kg	22.68	22.68	23.59	21.77	22.23	23.13
Avg feed intake, kg/day	.75	.75	.75	.74	.75	.75
Avg daily gain, kg/day	.32	.23	.19	.26	.26	.23
Gain/Feed	.43	.31	.25	.35	.05	.31
PERIOD 2						
DIET	CSM	CSM	SBM	SBM	M&B	M&B
Starting wt, kg	27.22	25.85	26.31	25.40	22.85	26.31
Avg feed intake, kg/day	.99	.99	.91	.99	.71	.99
Avg daily gain, kg/day	.39	.42	.36	.36	.28	.39
Gain/Feed	.39	.42	.39	.36	.39	.39
PERIOD 3						
DIET	M&B	M&B	CSM	CSM	SBM	SBM
Starting wt, kg	32.66	31.75	31.30	30.39	26.76	31.75
Avg feed intake, kg/day	1.27	1.28	1.28	1.28	1.28	1.28
Avg daily gain, kg/day	.45	.45	.68	.62	.65	.45
Gain/Feed	.35	.35	.53	.48	.48	.35
ENTIRE TEST						
Avg feed intake, kg/day	1.00	1.00	.98	1.00	.91	1.00
Avg daily gain, kg/day	.39	.37	.41	.41	.32	.36
Gain/Feed	.39	.37	.39	.41	.31	.36

[a]Period length of 14 days, entire test length of 42 days.

[b]As-fed basis.

During the first period, pig 5 on the CSM diet made very slow gains. This carried over for a short time during the second experimental period while consuming the M&B diet, but appetite and gains returned to that of the other pigs midway through period 2. Nutrient digestibilities were not greatly different between pig 5 and other pigs fed the same diet.

Digestible and Metabolizable Energy. The digestibility of gross energy and digestible and metabolizable energy values for the experimental diets determined by total fecal and urine collections are shown in Table 5. Although the diets were similar in energy content (4.33, 4.43 and 4.23 kcal/g for SBM, CSM and M&B, respectively), digestibility of gross energy was lower ($P<.05$) for the CSM diet than the SBM and M&B diets. The low energy digestibility for CSM probably resulted from the higher fiber content (10.3%) compared to SBM (3.2%) and M&B (3.3%). The SBM diet had the highest ($P<.05$) digestible energy (3.93 kcal/g) and metabolizable energy values (3.83 kcal/g). CSM had the lowest ($P<.05$) digestible (3.62 kcal/g) and metabolizable energy values (3.50 kcal/g). The combination of a slightly lower gross energy value (4.23 *vs* 4.33 kcal/g) and gross energy digestibility (89.43 *vs* 90.78%) compared to SBM gave lower digestible (3.78 kcal/g) and metabolizable (3.68 kcal/g) energy values for M&B than SBM.

Nitrogen Balance. Nitrogen utilization for the three high-protein meals is given in Table 6. Nitrogen intake was higher ($P<.05$) for the CSM diet because of its higher protein content. Even though there was more ($P<.05$) fecal and urinary nitrogen loss on the CSM diet, it had the highest amount of nitrogen absorbed on a quantitative basis

TABLE 5. APPARENT DIGESTIBILITY OF GROSS ENERGY, DIGESTIBLE AND METABOLIZABLE ENERGY VALUES OF DIETS CONTAINING SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS[a]

	High-protein meals		
Item	Soybean	Cottonseed	Meat&Bone
Gross energy, kcal/g	4.33	4.43	4.23
Gross energy, % digested	90.78 ± 1.03[b]	81.66 ± .73[c]	89.43 ± 3.91[b]
Digestible energy, kcal/g	3.93 ± .04[b]	3.62 ± .03[d]	3.78 ± .17[c]
Metabolizable energy, kcal/g	3.83 ± .05[b]	3.50 ± .04[d]	3.68 ± .15[c]

[a]Dry-matter basis. Values are means for six pigs ± standard deviation using total fecal and urine collections.

[bcd]Means on the same line with different superscripts differ significantly (P<.05).

TABLE 6. NITROGEN BALANCE OF GROWING PIGS FED SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS[a]

	High-protein meals		
Item	Soybean	Cottonseed	Meat&Bone
Nitrogen, g/day			
Intake	17.54 ± 4.12[c]	24.06 ± 5.53[b]	18.24 ± 5.09[c]
Feces	2.11 ± .57[d]	3.88 ± .80[b]	2.90 ± 1.19[c]
Absorbed	15.42 ± 3.66[c]	20.18 ± 4.80[b]	15.34 ± 4.53[c]
Urine	4.06 ± .66[b]	11.03 ± 2.33[b]	8.39 ± 2.14[c]
Retained	11.36 ± 3.10[b]	9.15 ± 2.57[c]	6.94 ± 2.44[d]
% of consumed	64.32 ± 4.18[b]	37.70 ± 2.92[c]	37.50 ± 4.42[c]
% of absorbed	73.12 ± 3.73[b]	45.00 ± 2.93[c]	44.66 ± 3.10[c]

[a]Values are the mean for six pigs ± standard deviation using total fecal and urine collections.

[bcd]Means on the same line with different superscripts differ significantly (P<.05).

(g/day). However, pigs fed the SBM diet retained a higher percentage of nitrogen than those fed the CSM and M&B diets, when retention was expressed as a percentage of nitrogen consumed or absorbed. This indicates the better protein quality of SBM compared to CSM and M&B.

Nitrogen, Dry Matter, Gross Energy and Ash Digestibilities. Nitrogen, dry matter, gross energy and ash digestibilities are given in Table 7. M&B had the lowest (P<.05) nitrogen digestibility measured at both the end of the small intestine (66.0%) and over the total tract (76.7%) and also showed the largest (P<.05) difference in nitrogen digestibility between the two locations (10.8%). There was no difference (P>.10) between the digestibility of nitrogen in SBM and CSM at the end of the small intestine; however, SBM had the highest (P<.05) nitrogen digestibility over the total tract (86.7%) with CSM intermediate and different (P<.05) from the SBM and M&B meals. Nitrogen losses in the large intestine for all three high-protein meals were different (P<.05) from each other with the SBM being intermediate between the high value for M&B and low value for CSM.

Dry matter digestibility measured at both locations was highest (P<.05) for SBM, lowest (P<.05) for CSM with M&B intermediate and different (P<.05) from the other meals.

Apparent digestibilities of gross energy using the indigestible marker (Table 7) were similar to values obtained using total fecal collection (Table 6). Once again, CSM had the lowest (P<.05) energy digestibility at both locations and SBM the highest. Consistent with other reports (Rerat, 1978; Purser, 1979; Rudolph, 1979) dry matter and gross energy digestibilities were higher measured over the total

TABLE 7. APPARENT DIGESTIBILITY OF NITROGEN, DRY MATTER, GROSS ENERGY AND ASH IN SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS AT TWO LOCATIONS IN GROWING PIGS[a]

	High-protein meals		
Item	Soybean	Cottonseed	Meat&Bone
Nitrogen, %			
Terminal ileum	79.3 ± 2.75[c]	79.0 ± 1.35[c]	66.0 ± 2.91[d]
Total tract	86.7 ± 1.92[c]	81.8 ± 2.15[d]	76.7 ± 3.63[e]
Difference (T-I)[b]	7.4 ± 2.23[d]	2.8 ± 2.21[e]	10.8 ± 2.05[c]
Dry matter, %			
Terminal ileum	80.8 ± 1.44[c]	72.5 ± 1.59[e]	79.2 ± .98[d]
Total tract	88.5 ± .79[c]	78.2 ± 1.27[e]	83.7 ± 1.48[d]
Difference (T-I)[b]	7.7 ± 1.46[c]	5.7 ± 2.07[d]	4.5 ± 1.04[d]
Gross energy, %			
Terminal ileum	83.4 ± 1.37[c]	75.5 ± 1.77[e]	81.2 ± 1.67[d]
Total tract	89.9 ± .74[c]	79.5 ± 1.42[e]	85.0 ± 1.54[d]
Difference (T-I)[b]	6.5 ± 1.11[c]	4.0 ± 2.15[d]	3.8 ± 1.20[d]
Ash, %			
Terminal ileum	33.1 ± 5.99[c]	25.4 ± 7.06[d]	28.7 ± 4.87[cd]
Total tract	50.5 ± 5.37[c]	42.5 ± 3.65[d]	36.3 ± 7.52[e]
Difference (T-I)[b]	17.4 ± 8.62	17.1 ± 10.36	7.6 ± 7.70

[a]Dry-matter basis. Values are means of six observations ± standard deviation using chromic oxide as an indigestible marker.

[b]Total tract minus terminal ileum digestibility.

[cde]Means in the same line with different superscripts differ significantly ($P<.05$).

tract than at the end of the small intestine.

Measured at the end of the small intestine, the digestibility coefficient for ash was higher for SBM (33.1%) than CSM (25.4%) with M&B being intermediate and not different from the other two. Determined over the total tract, ash digestibility was highest (P<.05) for SBM, intermediate (P<.05) for CSM and lowest (P<.05) for M&B (50.5, 42.5 and 36.2%, respectively). Digestibilities for ash at both the terminal ileum and over the total tract were much lower than for dry matter, nitrogen and energy. Also, the amount of ash digested in the large intestine was higher than the amount digested in the small intestine for all three meals. It is difficult to explain the wide difference in ash digestibility for M&B and SBM at the end of the small intestine (28.7 *vs* 33.1%) and over the total tract (36.3 *vs* 50.5%) since steamed bone meal was added to the SBM diet (1.84%) in an effort to standardize the source of calcium and phosphorus. However, the percentage of ash in the M&B diet was 2.70% higher than in the SBM diet (7.87 *vs* 5.17%).

Nitrogen and Amino Acid Digestibility at the End of the Small Intestine. In general, nitrogen and amino acid digestibilities tended to be highest for SBM, intermediate for CSM and lowest for M&B (Table 8). Average digestibilities of the essential amino acids were 82.8, 79.6and 67.1% for the SBM, CSM and M&B diets, respectively. Among the essential amino acids, arginine had the highest digestibility in all meals; threonine was the least digestible in SBM (72.9%) and CSM (69.3%) while tryptophan was least digestible in M&B meal (49.7%). The low digestibility for threonine has been reported previously

TABLE 8. APPARENT DIGESTIBILITY OF NITROGEN AND AMINO ACIDS IN SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS/MEASURED AT THE END OF THE SMALL INTESTINE IN GROWING PIGS

	High-protein meals		
Amino Acid	Soybean	Cottonseed	Meat & Bone
Dietary essential			
Arginine	88.9 ± 1.51[c]	92.1 ± .75[b]	78.4 ± 3.07[d]
Histidine	86.5 ± 2.79[b]	85.0 ± 1.38[b]	68.0 ± 4.64[c]
Isoleucine	81.5 ± 2.68[b]	76.2 ± 1.03[c]	64.5 ± 2.62[d]
Leucine	80.8 ± 3.84[b]	77.0 ± 3.62[c]	68.6 ± 3.52[d]
Lysine	85.6 ± 2.58[b]	69.8 ± 2.51[c]	67.4 ± 4.44[c]
Methionine	86.7 ± 2.98	82.2 ± 2.32	73.8 ± 1.87
Phenylalanine	83.4 ± 2.31[b]	87.0 ± 1.00[c]	71.4 ± 3.71[d]
Threonine	72.9 ± 4.53[b]	69.3 ± 3.83[c]	60.8 ± 4.17[d]
Tryptophan	80.9 ± 4.22[b]	77.6 ± 3.83[b]	49.7 ± 7.01[c]
Valine	80.9 ± 2.85[b]	79.3 ± 2.35[b]	68.2 ± 3.16[c]
Average	82.8	79.6	67.1
Non-dietary essential			
Alanine	78.3 ± 3.34[b]	75.7 ± 2.53[bc]	73.8 ± 3.44[c]
Aspartic acid	82.6 ± 2.60[b]	79.7 ± 2.52[c]	53.0 ± 3.60[d]
Glutamic acid	88.0 ± 2.25[b]	88.7 ± 1.26[b]	69.7 ± 2.97[c]
Glycine	68.2 ± 7.05	68.8 ± 5.57	71.9 ± 5.34
Proline	56.8 ± 8.23	56.5 ±15.64	65.2 ± 7.76
Serine	79.9 ± 3.00[b]	77.2 ± 2.71[c]	63.6 ± 2.79[d]
Tyrosine	76.3 ± 6.26[b]	76.0 ± 2.90[b]	57.1 ± 5.02[c]
Average	75.7	74.7	64.9
Nitrogen	79.3 ± 2.75[b]	79.0 ± 1.35[b]	66.0 ± 2.91[c]

[a]Dry-matter basis. Values are the mean for six pigs ± standard deviation. Values determined using chromic oxide as an indigestible marker.

[bcd]Values on the same line with different superscripts differ significantly ($P<.05$).

(Zebrowska, 1973; Holmes *et al.*, 1974; Sauer, 1977) and is probably due to the high concentrations of threonine in the endogenous protein and threonine's slower absorption compared to other amino acids (Adibi, 1960; Buraczewska, 1977).

The average digestibility of the essential amino acids in SBM agree fairly well with previous reported values. The average values reported by Tanksley *et al.* (1978), 84.0%,and Rudolph (1979), 83.3%, are only 1.2 and .5% percentage units higher than the 82.8% found in this trial. Digestibilities of the four most limiting amino acids in grain-soybean meal based swine diets were also similar. Tanksley *et al.* (1978) and Rudolph (1979) reported 88.5, 83.4, 77.0 and 81.6% and 85.1, 82.3, 74.5 and 77.5% digestibilities for lysine, isoleucine, threonine and tryptophan, which are .7 to 4.6 percentage units higher than the values found in this study. CSM digestibility values for lysine, isoleucine, threonine and tryptophan of 69.8, 76.2, 69.3 and 77.6%, respectively are from 7.3 to 10.0 percentage units higher than values reported by Tanksley *et al.* (1978) (61.7, 66.2, 62.0 and 68.7, respectively). Tanksley and Knabe (1979) reported digestibility values of 60.5, 58.7, 50.0 and 54.7% for lysine, isoleucine, threonine and tryptophan, respectively for a 51.8% crude protein meat and bone meal which are generally lower than the respective values of 67.4, 64.5, 60.8 and 49.7% for this study.

The low digestibilities of tryptophan in M&B and lysine in CSM have practical importance since they are the first limiting amino acids in swine diets. Bloss *et al.*, 1953; Meade and Teter, 1957; Luce *et al.*, 1964 have suggested that tryptophan is the first limiting amino acid in corn-based diets containing from 5 to 20% M&B meal.

Nitrogen and Amino Acid Digestibility over the Total Tract. Nitrogen and individual amino acid digestibilities over the total tract are found in Table 9. Digestibilities for all amino acids in all three meals tended to be higher amd more uniform than found at the end of the small intestine. Nitrogen and amino acid digestibilities were highest in SBM and lowest in M&B meal. All essential amino acids (except methionine) in SBM were higher (P<.05) than in M&B. There were no differences (P<.05) in methionine digestibility among the three meals. Tanksley *et al.* (1978) reported an average of 70.3% digestibility for the ten essential amino acids in CSM, which is 10.3% lower than the 80.9% reported in this study when measured over the total tract.

Lysine was least (P<.05) digestible in CSM (69.3%), highest (P<.05) in SBM (87.6%) and intermediate in M&B which was different (P<.05) from the other meals (76.1%). Tanksley *et al.* (1978) reported a 57.9% lysine digestibility for CSM compared to the 69.3% value found in this study. However, the SBM lysine digestibility found here (87.6%) compared well to Rudolph's (1979) value of 89.74% and to 89.1% reported by Tanksley *et al.* (1978).

Digestibility Differences Between the End of the Small Intestine and Over the Total Tract. Mean differences in nitrogen and amino acid digestibilities measured at the end of the small intestine and over the total tract are given in Table 10. As expected, values measured over the total tract were generally higher than the values determined at the end of the small intestine indicating a disappear-

TABLE 9. APPARENT DIGESTIBILITY OF NITROGEN AND AMINO ACIDS IN SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS DETERMINED OVER THE TOTAL TRACT IN GROWING PIGS[a]

	High-protein meals		
Amino Acid	Soybean	Cottonseed	Meat & Bone
Dietary essential			
Arginine	92.2 ± 1.31[b]	92.9 ± .85[b]	82.4 ± 2.99[c]
Histidine	92.1 ± 3.71[b]	87.9 ± 1.95[b]	78.3 ± 3.94[c]
Isoleucine	85.1 ± 2.43[b]	75.6 ± 3.54[c]	70.6 ± 3.69[d]
Leucine	86.3 ± 2.41[b]	78.0 ± 2.07[c]	75.1 ± 4.25[c]
Lysine	87.6 ± 2.96[b]	69.3 ± 4.01[d]	76.1 ± 3.40[c]
Methionine	78.0 ±20.20	80.2 ± 2.29	79.2 ± 2.45
Phenylalanine	87.6 ± 1.86[b]	85.7 ± 1.39[b]	76.8 ± 3.87[c]
Threonine	84.7 ± 2.55[b]	75.7 ± 3.33[c]	72.6 ± 3.29[c]
Tryptophan	89.3 ± 2.96[b]	83.9 ± 2.39[c]	54.8 ± 7.20[d]
Valine	85.7 ± 2.28[b]	80.0 ± 2.54[c]	75.6 ± 3.65[d]
Average	86.9	80.9	74.2
Non-dietary essential			
Alanine	82.8 ± 2.39[b]	74.9 ± 3.07[c]	81.9 ± 2.16[b]
Aspartic acid	89.2 ± 1.09[b]	83.5 ± 2.52[c]	75.2 ± 2.92[d]
Glutamic acid	92.1 ± 1.11[b]	90.4 ± 1.12[c]	79.4 ± 2.40[d]
Glycine	85.5 ± 1.95[b]	77.8 ± 1.83[c]	87.3 ± 3.73[b]
Proline	90.4 ± 1.67[b]	70.9 ± 7.22[d]	84.4 ± 3.98[c]
Serine	88.9 ± 1.63[b]	82.4 ± 2.05[b]	76.7 ± 2.37[c]
Tyrosine	84.7 ± 2.71[b]	80.1 ± 2.78[c]	68.5 ± 4.61[d]
Average	87.7	80.0	79.1
Nitrogen	86.7 ± 1.92[b]	81.8 ± 2.65[c]	76.7 ± 3.63[d]

[a]Dry-matter basis. Values are the mean for six observations ± standard deviation. Values determined using chromic oxide as an indigestible marker.

[bcd]Values on the same line with different superscripts differ significantly ($P<.05$).

TABLE 10. MEAN DIFFERENCES BETWEEN DIGESTIBILITIES IN SOYBEAN, COTTONSEED AND MEAT AND BONE MEALS MEASURED AT THE END OF THE SMALL INTESTINE AND OVER THE TOTAL TRACT IN GROWING PIGS[a]

	High-protein meals		
Amino Acid	Soybean	Cottonseed	Meat & Bone
Dietary essential			
Arginine	3.3 ± 1.48[b]	.8 ± .71[c]	4.0 ± 2.09[b]
Histidine	5.6 ± 2.72[bc]	2.9 ± 1.46[c]	10.3 ± 5.17[b]
Isoleucine	3.6 ± .63[b]	-.7 ± 2.88[c]	6.1 ± 5.08[b]
Leucine	5.4 ± 3.56[bc]	1.0 ± 3.04[c]	6.5 ± 4.85[b]
Lysine	2.0 ± 2.41[b]	-.6 ± 2.37[c]	8.7 ± 4.95[b]
Methionine	-8.7 ±22.15	-2.1 ± 2.75	5.4 ± 2.34
Phenylalanine	4.2 ± 1.82[b]	-1.3 ± 1.01[c]	5.4 ± 4.79[b]
Threonine	11.8 ± 3.07[b]	6.4 ± 3.28[c]	11.8 ± 4.72[b]
Tryptophan	8.4 ± 1.45	6.4 ± 8.78	5.1 ±11.22
Valine	4.8 ± 1.64[b]	.7 ± 1.72[c]	7.4 ± 4.00[b]
Average	4.04	1.36	7.08
Non-dietary essential			
Alanine	4.6 ± 2.48[c]	-.9 ± 2.43[d]	8.1 ± 2.45[b]
Aspartic acid	6.7 ± 1.90[c]	3.8 ± 1.77[c]	22.2 ± 4.03[b]
Glutamic acid	4.1 ± 1.73[c]	1.7 ± .96[d]	9.6 ± 2.34[b]
Glycine	17.2 ± 5.7[b]	9.0 ± 4.86[c]	15.4 ± 2.29[b]
Proline	33.7 ± 7.46[b]	14.4 ±10.22[c]	19.2 ± 7.80[c]
Serine	9.1 ± 2.27[c]	5.2 ± 2.43[d]	13.1 ± 2.87[b]
Tyrosine	8.7 ± 4.61[bc]	4.2 ± 2.56[c]	11.4 ± 7.14[b]
Average	12.0	5.3	14.1
Nitrogen	7.4 ± 2.23[c]	2.8 ± 2.21[d]	10.8 ± 2.05[b]

[a]Values were obtained by subtracting ileal from total tract digestibilities. Values are the means for six pigs ± stadard deviation.

[bcd]Values on the same line with different superscripts differ significantly ($P<.05$).

ance of amino acids in the hind gut. M&B tended to show the greatest average difference and greater variability among differences compared to SBM and CSM. CSM exhibited the least difference in digestibility values between the two locations.

Disappearance of amino acids in the hind gut of the pig (Cho and Bayley, 1972; Holmes *et al.*, 1974; Sauer *et al.*, 1977; Zebrowska *et al.*, 1977a) and a net synthesis of some amino acids in the lower gut of the pig (Holmes *et al.*, 1974; Sauer *et al.*, 1977; Zebrowska *et al.*, 1977a) have been reported previously. Zebrowska *et al.* (1977b) reported that the nitrogenous compounds that enter the hind gut are modified to amines or ammonia by the microflora and are not biologically available to the pig. Therefore, using fecal digestibility values would tend to overestimate the amount of each amino acid that is actually digestible and absorbable by the pig.

SBM and M&B seemed to follow the pattern reported by Zebrowska (1973) and Sauer *et al.* (1977a) that as ileal digestibility is lowered, the microflora in the hind gut are offered more substrate to modify, resulting in a greater amino acid digestibility over the total tract. However, CSM does not seem to fit this pattern. One possible explanation is that the depressed hind gut digestibility of amino acids in CSM results from the protein-gossypol and carbohydrate-gossypol complexes that are formed during processing are so resistant to hydrolysis that the microorganisms in the large intestine are incapable of breaking them down.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Measured at the end of the small intestine and over the total tract, digestibilities of nitrogen and individual amino acids tended to be higher for SBM, lowest for M&B and intermediate for CSM. The average digestibility for the ten essential amino acids was higher measured over the total tract than at the end of the small intestine: 4.1% for SBM (86.9 *vs* 82.8%), 1.3% for CSM (80.9 *vs* 79.6%) and 7.1% for M&B (74.2 *vs* 67.1%). The average digestibility for the essential amino acids closely paralleled nitrogen digestibility at the end of the small intestine (82.8 *vs* 79.3% SBM; 79.6 *vs* 79.0% CSM; 67.1 *vs* 66.0% M&B) and over the total tract (86.9 *vs* 86.7% SBM; 80.9 *vs* 81.8% CSM: 74.2 *vs* 76.7% M&B) although there was a wide variation between the digestibility of individual amino acids and nitrogen.

Lysine, the first limiting amino acid in corn or sorghum-SBM or CSM diets, had the highest ($P<.05$) digestibility in SBM (85.6%) while CSM (69.8%) and M&B (67.4%) were not different ($P<.05$) measured at the end of the small intestine. Over the total tract, lysine digestibility was highest ($P<.05$) in SBM (87.6%), lowest ($P<.05$) for CSM (69.3%), while M&B (76.1%) was intermediate and different ($P<.05$) from the two others. Tryptophan digestibility (the first limiting amino acid in corn-M&B diets) was lowest ($P<.05$) in M&B (49.7%) and similar in SBM (80.9%) and CSM (77.6%) measured at the end of the small intestine. It appears that amino acid digestibility values determined at the end of the small intestine give a more accurate measure of what is actually available to the pig than measurements made over the total digestive tract.

Gross energy digestibilities over the total tract were similar determined by total collection procedures or using an indigestible marker 89.9 *vs* 90.8% SBM; 79.5 *vs* 81.7% CSM: 85.0 *vs* 89.4% M&B. Regardless of method of determination or location, gross energy digestibility favored the SBM followed by M&B and CSM. Digestible and metabolizable energy values were highest (P<.05) for SBM (3.93 and 3.83 kcal/g), lowest (P<.05) for CSM (3.62 and 3.50 kcal/g), with M&B (3.67 and 3.68 kcal/g) intermediate.

Ash digestibility in M&B measured at the end of the small intestine (28.7%) was not significantly different from either SBM (33.1%) or CSM (25.8%), but SBM and CSM were different (P<.05) from each other. However, over the total tract ash digestibility in M&B (36.3%) was lowest (P<.05), SBM (50.5%) was highest (P<.05) with CSM (47.5%) intermediate and different (P<.05) from the two others. The low digestibility of ash in M&B may be due to its high ash concentration compared to the other meals (24.26 *vs* 6.18 and 5.92% for M&B, SBM and CSM, respectively). A larger amount of ash disappeared in the lower gut than in the small intestine for all three meals.

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