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Comparative Protein and Amino Acid Digestibilities in Growing Pigs and Sows[1,2,3,4]

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ABSTRACT: An experiment was conducted to compare apparent total tract protein digestibilities and apparent ileal digestibilities of protein and amino acids in growing pigs and adult pregnant and lactating sows. Twelve growing pigs and 12 sows were used and surgically fitted with simple T-cannulas at the distal ileum. Six experimental diets based on corn, barley, wheat, soybean meal, canola meal, or meat and bone meal were formulated, and each diet was fed to growing pigs, gestating sows, and lactating sows for 7 d. Chromium oxide was included in all diets as an indigestible marker (.25%) for calculating nutrient digestibilities. Fecal material was collected on d 5 of each feeding period by grab sampling, and ileal samples were collected for 12 h/d during the last 2 d of each feeding period. Apparent fecal protein digestibilities for all feed ingredients were higher ($P < .05$) in gestating and lactating sows compared to growing pigs, but no differences between the two groups of sows were observed ($P > .05$). At the distal ileum, no differences ($P > .05$) in protein digestibilities were detected between sows and growing pigs regardless of feed ingredient. For all feed ingredients tested, lactating sows had apparent ileal digestibilities of most amino acids that were two to six percentage units higher than those obtained in growing pigs, but not all of the differences were significant. Gestating sows had digestibilities of most amino acids that were intermediate between those of growing pigs and lactating sows. The combined results from the six feed ingredients showed that lactating sows had higher ($P < .05$) digestibilities of all indispensable amino acids except arginine, and gestating sows had higher ($P < .05$) digestibilities of five of the indispensable amino acids than did growing pigs. The results of this experiment indicate that apparent fecal protein and apparent ileal amino acid digestibilities obtained in growing pigs are not always representative of digestibilities in either gestating or lactating sows.

Key Words: Sows, Protein, Amino Acids, Digestibility, Ileum

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Introduction

Apparent fecal nitrogen digestibility in growing pigs increases with age (Roth and Kirchgessner, 1984; Shi and Noblet, 1994). Likewise, total tract nitrogen digestibility coefficients in sows seem to be higher than in growing pigs (Fernandez et al., 1986; Noblet and Shi, 1993; Etienne et al., 1997). However, for proper feed formulation, ileal amino acid digestibility values should be used (Sauer and Ozimek, 1986; Batterham, 1994).

Values for apparent ileal amino acid digestibilities for different feed ingredients have been summarized (Sauer and Ozimek, 1986; Southern, 1991; Tanksley and Knabe, 1993; Jondreville et al., 1995). Most of these values were obtained with growing pigs between 25 and 125 kg live weight or in neonatal pigs (e.g., Walker et al., 1986; Li et al., 1993; Caine et al., 1997). However, to our knowledge, no apparent ileal amino acid digestibility data exist for sows. Therefore, models of amino acid metabolism in sows (Whittemore and Morgan, 1990; Pettigrew et al., 1992) have used digestibility values from growing pigs without experimental evidence that they are also representative for sows. Several physiological factors (i.e., age, body weight, and feeding level) have been shown to influence the degree to which an animal can digest

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amino acids in a given diet (Moughan, 1993). Therefore, sows and growing pigs may digest dietary proteins differently.

The objective of the present experiment was to test the hypothesis that apparent ileal digestibility coefficients for amino acids obtained in growing pigs are not different from values obtained with sows fed three cereal grains and three commonly used protein concentrates.

Materials and Methods

Animals and Experimental Design

Twelve adult, gestating, multiparous sows (PIC, Camborough 15, Pig Improvement Company, Franklin, KY) and 12 growing barrows (PIC, Camborough 15 dams sired by PIC 326 boars, Pig Improvement Company) of approximately 42 (±4) kg BW were used in the experiment. All animals were surgically fitted with simple T-cannulas in the distal ileum. The sows were cannulated at d 40 (±5 d) of gestation using the technique described previously (Stein et al., 1998). Six sows and six growing pigs were arranged in one of two repeated 3 × 3 Latin square designs and fed diets based on one of three cereal grains (corn, barley, and wheat). The remaining six sows and six pigs were arranged in a similar design and fed diets based on one of three protein ingredients (soybean meal, canola meal, and meat and bone meal). Sows were fed the test diets during gestation as well as lactation.

The experiment was approved by the University of Illinois Laboratory Animal Care Committee (protocol no. A3S-164).

Housing Systems

Gestating sows and growing pigs were kept in an environmentally controlled building; the room temperature was maintained at 20°C. All animals were penned individually in pens with fully slatted concrete floors. Pen dimensions for gestating sows were 1.82 × 1.82 m, and growing pigs were kept in 1.82- × .91-m pens. A feeder was suspended to the front of each pen and a drinking nipple was suspended to one of the side panels. Lactating sows were kept in regular farrowing stalls (.66 × 2.13 m) on a plastic-coated expanded-metal floor. The temperature in the farrowing barn was maintained at approximately 22°C. The farrowing stalls that had horizontal sidebars and vertical fingers on the lowest bar were not modified before or during the experiment.

Diets

The amino acid composition values for the test feed ingredients are shown in Table 1. The three experimental diets containing cereal grains were formulated by adding soybean oil, vitamins, and minerals to the test feed ingredients (Table 2). The three diets containing the protein concentrates were formulated as semisynthetic cornstarch-based diets, with the addition of soybean oil, solka floc (a source of cellulose), vitamins, and minerals. Synthetic amino acids were added when needed to meet the NRC requirements for indispensable amino acids for lactating sows (NRC, 1988). Glutamate and glycine were added to all diets to give an equivalent of approximately 13% crude protein in order to provide sufficient nitrogen for the synthesis of dispensable amino acids

Table 1. Analyzed composition (%) of the feed ingredients tested

Item	Corn	Barley	Wheat	SBM[a]	CM[a]	MBM[a]
Dry matter	83.30	86.50	84.50	87.40	89.10	95.50
Crude protein	7.50	8.50	10.80	43.30	31.40	60.10
Ash	1.02	1.54	1.99	6.10	6.40	20.70
Lysine	.24	.35	.35	3.05	2.05	3.45
Tryptophan	.07	.09	.12	.65	.47	.41
Threonine	.30	.29	.33	1.91	1.55	1.99
Methionine	.18	.15	.21	.68	.70	.90
Valine	.40	.46	.52	2.30	1.80	2.54
Isoleucine	.29	.29	.37	2.13	1.32	1.67
Leucine	1.07	.58	.74	3.74	2.48	3.60
Phenylalanine	.43	.40	.49	2.47	1.44	2.07
Histidine	.235	.20	.27	1.30	.98	1.08
Arginine	.40	.45	.57	3.55	2.19	4.22
Proline	.72	.81	1.04	2.55	2.14	5.19
Glycine	.325	.39	.49	2.04	1.82	8.21
Glutamate	1.57	1.72	2.92	8.66	5.82	7.25
Aspartate	.515	.56	.58	5.43	2.57	4.43
Serine	.39	.32	.45	2.34	1.52	2.47
Cysteine	.19	.20	.30	.73	.85	.59
Tyrosine	.28	.22	.27	1.75	1.02	1.39
Alanine	.64	.38	.42	2.12	1.59	4.49

[a]SBM = soybean meal, CM = canola meal, and MBM = meat and bone meal.

Table 2. Ingredient composition (%) of the experimental diets (as-is basis)

Diet	C[a]	B[a]	W[a]	SBM[a]	CM[a]	MBM[a]
Corn	84.01	—	—	—	—	—
Barley	—	89.07	—	—	—	—
Wheat	—	—	90.77	—	—	—
Soybean meal	—	—	—	19.2	—	—
Canola meal	—	—	—	—	20.0	—
Meat and bone meal	—	—	—	—	—	15.96
Cornstarch	—	—	—	63.8	61.26	68.49
Solka floc[b]	—	—	—	4	4	4
Soybean oil	4	4	4	4	4	4
Dicalcium phosphate	1.97	1.6	1.4	2.57	1.98	—
Limestone	.79	.93	1.05	.39	.47	—
Trace mineral salt[c]	.35	.35	.35	.35	.35	.35
Vitamin premix[d]	.20	.20	.20	.20	.20	.20
L-Glutamate	4.8	2.0	1.0	3.2	4.3	3.5
L-Glycine	2.4	1.0	.5	1.6	2.15	1.75
L-Lysine·HCl	.51	.31	.3	.06	.19	.18
DL-Methionine	.07	.03	—	.10	.14	.19
L-Threonine	.20	.12	.10	.08	.10	.19
L-Tryptophan	.07	—	—	—	.04	.08
L-Valine	.21	.10	.08	.20	.22	.27
L-Histidine	.02	.04	—	—	.04	.10
L-Isoleucine	.10	—	—	—	.09	.16
L-Arginine·HCl	.05	—	—	—	.22	.33
Chromium oxide	.25	.25	.25	.25	.25	.25
Total	100	100	100	100	100	100

[a]C = corn diet, B = barley diet, W = wheat diet, SBM = soybean meal diet, CM = canola meal diet, and MBM = meat and bone meal diet.
[b]James River, Berlin, NH.
[c]Trace mineral mix provided the following quantities of nutrients per kilogram of diet: Se, .30 mg; I, .35 mg; Cu, 8 mg; Mn, 20 mg; Fe, 90 mg; Zn, 100 mg; NaCl, 2.73 g.
[d]Vitamin premix provided the following quantities of vitamins per kilogram of diet: Vitamin A, 5,250 IU; vitamin D_3, 525 IU; vitamin E, 40 IU; menadione K, 2 mg; vitamin B_{12}, .016 mg; riboflavin, 4 mg; D-pantothenic acid, 11 mg; niacin, 15 mg; choline chloride, 110 mg.

and other nitrogenous compounds (Allen and Baker, 1974; Chung and Baker, 1991; Henry et al., 1992). Chromic oxide (.25%) was included in the diets as an indigestible marker. The analyzed nutrient compositions of the diets were, with a few exceptions, close to the calculated values (Table 3).

Feeding and Sampling

Gestating sows were fed 2 kg of feed daily in two equal meals at 0800 and 2000 throughout the experimental period. Growing pigs and lactating sows were allowed ad libitum access to feed; fresh feed was added to the feeders twice daily, and stale feed was removed and weighed every morning. Feed intake data for each animal and day were recorded. Each feeding period consisted of 7 d. In the first meal of each feeding period, ferric oxide (.1%) was included as a fecal marker. The initial 4 d of each period was considered an adaptation period. On d 5, fecal material was collected by grab sampling. During the last 2 d of each feeding period, digesta were collected through the cannulas for 12 h starting approximately 15 min after feeding the morning meal. The caps were removed from the cannulas, and a 225-mL plastic bag (Gerber baby bottle bag, Gerber Products Company, Fremont, MI) was attached to the cannula barrel with an autolocking cable tie. Bags were removed and immediately frozen as soon as they were filled with digesta, or at least once every 30 min. All samples were frozen immediately after collection.

Sample Analysis

At the end of the experiment, digesta samples were thawed and mixed within animal and diet, and a subsample was removed and frozen. Prior to chemical analysis, fecal and digesta samples were freeze-dried and finely ground. Proximate analyses were performed on all samples according to AOAC procedures (AOAC, 1990). The amino acid content of feed and digesta samples was determined with HPLC using a Beckman 6300 Amino Acid Analyzer (Beckman Instruments Corp., Palo Alto, CA) using ninhydrin for postcolumn derivatization (AOAC, 1990). Norleucine was used as the internal standard. All samples were hydrolyzed for 24 h at 110°C with 6 *N* HCl prior to amino acid analysis. Sulfur-containing amino acids were analyzed after cold performic acid oxidation overnight and subsequent hydrolysis. Tryptophan was determined after alkaline hydrolysis for 22 h at 110°C. The chromium content of feed, feces, and digesta was determined by atomic spectrophotometry (Williams et al., 1962).

Calculations and Statistical Analysis

Data for feed intake were summarized and daily feed intake during each feeding period was calculated for each animal. The apparent ileal digestibility of each amino acid and for individual animals was calculated for each feed ingredient using the chromium content in feed and digesta as the marker according to the following formula (Fan et al., 1995): AID = (100 − [(AAd/AAf) × (Crf/Crd)] × 100%, where AID is the apparent ileal digestibility of an amino acid (%), AAd is the amino acid content in the ileal sample DM, AAf is the amino acid content in the feed DM, Crf is the chromium content in the feed DM, and Crd is the chromium content in the ileal sample DM. Apparent fecal and apparent ileal digestibilities of protein were calculated in a similar way. We assumed that the dietary synthetic amino acids were completely absorbed prior to the distal ileum (Chung and Baker, 1992; Butts et al., 1993a), and the dietary contents of synthetic amino acids were disregarded in the calculations.

Statistical analyses of the data were performed using the Proc Mixed procedure of SAS (Littell et al., 1996). Values for digestibilities obtained in gestating sows and lactating sows were compared using a repeated measures analysis. Values obtained in growing pigs were compared separately to those obtained in gestating sows and lactating sows using a model that included the physiological state of the animal, the diet, and the interaction between the physiological state and the diet as the main effects. Treatment means were separated using the LSMeans statement and the DIFF option in Proc Mixed.

Results

All animals recovered quickly after the surgery, and feed intake was normal within 3 d after the surgeries. Postoperative body temperatures were normal and digesta started flowing from the cannulas within 2 d after the surgery. One gestating sow developed peritonitis shortly before farrowing and had to be removed from the experiment. Therefore, only 11 sows were available for collection of ileal digesta during lactation, and the values presented for lactating sows for the three protein concentrates are the means of only five observations.

After calculating the apparent ileal digestibilities of protein and amino acids, we discovered that one growing pig and one gestating sow fed the corn and barley diets had digestibility coefficients that were less than half of the values obtained for the other animals. Samples were reanalyzed, but the results did not change. Plotting the residuals from the statistical analysis strongly indicated that these animals were outliers. Therefore, the values from these animals were disregarded in the final analysis and the results presented are means of the remaining observations.

In a few cases, the fecal marker was not passed by d 5 of the feeding period; hence, fecal samples were not collected from these animals. Feed intake for all diets was considered normal (Table 4). As expected, growing pigs and lactating sows consumed more feed than did the restricted-fed gestating sows ($P < .05$). Lactating sows also consumed more feed ($P < .05$) than did the growing pigs, except those fed the barley diet.

The apparent total tract protein digestibility coefficients for each feed ingredient are presented in Table 5. For all diets, gestating and lactating sows had higher ($P < .05$) total tract digestibility coefficients

Table 3. Analyzed nutrient composition of the experimental diets (as-is basis)

Diet	C[a]	B[a]	W[a]	SBM[a]	CM[a]	MBM[a]
ME, kcal/kg[b]	3,414	3,110	3,353	3,696	3,551	3,653
CP, %	12.6	10.5	12.2	12.6	13.2	15.2
Calcium, %[b]	.75	.75	.75	.75	.75	1.5
Phosphorus, %[b]	.6	.6	.6	.6	.6	.73
Arginine, %	.34	.40	.51	.53	.44	.73
Histidine, %	.21	.20	.24	.20	.27	.18
Isoleucine, %	.33	.25	.32	.33	.41	.46
Leucine, %	.88	.53	.68	.59	.51	.69
Lysine, %	.53	.56	.54	.53	.59	.55
Methionine, %	.21	.17	.18	.19	.28	.40
Phenylalanine, %	.36	.36	.45	.38	.45	.57
Threonine, %	.40	.39	.38	.36	.40	.52
Tryptophan, %	.11	.08	.12	.11	.13	.14
Valine, %	.51	.51	.50	.59	.62	.72

[a]C = corn diet, B = barley diet, W = wheat diet, SBM = soybean meal diet, CM = canola meal diet, and MBM = meat and bone meal diet.
[b]Calculated.

Table 4. Average daily feed intake (kg) of the experimental diets by growing pigs and gestating and lactating sows[a]

	Growing pigs	Gestating sows	Lactating sows
Item	Mean ± SE[b]	Mean ± SE[c]	Mean ± SE[d]
Corn diet	3.2 ± .6[f]	2.0 ± .1[e]	4.7 ± .6[g]
Barley diet	3.1 ± .6[f]	2.0 ± .1[e]	4.3 ± .6[f]
Wheat diet	2.8 ± .6[f]	2.0 ± .1[e]	5.4 ± .6[g]
Soybean meal diet	2.6 ± .6[f]	2.0 ± .1[e]	6.9 ± .6[g]
Canola meal diet	2.4 ± .6[f]	2.0 ± .1[e]	5.7 ± .6[g]
Meat and bone meal diet	2.4 ± .6[f]	2.0 ± .1[e]	5.4 ± .6[g]

[a]For growing pigs, values are means of five observations for the corn diet and the barley diet and six observations for all other diets. For gestating sows, values are means of six observations for the wheat diet, the soybean meal diet, and the canola meal diet and five observations for the other diets. For lactating sows, values are means of six observations for the corn diet, the barley diet, and the wheat diet and five observations for the other diets.

[b]Standard error associated with the comparison of growing pigs and lactating sows.

[c]Standard error associated with the comparison of gestating sows and growing pigs.

[d]Standard error associated with the comparison of lactating sows and growing pigs.

[e,f,g]Means within a row lacking a common superscript differ ($P <$ .05).

than growing pigs. However, there were no differences ($P >$ .05) in the digestibility values between gestating and lactating sows.

The apparent ileal digestibility of protein in corn was higher ($P <$ .05) in gestating sows than in lactating sows (Table 6). The value for growing pigs was intermediate and not different ($P <$ .05) from that for either gestating or lactating sows. For all indispensable amino acids except arginine, gestating and lactating sows had numerically higher digestibilities than growing pigs, and the differences between gestating sows and growing pigs were significant for all indispensable amino acids except for lysine, threonine, and arginine. Lactating sows had higher (P < .05) digestibilities of tryptophan, methionine, and leucine than growing pigs ($P <$ .05). Digestibility coefficients of all dispensable amino acids except proline and aspartate were higher ($P <$ .05) in gestating sows than in the growing pigs, and the differences between lactating sows and growing pigs were significant for glutamate and tyrosine ($P <$ .05).

Differences in apparent ileal digestibility coefficients in barley between pigs and sows were smaller than those in corn (Table 7). The only significant ($P <$ .05) difference was the digestibility coefficient for tryptophan between lactating sows and growing pigs.

In the case of wheat, the apparent ileal digestibilities of protein and all indispensable amino acids except valine, methionine, isoleucine, and arginine were higher ($P <$ .05) in lactating sows than in growing pigs (Table 8). Of the dispensable amino acids, only the differences for serine, tyrosine, aspartate, and alanine were significant ($P <$ .05) between growing pigs and lactating sows. Ileal digestibility values for gestating sows were similar to those obtained for growing pigs. All values in gestating sows were lower than in lactating sows, and the differences for tryptophan, threonine, leucine, phenylalanine, histidine, serine, tyrosine, aspartate, alanine, and the mean of the indispensable amino acids were significant ($P <$ .05).

Apparent ileal amino acid digestibilities of all indispensable amino acids in soybean meal (Table 9) were numerically higher in gestating and lactating sows than in growing pigs. Higher values ($P <$ .05) were obtained only for tryptophan in lactating sows and for methionine, valine, isoleucine, leucine, and phenylalanine in gestating sows compared to growing pigs.

Amino acid digestibilities in canola meal are reported in Table 10. Lactating sows had higher ($P <$ .05) digestibilities than growing pigs for all amino acids except for proline, arginine, cysteine (P = .16), lysine (P = .06), and threonine (P = .07). Values obtained in gestating sows were close and not different ($P >$ .05) from those obtained in growing pigs. However, gestating sows had lower ($P <$ .05) digesti-

Table 5. Apparent total tract digestibility coefficients (%) of crude protein for corn, barley, wheat, soybean meal, canola meal, and meat and bone meal by growing pigs and gestating and lactating sows[a b]

	Growing pigs	Gestating sows	Lactating sows
Item	Mean ± SE[c]	Mean ± SE[d]	Mean ± SE[e]
Corn	53.7 ± 2.6[f]	70.5 ± 3.4[g]	70.4 ± 2.4[g]
Barley	57.4 ± 2.6[f]	69.0 ± 2.2[g]	67.4 ± 2.4[g]
Wheat	79.2 ± 2.6[f]	86.7 ± 2.0[g]	86.6 ± 2.4[g]
Soybean meal	76.0 ± 2.3[f]	84.1 ± 2.8[g]	84.4 ± 2.6[g]
Canola meal	64.4 ± 2.3[f]	70.8 ± 2.2[g]	75.0 ± 2.6[g]
Meat and bone meal	79.5 ± 2.6[f]	87.6 ± 2.4[g]	85.9 ± 2.6[g]
Average	68.4 ± 1.1[f]	78.1 ± 1.0[g]	78.3 ± 1.1[g]

[a](100 − [(CP in feces/CP in feed) × (chromium in feed/chromium in feces)] × 100%.

[b]For growing pigs, values are means of six observations for the soybean meal diet and the canola meal diet and five observations for all other diets. For gestating sows, values are means of three observations for the corn diet, four observations for the soybean meal diet, five observations for the barley diet and the meat and bone meal diet, and six observations for the other diets. For lactating sows, values are means of six observations for the corn diet, the barley diet, and the wheat diet, but only five observations for the other diets.

[c]Standard error associated with the comparison of growing pigs and lactating sows.

[d]Standard error associated with the comparison of gestating sows and growing pigs.

[e]Standard error associated with the comparison of lactating sows and growing pigs.

[f,g]Means within a row lacking a common superscript differ ($P <$ .05).

Table 6. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for corn by growing pigs and gestating and lactating sows[a]

Item	Growing pigs (n = 5) Mean ± SE[b]	Gestating sows (n = 5) Mean ± SE[c]	Lactating sows (n = 6) Mean ± SE[d]
Crude protein	58.4 ± 3.2[ef]	63.9 ± 3.1[f]	57.0 ± 2.9[e]
Indispensable amino acid			
Arginine	76.3 ± 1.4[ef]	78.8 ± 1.5[e]	72.9 ± 1.4[f]
Histidine	74.4 ± 1.6[e]	80.5 ± 1.6[f]	76.7 ± 1.5[ef]
Isoleucine	67.1 ± 1.9[e]	75.6 ± 1.8[f]	69.9 ± 1.8[e]
Leucine	75.5 ± 1.7[e]	85.1 ± 1.9[f]	80.2 ± 1.6[f]
Lysine	59.3 ± 2.0	62.8 ± 1.9	60.5 ± 1.8
Methionine	75.8 ± 1.5[e]	83.1 ± 1.4[f]	79.7 ± 1.4[ef]
Phenylalanine	73.4 ± 1.5[e]	81.4 ± 1.5[f]	77.2 ± 1.4[e]
Threonine	58.7 ± 2.7	64.7 ± 2.3	62.1 ± 2.5
Tryptophan	61.4 ± 2.5[e]	68.0 ± 2.1[f]	76.9 ± 2.3[g]
Valine	67.1 ± 2.0[e]	73.7 ± 1.8[f]	70.6 ± 1.9[ef]
Mean	68.9 ± 1.7[e]	75.4 ± 1.6[f]	72.7 ± 1.5[ef]
Dispensable amino acid			
Alanine	71.1 ± 2.5[e]	78.3 ± 2.4[f]	73.9 ± 2.3[ef]
Aspartate	62.3 ± 2.8	66.5 ± 2.6	64.2 ± 2.5
Cysteine	62.3 ± 3.0[e]	71.6 ± 2.3[f]	67.3 ± 2.8[ef]
Glutamate	66.7 ± 2.0[e]	81.4 ± 2.0[f]	76.0 ± 1.8[g]
Glycine	47.1 ± 4.1[e]	58.2 ± 4.7[f]	34.4 ± 3.8[g]
Proline	65.7 ± 6.1[e]	80.7 ± 8.0[e]	36.4 ± 6.8[f]
Serine	68.2 ± 2.1[e]	74.1 ± 1.8[f]	72.1 ± 1.9[ef]
Tyrosine	66.7 ± 1.8[e]	76.4 ± 1.8[f]	72.0 ± 1.7[f]
Mean	63.7 ± 2.0[e]	75.2 ± 2.8[f]	61.7 ± 2.3[e]

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of growing pigs and gestating sows.
[d]Standard error associated with the comparison of growing pigs and lactating sows.
[e,f,g]Means within a row lacking a common superscript differ ($P < .05$).

bility coefficients than lactating sows for all indispensable amino acids except for isoleucine, lysine, methionine, and threonine. The same was true for aspartate, glutamate, glycine, and serine.

For meat and bone meal, sows had numerically higher amino acid digestibilities than growing pigs (Table 11), but only the differences between lactating sows and growing pigs in the digestibility of methionine, lysine, tryptophan, and proline were significant ($P < .05$). The lowest digestibility values in meat and bone meal in the present experiment were obtained for cysteine, and a very low digestibility of this amino acid was observed in sows as well as in pigs.

Combined results of the apparent ileal protein and amino acid digestibilities of all six feed ingredients tested in this experiment are presented in Table 12. Lactating sows had higher ($P < .05$) digestibilities of all indispensable amino acids except arginine than growing pigs. Gestating sows had slightly lower digestibilities than lactating sows, but the values were not significantly different, except for tryptophan. However, for methionine, phenylalanine, and the branched-chained amino acids, digestibility values in gestating sows were higher than those obtained in growing pigs ($P < .05$). On average, for all the indispensable amino acids, gestating sows had higher ($P < .05$) digestibilities than growing pigs. Of the dispensable amino acids, gestating and lactating sows had higher digestibilities of glutamate, cysteine, and tyrosine ($P < .05$) compared to growing pigs, but no differences ($P > .05$) between gestating and lactating sows were observed.

The interactions between the physiological state of the animal and the diet are presented in Table 13. Except for glycine and proline, there were no interactions between growing pigs and lactating sows ($P > .05$). However, significant interactions ($P < .05$) for most amino acids were observed when comparing growing pigs and gestating sows; the same was the case when gestating sows were compared to lactating sows.

Table 7. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for barley by growing pigs and gestating sows and lactating sows[a]

Item	Growing pigs (n = 5) Mean ± SE[b]	Gestating sows (n = 5) Mean ± SE[c]	Lactating sows (n = 6) Mean ± SE[d]
Crude protein	61.0 ± 3.2	62.6 ± 3.1	60.2 ± 2.9
Indispensable amino acid			
Arginine	77.4 ± 1.5	77.5 ± 1.5	77.9 ± 1.4
Histidine	76.6 ± 1.6	80.5 ± 1.6	77.5 ± 1.5
Isoleucine	71.2 ± 1.9	70.5 ± 1.8	72.5 ± 1.8
Leucine	73.5 ± 1.7	73.0 ± 1.9	74.3 ± 1.6
Lysine	71.7 ± 2.0	68.5 ± 1.9	72.3 ± 1.8
Methionine	77.3 ± 1.5	76.6 ± 1.4	78.1 ± 1.4
Phenylalanine	74.6 ± 1.5	76.0 ± 1.5	77.2 ± 1.4
Threonine	61.3 ± 2.7	58.0 ± 2.3	60.3 ± 2.5
Tryptophan	71.7 ± 2.5[f]	68.6 ± 2.0[e]	76.0 ± 2.3[f]
Valine	72.5 ± 2.0	72.5 ± 1.8	75.2 ± 1.9
Mean	72.9 ± 1.7	71.8 ± 1.6	74.2 ± 1.6
Dispensable amino acid			
Alanine	62.3 ± 2.5	59.6 ± 2.4	62.3 ± 2.3
Aspartate	66.3 ± 2.8	61.9 ± 2.6	65.3 ± 2.5
Cysteine	69.5 ± 3.0	69.1 ± 2.3	73.1 ± 2.8
Glutamate	80.6 ± 2.0	81.2 ± 2.0	82.0 ± 1.8
Glycine	55.8 ± 4.1	57.3 ± 3.8	57.2 ± 3.8
Proline	77.4 ± 6.1	71.2 ± 6.2	67.3 ± 6.1
Serine	66.8 ± 2.1	65.3 ± 1.8	66.8 ± 1.9
Tyrosine	69.6 ± 1.8	67.6 ± 1.8	71.3 ± 1.7
Mean	68.4 ± 2.0	66.7 ± 2.2	70.0 ± 2.0

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)] × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of growing pigs and gestating sows.
[d]Standard error associated with the comparison of growing pigs and lactating sows.
[e,f]Means within a row lacking a common superscript differ ($P < .05$).

Discussion

Apparent Protein Digestibilities

Adult nonlactating and nongravid sows had 4 to 11% higher apparent total tract protein digestibility than growing pigs (Fernandez et al., 1986; Noblet and Shi, 1993). On average, of 14 diets tested, apparent total tract protein digestibility by growing pigs was only 87% of that obtained in sows (Noblet and Shi, 1993). Etienne et al. (1997) compared growing pigs and lactating sows and reported that apparent total tract protein digestibility by lactating sows is approximately 6% higher than that by growing pigs. In contrast, Everts et al. (1986) found no difference in apparent total tract protein digestibility between growing pigs and sows if the feeding level relative to the maintenance requirement was constant. Our results are in agreement with those of Fernandez et al. (1986), Noblet and Shi (1993), and Etienne et al. (1997).

Table 8. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for wheat by growing pigs and gestating and lactating sows[a]

Item	Growing pigs (n = 6) Mean ± SE[b]	Gestating sows (n = 6) Mean ± SE[c]	Lactating sows (n = 6) Mean ± SE[d]
Crude protein	71.4 ± 2.9[e]	75.4 ± 2.9[ef]	80.5 ± 2.9[f]
Indispensable amino acid			
Arginine	85.2 ± 1.4	85.3 ± 1.4	86.3 ± 1.4
Histidine	84.4 ± 1.5[e]	82.7 ± 1.5[e]	88.2 ± 1.5[f]
Isoleucine	80.4 ± 1.8	80.1 ± 1.6	83.0 ± 1.8
Leucine	81.9 ± 1.6[ef]	78.1 ± 1.8[e]	84.9 ± 1.6[f]
Lysine	74.1 ± 1.8[e]	75.5 ± 1.8[ef]	79.4 ± 1.8[f]
Methionine	85.3 ± 1.4	85.2 ± 1.3	87.4 ± 1.4
Phenylalanine	84.0 ± 1.4[ef]	82.6 ± 1.4[e]	86.2 ± 1.4[f]
Threonine	70.4 ± 2.5[e]	67.2 ± 2.1[e]	76.7 ± 2.5[f]
Tryptophan	75.9 ± 2.3[e]	78.1 ± 1.9[e]	86.1 ± 2.3[f]
Valine	78.6 ± 1.9	78.4 ± 1.7	83.0 ± 1.9
Mean	80.1 ± 1.6[e]	79.3 ± 1.5[e]	84.1 ± 1.5[f]
Dispensable amino acid			
Alanine	70.5 ± 2.3[ef]	66.7 ± 2.2[e]	74.9 ± 2.3[f]
Aspartate	75.1 ± 2.5[ef]	69.5 ± 2.3[e]	75.7 ± 2.5[f]
Cysteine	81.4 ± 2.8	80.3 ± 2.1	85.4 ± 2.8
Glutamate	91.3 ± 1.8	90.2 ± 1.8	92.2 ± 1.8
Glycine	70.1 ± 3.8	65.8 ± 3.5	74.4 ± 3.8
Proline	89.8 ± 5.5	84.4 ± 5.7	89.0 ± 5.5
Serine	80.1 ± 1.9[ef]	77.8 ± 1.7[e]	84.0 ± 1.9[f]
Tyrosine	77.5 ± 1.7[ef]	75.0 ± 1.7[e]	81.6 ± 1.7[f]
Mean	79.4 ± 1.9	79.2 ± 2.0	82.1 ± 1.9

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of growing pigs and gestating sows.
[d]Standard error associated with the comparison of growing pigs and lactating sows.
[e,f]Means within a row lacking a common superscript differ ($P < .05$).

Table 9. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for soybean meal by growing pigs and gestating and lactating sows[a]

Item	Growing pigs (n = 6) Mean ± SE[b]	Gestating sows (n = 6) Mean ± SE[c]	Lactating sows (n = 5) Mean ± SE[d]
Crude protein	71.4 ± 2.9	76.4 ± 2.9	71.7 ± 3.2
Indispensable amino acid			
Arginine	87.7 ± 1.4	90.2 ± 1.4	88.8 ± 1.5
Histidine	85.6 ± 1.5	87.9 ± 1.5	85.3 ± 1.6
Isoleucine	80.4 ± 1.8[e]	85.5 ± 1.6[f]	82.8 ± 1.9[ef]
Leucine	80.2 ± 1.6[e]	85.0 ± 1.8[f]	82.1 ± 1.7[ef]
Lysine	85.0 ± 2.0	89.3 ± 1.8	85.6 ± 2.0
Methionine	81.4 ± 1.4[e]	86.5 ± 1.3[f]	82.5 ± 1.5[e]
Phenylalanine	82.2 ± 1.4[e]	86.2 ± 1.4[f]	83.7 ± 1.5[ef]
Threonine	72.9 ± 2.5	78.0 ± 2.1	76.3 ± 2.7
Tryptophan	79.4 ± 2.3[e]	83.0 ± 1.9[ef]	86.4 ± 2.5[f]
Valine	76.3 ± 1.9[e]	81.3 ± 1.7[f]	79.0 ± 2.0[ef]
Mean	81.1 ± 1.6[e]	85.3 ± 1.5[f]	83.2 ± 1.7[ef]
Dispensable amino acid			
Alanine	70.5 ± 2.2[e]	77.7 ± 2.2[f]	72.2 ± 2.5[ef]
Aspartate	80.2 ± 2.5	84.8 ± 2.3	79.1 ± 2.8
Cysteine	68.8 ± 2.8[e]	75.2 ± 2.1[f]	72.5 ± 3.0[ef]
Glutamate	81.4 ± 1.8[e]	87.8 ± 1.8[f]	81.2 ± 2.0[e]
Glycine	60.4 ± 3.8[ef]	66.5 ± 3.5[e]	54.3 ± 4.1[f]
Proline	58.0 ± 5.5	54.6 ± 6.2	42.5 ± 9.5
Serine	80.1 ± 1.9	83.6 ± 1.7	81.5 ± 2.1
Tyrosine	82.0 ± 1.7	86.6 ± 1.7	85.0 ± 1.8
Mean	72.7 ± 1.9	77.4 ± 2.2	76.2 ± 3.2

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of gestating sows and growing pigs.
[d]Standard error associated with the comparison of lactating sows and growing pigs.
[e,f]Means within a row lacking a common superscript differ ($P < .05$).

Despite the significant difference in apparent total tract protein digestibility, no differences in apparent ileal protein digestibility were detected between sows and growing pigs. Therefore, the increase in apparent total tract digestibility by sows was caused by a difference in protein disappearance in the hindgut. By comparing apparent ileal protein digestibility in growing pigs to apparent fecal protein digestibility in growing pigs and sows, Shi and Noblet (1993) calculated that hindgut crude protein digestibility in sows is 49.6%, but only 15.2% in growing pigs. In the present experiment, apparent ileal protein digestibility was measured in sows as well as in growing pigs. This allowed us to make a direct comparison between the two groups of animals. We obtained results similar to those reported by Shi and Noblet (1993), thus confirming the findings of those authors.

Table 10. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for canola meal by growing pigs and gestating sows and lactating sows[a]

Item	Growing pigs (n = 6) Mean ± SE[b]	Gestating sows (n = 6) Mean ± SE[c]	Lactating sows (n = 5) Mean ± SE[d]
Crude protein	58.38 ± 2.9[ef]	52.2 ± 2.9[e]	61.32 ± 3.2[f]
Indispensable amino acid			
Arginine	79.6 ± 1.4[e]	74.8 ± 1.4[f]	80.7 ± 1.5[e]
Histidine	80.1 ± 1.5[ef]	78.7 ± 1.5[e]	83.4 ± 1.6[f]
Isoleucine	68.0 ± 1.8[e]	70.6 ± 1.6[ef]	75.7 ± 1.9[f]
Lysine	74.3 ± 1.8	76.7 ± 1.8	79.3 ± 2.0
Leucine	71.7 ± 1.6[e]	72.9 ± 1.8[e]	78.3 ± 1.7[f]
Methionine	78.8 ± 1.4[e]	80.4 ± 1.3[ef]	84.0 ± 1.5[f]
Phenylalanine	72.2 ± 1.4[e]	73.1 ± 1.4[e]	78.2 ± 1.5[f]
Threonine	63.3 ± 2.5	63.1 ± 2.1	70.2 ± 2.7
Tryptophan	74.1 ± 2.3[e]	71.3 ± 1.9[e]	82.1 ± 2.5[f]
Valine	67.2 ± 1.9[e]	67.6 ± 1.7[e]	74.8 ± 2.0[f]
Mean	72.9 ± 1.5[e]	72.9 ± 1.5[e]	78.7 ± 1.7[f]
Dispensable amino acid			
Alanine	63.4 ± 2.3[e]	64.2 ± 2.2[ef]	71.0 ± 2.5[f]
Aspartate	65.8 ± 2.5[ef]	63.5 ± 2.3[e]	71.8 ± 2.8[f]
Cysteine	69.1 ± 2.8	70.0 ± 2.1	74.8 ± 3.0
Glutamate	74.1 ± 1.8[ef]	71.8 ± 1.8[e]	79.2 ± 2.0[f]
Glycine	56.5 ± 3.8[f]	41.8 ± 3.5[e]	56.2 ± 4.1[f]
Proline	57.0 ± 6.1	49.3 ± 13.8	50.2 ± 7.8
Serine	67.8 ± 1.9[ef]	64.6 ± 1.7[e]	71.7 ± 2.1[f]
Tyrosine	68.8 ± 1.7[e]	70.4 ± 1.7[ef]	75.2 ± 1.8[f]
Mean	65.5 ± 2.0	63.0 ± 4.9	70.6 ± 2.6

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of gestating sows and growing pigs.
[d]Standard error associated with the comparison of lactating sows and growing pigs.
[e,f]Means within a row lacking a common superscript differ ($P < .05$).

The difference in hindgut protein digestibility can be attributed to more microbial fermentation in sows than in growing pigs and to the absorption of fermentation products (Rérat, 1978). Nitrogen absorbed from the large intestine is mainly in the form of ammonia, amines, and amides, which are excreted as urinary urea, and thus are of no benefit to the host animal (Rérat, 1978; Just et al., 1981; Darragh et al., 1994). Total hindgut protein digestibility has been reported at 10 to 20% in growing pigs (Poppe et al., 1983; Shi and Noblet, 1993). The results from the present experiment are in good agreement with these values.

Apparent Ileal Amino Acid Digestibilities

In general, the apparent ileal digestibility values observed in growing pigs are within the wide range of published values for the feedstuffs that were examined (Sauer and Ozimek, 1986; Southern, 1991; Tanksley and Knabe, 1993; Jondreville et al., 1995).

Using the direct method for estimating apparent ileal amino acid digestibilities in cereal grains often results in diets with amino acid contents that are below the animal's requirement for maximal productivity. Feeding such diets for a prolonged period of time may lead to impaired physiological functions (D'Mello, 1994). We attempted to prevent this by adding synthetic amino acids to the diets, assuming that all synthetic amino acids were absorbed prior to the end of the distal ileum (Chung and Baker, 1992; Butts et al., 1993a). The fact that the estimates for apparent ileal amino acid digestibilities in growing pigs obtained in this experiment generally compare favorably with those previously reported gives support to this assumption.

The values for amino acid digestibilities in rapeseed meal obtained for growing pigs and reported by Jondreville et al. (1995) are somewhat lower than the values we obtained for canola meal for growing pigs.

Table 11. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for meat and bone meal by growing pigs and gestating and lactating sows[a]

Item	Growing pigs (n = 6) Mean ± SE[b]	Gestating sows (n = 5) Mean ± SE[c]	Lactating sows (n = 5) Mean ± SE[d]
Crude protein	68.9 ± 2.9	69.5 ± 3.1	72.2 ± 3.2
Indispensable amino acid			
Arginine	83.4 ± 1.4	84.5 ± 1.5	85.6 ± 1.5
Histidine	76.2 ± 1.5	76.3 ± 1.6	78.4 ± 1.6
Isoleucine	69.5 ± 1.8	74.2 ± 1.8	72.1 ± 1.9
Leucine	73.6 ± 1.6	77.1 ± 1.9	75.6 ± 1.7
Lysine	74.1 ± 1.8[e]	77.2 ± 1.9[ef]	79.7 ± 2.0[f]
Methionine	75.7 ± 1.4[e]	79.6 ± 1.4[f]	80.5 ± 1.5[f]
Phenylalanine	74.1 ± 1.4	77.5 ± 1.5	76.1 ± 1.5
Threonine	65.5 ± 2.5	67.8 ± 2.3	69.4 ± 2.7
Tryptophan	61.6 ± 2.3[e]	63.7 ± 2.1[e]	71.6 ± 2.5[f]
Valine	70.6 ± 1.9	73.2 ± 1.8	73.8 ± 2.0
Mean	72.7 ± 1.6	75.1 ± 1.6	76.3 ± 1.7
Dispensable amino acid			
Alanine	76.1 ± 2.3	79.3 ± 2.4	81.8 ± 2.5
Aspartate	58.8 ± 2.5	58.8 ± 2.3	61.8 ± 2.8
Cysteine	35.4 ± 2.8[e]	41.9 ± 2.3[f]	40.8 ± 3.0[ef]
Glutamate	73.5 ± 1.8	76.2 ± 2.0	76.4 ± 2.0
Glycine	76.7 ± 3.8	77.2 ± 3.8	81.1 ± 4.1
Proline	62.8 ± 5.5[ef]	50.6 ± 6.2[e]	70.9 ± 6.1[f]
Serine	71.3 ± 1.9	72.7 ± 1.8	72.3 ± 2.1
Tyrosine	72.0 ± 1.7	74.7 ± 1.8	75.7 ± 1.8
Mean	65.8 ± 1.9	66.5 ± 2.2	70.1 ± 2.0

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of gestating sows and growing pigs.
[d]Standard error associated with the comparison of lactating sows and growing pigs.
[e,f]Means within a row lacking a common superscript differ ($P < .05$).

However, our values are close to those reported by Sauer et al. (1982a) and Green and Kiener (1989). Significant differences in apparent ileal amino acid digestibilities in canola meal between different varieties have been documented (Fan et al., 1996) and may explain these differences.

There is some variation in the digestibility values reported for meat and bone meal. Our values for digestibilities of most amino acids in growing pigs were considerably higher than those reported in several other experiments (Sauer and Ozimek, 1986; Southern, 1991; Tanksley and Knabe, 1993) but very close to those reported by Jondreville et al. (1995) and somewhat lower than the values obtained by Donkoh et al. (1994a). Digestibility values for meat and bone meal have been shown to vary according to the choice of raw materials and the method of processing (Donkoh et al., 1994b; Bellaver et al., 1997). The relatively high digestibilities obtained in this experiment compared to most other studies indicate that the meat and bone meal used in the present experiment was of high quality.

Table 12. Apparent ileal digestibility coefficients (%) of crude protein and amino acids for corn, barley, wheat, soybean meal, canola, and meat and bone meal by pigs and sows[a]

Item	Growing pigs (n = 34) Mean ± SE[b]	Gestating sows (n = 34) Mean ± SE[c]	Lactating sows (n = 33) Mean ± SE[d]
Crude protein	64.9 ± 1.2	66.6 ± 1.4	67.2 ± 1.3
Indispensable amino acid			
Arginine	81.6 ± .7	81.9 ± .9	82.0 ± .7
Histidine	79.5 ± .6[e]	80.4 ± .8[ef]	81.6 ± .6[f]
Isoleucine	72.8 ± .8[e]	76.1 ± .7[f]	76.0 ± .8[f]
Leucine	76.1 ± .7[e]	78.5 ± .8[f]	79.3 ± .7[f]
Lysine	73.1 ± 1.0[e]	75.0 ± .9[ef]	76.1 ± 1.0[f]
Methionine	79.1 ± .7[e]	81.9 ± .6[f]	82.0 ± .7[f]
Phenylalanine	76.7 ± .6[e]	79.5 ± .7[f]	79.7 ± .6[f]
Threonine	65.3 ± 1.1[e]	66.5 ± .9[ef]	69.2 ± 1.1[f]
Tryptophan	71.2 ± 1.0[e]	72.1 ± 1.0[e]	79.9 ± 1.0[f]
Valine	72.1 ± .8[e]	74.5 ± .9[f]	76.1 ± .8[f]
Mean	74.8 ± .7[e]	76.6 ± .2[f]	78.2 ± .7[f]
Dispensable amino acid			
Alanine	69.0 ± 1.0[e]	71.0 ± 1.0[ef]	72.7 ± 1.0[f]
Aspartate	68.1 ± 1.2	67.6 ± 1.0	69.6 ± 1.2
Cysteine	64.4 ± 1.2[e]	68.0 ± .9[f]	69.0 ± 1.3[f]
Glutamate	77.9 ± .9[e]	81.4 ± .8[f]	81.2 ± .9[f]
Glycine	61.1 ± 1.7	61.1 ± 2.3	59.6 ± 1.7
Proline	68.5 ± 2.6[e]	64.8 ± 3.5[ef]	59.4 ± 3.1[f]
Serine	72.4 ± .9[e]	73.0 ± .7[ef]	74.7 ± .9[f]
Tyrosine	72.8 ± .7[e]	75.1 ± .7[f]	76.8 ± .7[f]
Mean	69.3 ± .9	71.3 ± 1.2	71.8 ± 1.0

[a](100 − [(CP or amino acids in digesta/CP or amino acids in feed) × (chromium in feed/chromium in digesta)]) × 100%.
[b]Standard error associated with the comparison of growing pigs and lactating sows.
[c]Standard error associated with the comparison of gestating sows and growing pigs.
[d]Standard error associated with the comparison of lactating sows and growing pigs.
[e,f]Within a row, means lacking a common superscript differ ($P < .05$).

Table 13. Interactions between the physiological state of the animals and the digestibility coefficients of diets[a]

Item	Growing pigs vs lactating sows (n = 34)	Growing pigs vs gestating sows (n = 34)	Lactating sows vs. gestating sows (n = 33)
Crude protein	NS	NS	**
Indispensable amino acids			
Arginine	NS	*	**
Histidine	NS	*	*
Isoleucine	NS	*	*
Leucine	NS	*	*
Lysine	NS	NS	*
Methionine	NS	*	**
Phenylalanine	NS	*	*
Threonine	NS	NS	NS
Tryptophan	NS	*	NS
Valine	NS	*	*
Mean	NS	*	*
Dispensable amino acids			
Alanine	NS	*	*
Aspartate	NS	NS	**
Cysteine	NS	NS	NS
Glutamate	NS	***	***
Glycine	*	**	***
Proline	*	*	***
Serine	NS	*	NS
Tyrosine	NS	**	*
Mean	NS	**	*

[a]NS = Nonsignificant; *$P < .05$; **$P < .01$; ***$P < .005$.

Results of this experiment suggest that lactating sows, and to a lesser extent gestating sows, have a higher apparent ileal digestibility coefficient for most amino acids than growing pigs. These results are supported by data from other experiments in our laboratory in which apparent ileal amino acid digestibilities by sows and growing pigs fed corn-soybean meal diets were compared (Stein, 1998).

The reason for the higher apparent amino acid digestibilities by sows is not known at present. Elevated secretions of digestive enzymes and, thus, a more efficient digestion of dietary proteins, more efficient amino acid transport from the gut lumen into the enterocytes, or a longer transit time because of a longer digestive tract may be possible explanations, albeit this is purely speculative at this time. It is also possible that amino acids of endogenous origin are lost at different rates at the terminal ileum. Lactating sows given ad libitum access to a nitrogen-free diet had somewhat lower losses of endogenous amino acids per kilogram of DMI than growing pigs (Stein and Easter, 1997). If this is also true for protein-containing diets, the reason for the observed differences in ileal apparent digestibilities may at least partly be explained by this difference in endogenous losses. A reduced loss of endogenous amino acids at the distal ileum would result in higher estimates of apparent ileal digestibilities, even if true digestibilities were the same.

An alternative explanation for the higher digestibility coefficients for lactating sows could be differences in microbial fermentation in the small intestine. Bacterial nitrogen accounted for a substantial part of the nitrogen found in digesta from growing pigs (Wűnsche et al., 1991; Rowan et al., 1992). In the present experiment, the amount of bacterial nitrogen in digesta was not determined; however, it could be speculated that more microbes are present in the small intestine of sows than in the small intestine of growing pigs. If this assumption is correct, it might also influence the apparent ileal digestibility of amino acids, thus explaining the differences between sows and growing pigs observed in the present experiment.

It is unclear why gestating sows have lower digestibilities than lactating sows. If a physiological mechanism was responsible for the improved digestibility in lactating animals, the same mechanism does not seem to be present in gestating animals. However, on several occasions endogenous losses were elevated in animals restricted in their feed allowance (Fuller and Cadenhead, 1991; Butts et al., 1993b; Stein and Easter, 1997). Because gestating sows were restricted to only 2 kg feed/d in this experiment, higher endogenous losses per kilogram of feed at the distal ileum would be expected, as compared to the pigs and lactating sows permitted free access to feed. Higher endogenous losses would in turn lead to a lower estimate for the apparent ileal digestibility. The fact that we did not detect a decreased apparent digestibility for gestating sows compared to growing pigs indicates that the true digestibility was, indeed, higher in the sows, but due to higher endogenous losses, the calculated apparent ileal digestibility remained almost constant. Feeding level did not influence apparent ileal amino acid digestibilities in growing pigs (Sauer et al., 1982b; Haydon et al., 1984; van Leuwen et al., 1987), which is in good agreement with our observations on growing pigs and gestating sows.

The lack of significant interactions between animals and diets when comparing growing pigs and lactating sows indicates that the difference between these two groups of animals is constant. If that is true, the digestibility coefficients for one group can be calculated from the results obtained for the other group. However, further research is needed to verify this hypothesis. The significant interactions between growing pigs and gestating sows and between lactating sows and gestating sows were expected, because the digestibility coefficients for most amino acids were not significantly different between these groups.

Implications

Inaccuracies may be associated with extrapolating estimates for apparent ileal digestibilities from growing pigs to lactating sows and, to a lesser degree, to gestating sows. Therefore, amino acid digestibilities obtained from sows should be used in feed formulation and in factorial calculations aimed at modeling amino acid metabolism in sows.

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