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Digestibility of amino acids in corn, corn coproducts, and bakery meal fed to growing pigs[1]

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ABSTRACT: The objectives of this experiment were to determine the apparent ileal digestibility and the standardized ileal digestibility (SID) of CP and AA in bakery meal, corn gluten meal, corn gluten feed, corn germ meal, and hominy feed and to compare these values with the apparent ileal digestibility and SID of CP and AA in corn and distillers dried grains with solubles (DDGS). Eight growing barrows (initial BW: 82.5 ± 5.5 kg) were randomly allotted to an 8 × 8 Latin square design with 8 diets and 8 periods. Diets contained corn, DDGS, bakery meal, corn gluten meal, corn gluten feed, corn germ meal, or hominy feed as the sole source of protein and AA. An N-free diet was used to measure basal endogenous losses of AA and protein. Pigs were fed experimental diets for eight 7-d periods, with ileal digesta being collected on d 6 and 7 of each period. Results indicated that the SID of Lys in corn gluten meal (78.7%) was greater ($P < 0.01$) than in DDGS, bakery meal, corn germ meal, and hominy feed (46.0, 48.4, 68.4, and 58.8%, respectively). The SID of all indispensable AA except Arg, Leu, and Met in bakery meal were not different from those in DDGS. The SID of Arg, His, Leu, and Met in corn gluten feed were less ($P < 0.01$) than in corn, but the SID of all other indispensable AA in corn gluten feed were not different from those in corn. However, for most indispensable AA, the SID in corn gluten feed was not different from the SID in DDGS. The SID of all indispensable AA in corn germ meal, except Arg, His, Leu, and Met, were not different from the SID in corn. Likewise, the SID of all indispensable AA in corn germ meal, except Arg and Leu, were not different from those in DDGS. The SID of Ile, Met, Phe, and Val in hominy feed were less ($P < 0.01$) than in corn, but the SID of the remaining indispensable AA in hominy feed were not different from the SID of indispensable AA in corn. All indispensable AA in hominy feed also had SID values that were not different from the SID values of AA in DDGS, except for Arg and Lys, which had greater ($P < 0.01$) SID than in DDGS. In conclusion, bakery meal had SID values of most AA that were less than in corn, but corn gluten meal had SID values for most AA that were greater than the SID of AA in corn, bakery meal, and corn coproducts.

Key words: amino acid digestibility, bakery meal, corn germ meal, corn gluten feed, corn gluten meal, hominy feed

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INTRODUCTION

Many coproducts from the corn milling and fermentation industries or from other industries, such as the baking and cereal industries, are often used in diets fed to swine. The apparent ileal digestibility (**AID**) and the standardized ileal digestibility (**SID**) of CP and AA in distillers dried grains with solubles (**DDGS**) have been reported (Stein et al., 2006, 2009; Pahm et al., 2008a; Urriola et al., 2009). Other coproducts from the corn milling industry include hominy feed, corn gluten meal, corn gluten feed, and corn germ meal, but in contrast to DDGS, very little research has been conducted to determine the AID and SID of CP and AA in these ingredients when fed to pigs. Hominy feed is a coproduct from the dry milling industry when corn grits are produced. Corn gluten meal, corn gluten feed, and corn germ meal are coproducts from the wet milling industry. In this process, corn is cleaned and steeped, and then it may undergo germ extraction, resulting in the production of corn oil for human consumption and corn germ meal for animal feed (Archer Daniels Midland, 2008). The cleaned and steeped corn may also undergo

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milling and washing to obtain bran and a bran-free product. The bran is further processed into corn gluten feed and is used for animal feeding. The bran-free product undergoes centrifugation to separate the gluten and starch. The gluten portion is processed into corn gluten meal and sold as animal feed. Bakery meal is produced by mixing, grinding, and drying a combination of available commodities, such as wheat products, pasta, potato chip waste, cakes, and breakfast cereals (Pork Checkoff, 2008). The objectives of this experiment were to determine the AID and SID of CP and AA in corn gluten meal, corn gluten feed, corn germ meal, hominy feed, and bakery meal fed to growing pigs and to compare these values with the AID and SID of CP and AA in DDGS and corn.

MATERIALS AND METHODS

The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois.

Animals, Housing, and Experimental Design

Eight growing barrows (initial BW: 82.5 ± 5.5 kg; G-Performer boars × F-25 females, Genetiporc, Alexandria, MN) were randomly allotted to an 8 × 8 Latin square design with 8 diets and 8 periods. Pigs were equipped with a T-cannula in the distal ileum by using procedures adapted from Stein et al. (1998) and were housed in individual pens (1.2 × 1.5 m) in a temperature-controlled room that was equipped with forced-air fans and a propane heater. The pens had fully slatted tri-bar floors and solid-sided pen walls. A feeder and a nipple drinker were installed in each pen.

Ingredients, Diets, and Feeding

A locally grown commercial hybrid of yellow dent corn was obtained from the University of Illinois Feed Mill, Champaign, IL (Table 1). The DDGS (Big Rivers Resources, West Burlington, IA), hominy feed (Agricor Inc., Marion, IN), bakery meal (Custom Trading & Blending, Terre Haute, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources.

Eight diets were prepared (Tables 2 and 3). Seven of the diets contained corn, DDGS, hominy feed, corn gluten meal, corn gluten feed, corn germ meal, or bakery meal as the sole source of protein and AA. An N-free diet that was used to measure basal endogenous losses of CP and AA was also formulated. Vitamins and minerals were included in all diets to meet or exceed current requirement estimates (NRC, 1998). All diets also contained 0.4% Cr_2O_3 as an indigestible marker.

Table 1. Analyzed nutrient composition of ingredients (as-fed basis)[1]

Item, %	Corn	DDGS	Bakery meal	Corn gluten meal	Corn gluten feed	Corn germ meal	Hominy feed
CP	6.68	25.43	11.30	62.88	23.00	24.76	8.71
DM	84.11	87.55	86.99	91.03	85.87	89.41	87.62
ADF	2.00	10.02	6.28	5.23	7.68	11.30	3.36
NDF	8.53	35.20	17.52	10.45	30.88	49.29	15.05
Starch	67.29	4.56	40.50	6.68	9.77	15.93	59.52
Ca	0.02	0.18	0.14	0.01	0.11	0.28	0.01
P	0.22	0.80	0.34	0.60	0.90	0.86	0.36
Indispensable AA							
Arg	0.33	1.13	0.46	2.26	0.95	1.55	0.47
His	0.19	0.67	0.27	1.31	0.61	0.64	0.24
Ile	0.23	0.92	0.39	2.60	0.79	0.84	0.30
Leu	0.76	2.75	1.10	10.09	1.86	1.86	0.91
Lys	0.22	0.75	0.27	1.18	1.02	0.94	0.33
Met	0.14	0.48	0.18	1.61	0.32	0.40	0.15
Phe	0.31	1.24	0.52	4.03	0.87	1.04	0.41
Thr	0.24	0.97	0.36	2.03	1.21	0.83	0.30
Trp	0.04	0.19	0.10	0.44	0.16	0.18	0.06
Val	0.32	1.33	0.52	2.89	1.12	1.30	0.42
Dispensable AA							
Ala	0.47	1.62	0.65	5.30	1.48	1.38	0.60
Asp	0.44	1.60	0.65	3.85	1.44	1.68	0.60
Cys	0.15	0.50	0.22	1.14	0.43	0.33	0.17
Glu	1.13	3.04	2.01	12.04	2.70	2.84	1.35
Gly	0.27	0.99	0.43	1.84	1.03	1.23	0.37
Pro	0.31	1.75	0.88	5.68	1.61	1.09	0.61
Ser	0.30	1.07	0.43	2.54	0.73	0.80	0.35
Tyr	0.21	0.91	0.36	3.27	0.64	0.67	0.27

[1]Distillers dried grains with solubles (DDGS; Big Rivers Resources, West Burlington, IA), bakery meal (Custom Trading & Blending, Terre Haute, IN), hominy feed (Agricor Inc., Marion, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources, and corn was obtained from the University of Illinois Feed Mill (Champaign, IL).

Table 2. Ingredient composition of experimental diets[1]

Item, %	Corn	DDGS	Bakery meal	Corn gluten meal	Corn gluten feed	Corn germ meal	Hominy feed	N-free
Ground corn	95.38	—	—	—	—	—	—	—
Bakery meal	—	—	97.45	—	—	—	—	—
Corn coproduct	—	50.00	—	40.00	50.00	60.00	88.45	—
Cornstarch	—	32.94	—	38.33	28.27	18.38	—	67.71
Soybean oil	2.00	—	—	4.00	4.00	4.00	4.00	4.00
Sugar	—	15.00	—	15.00	15.00	15.00	5.00	20.00
Solka Floc[2]	—	—	—	—	—	—	—	5.00
Ground limestone	0.66	0.96	0.60	0.65	0.69	0.72	0.65	0.61
Dicalcium phosphate	0.87	—	0.85	0.92	0.94	0.80	0.80	1.08
Magnesium oxide	—	—	—	—	—	—	—	0.10
Potassium carbonate	—	—	—	—	—	—	—	0.40
Chromic oxide	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sodium chloride	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin-mineral premix[3]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1]Distillers dried grains with solubles (DDGS; Big Rivers Resources, West Burlington, IA), bakery meal (Custom Trading & Blending, Terre Haute, IN), hominy feed (Agricor Inc., Marion, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources, and corn was obtained from the University of Illinois Feed Mill (Champaign, IL).

[2]Fiber Sales and Development Corp. (Urbana, OH).

[3]The vitamin-mineral premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2,204 IU; vitamin E as DL-α-tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamine as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide, 1.0 mg, and nicotinic acid, 43.0 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

Feed was provided to the pigs at a daily rate of 3 times the estimated energy requirement for maintenance (i.e., 106 kcal of ME/kg$^{0.75}$; NRC, 1998) in 2 equal meals at 0700 and 1600 h. Water was available at all times throughout the experiment.

Data Recording and Sample Collection

Pig BW were recorded at the beginning and at the end of each period, and the amount of feed supplied each day was recorded. The initial 5 d of each period

Table 3. Analyzed nutrient composition of experimental diets (as-fed basis)[1]

Item	Corn	DDGS	Bakery meal	Corn gluten meal	Corn gluten feed	Corn germ meal	Hominy feed	N-free
CP, %	6.43	12.72	11.03	26.99	11.17	14.89	7.57	0.37
DM, %	82.78	90.42	86.76	92.32	89.81	91.24	88.36	93.14
Indispensable AA, %								
Arg	0.31	0.56	0.44	0.92	0.47	1.03	0.42	0.01
His	0.18	0.33	0.26	0.54	0.30	0.43	0.22	0.01
Ile	0.24	0.47	0.39	1.08	0.39	0.57	0.26	0.02
Leu	0.72	1.35	1.04	4.17	0.93	1.17	0.81	0.03
Lys	0.20	0.36	0.27	0.49	0.50	0.62	0.29	0.01
Met	0.12	0.23	0.16	0.64	0.15	0.24	0.13	0.00
Phe	0.32	0.58	0.50	1.62	0.42	0.70	0.35	0.02
Thr	0.22	0.46	0.34	0.84	0.60	0.55	0.27	0.01
Trp	0.04	0.12	0.11	0.17	0.11	0.17	0.05	0.04
Val	0.33	0.65	0.52	1.22	0.56	0.89	0.39	0.02
Dispensable AA, %								
Ala	0.43	0.84	0.62	2.22	0.76	0.92	0.53	0.02
Asp	0.39	0.84	0.63	1.60	0.73	1.11	0.54	0.02
Cys	0.13	0.24	0.20	0.47	0.20	0.21	0.16	0.00
Glu	1.07	1.83	2.02	5.19	1.54	1.93	1.23	0.04
Gly	0.25	0.52	0.42	0.78	0.52	0.82	0.33	0.01
Pro	0.49	0.93	0.85	2.31	0.80	0.70	0.53	0.02
Ser	0.26	0.49	0.39	1.11	0.39	0.56	0.32	0.01
Tyr	0.24	0.41	0.35	1.18	0.31	0.45	0.26	0.01

[1]Distillers dried grains with solubles (DDGS; Big Rivers Resources, West Burlington, IA), bakery meal (Custom Trading & Blending, Terre Haute, IN), hominy feed (Agricor Inc., Marion, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources, and corn was obtained from the University of Illinois Feed Mill (Champaign, IL).

was considered a period of adaptation to the diet. Ileal digesta were collected from 0730 to 1530 h on d 6 and 7 by attaching a plastic bag to the opened cannula barrel by using an autolocking cable tie (Stein et al., 1998). Bags were removed whenever they were filled with digesta or every 30 min, and were stored at −20°C to prevent bacterial degradation of the AA in the digesta. At the conclusion of each experimental period, pigs were deprived of feed overnight, and the following morning, a new experimental diet was offered.

Chemical Analysis

At the conclusion of each period, ileal samples were thawed and mixed within animal and diet, and a subsample was collected for chemical analysis. A sample of each ingredient and of each diet was collected at the time of diet mixing. Digesta samples were lyophilized and finely ground before chemical analysis. All samples of ingredients, diets, and ileal digesta were analyzed for DM (method 930.15; AOAC Int., 2007), Cr (method 990.08; AOAC Int., 2007), CP (method 990.03; AOAC Int., 2007), and AA [method 982.30 E (a, b, c); AOAC Int., 2007].

Calculations and Statistical Analysis

The AID of CP and AA in the 7 diets containing 1 of the protein sources were calculated. Because corn, coproducts, and bakery meal were the only feed ingredients contributing CP and AA in each of the diets, these digestibility values also represented the digestibility values for each of the ingredients. The basal endogenous losses of CP and each AA were determined based on the flow to the distal ileum obtained after feeding the N-free diet, and by correcting the AID of CP and each AA for the basal endogenous loss, values for SID were calculated. Calculations were completed for each pig in each period by using the analyzed Cr and AA of each diet and ileal sample. In all calculations, previously published equations were used (Stein et al., 2007).

Data were analyzed using the PROC MIXED procedure (SAS Inst. Inc., Cary, NC). An ANOVA was conducted, and the model included diet as a fixed effect. Pig and period were included as random effects. Mean values for each diet were calculated using the LSMeans statement, and if significant differences were detected, treatment means were separated using the pdiff option in PROC MIXED. The pig was the experimental unit for all analyses and an α-value of 0.05 was used to assess significance among means.

RESULTS

All pigs stayed healthy throughout the experiment and readily consumed their diets. The AID for CP in corn gluten meal was greater ($P < 0.01$) than the AID for CP in all other ingredients used in this experiment (Table 4). The AID of CP in hominy feed was less ($P < 0.01$) than the SID of CP in corn and corn germ meal, but was not different from those in DDGS, bakery meal, and corn gluten feed.

The AID for all indispensable AA in bakery meal were less ($P < 0.01$) than in corn gluten meal, which had the greatest AID of indispensible AA among all ingredients. For Lys, the AID in corn gluten meal (73.6%) was greater ($P < 0.01$) than in both corn and DDGS, whereas the AID in corn gluten feed (64.0%) and corn germ meal (64.4%) were greater ($P < 0.01$) than in DDGS (39.2%), but not different from corn (58.0%). The mean AID for indispensable AA were greater ($P < 0.01$) in corn gluten meal (86.0%) than in all other ingredients. The mean AID for indispensable AA in corn gluten feed (72.0%), corn germ meal (74.1%), hominy feed (68.7%), and bakery meal (71.3%) were not different from the mean AID in corn and DDGS (74.5 and 70.8%, respectively).

The SID of CP in corn and corn gluten meal (89.1 and 85.5%, respectively) were greater ($P < 0.01$) than the SID of CP in all other ingredients (Table 5). The SID of CP in bakery meal (72.5%), corn germ meal (69.5%), and hominy feed (74.8%) were less ($P < 0.01$) than the SID of CP in corn, but was not different from the SID of CP in DDGS. The SID of Lys in corn gluten meal (78.7%) was greater ($P < 0.01$) than the SID of Lys in DDGS, bakery meal, corn germ meal, and hominy feed (46.0, 48.4, 68.4, and 58.8%, respectively). For all other indispensable AA except Trp, SID values in bakery meal were less ($P < 0.01$) than in corn. The SID of all indispensable AA except Arg, Leu, and Met in bakery meal were not different from the SID of AA in DDGS. For corn gluten feed, the SID of all indispensable AA were not different from those in corn, except for Arg, His, Leu, and Met, which had SID values that were less ($P < 0.01$) than in corn. However, for most indispensable AA, the SID in corn gluten feed was not different from the SID in DDGS. The SID of all indispensable AA in corn germ meal, except Arg, His, Leu, and Met, were not different from those in corn. Likewise, the SID of all indispensable AA in corn germ meal, except Arg, Leu, and Lys, were not different from the SID of AA in DDGS. For most of the indispensable AA in hominy feed, the SID values were not different from those in corn, with the exception of Ile, Met, Phe, and Val, which were less ($P < 0.01$) than in corn. All indispensable AA in hominy feed had SID values that were not different from the SID values of AA in DDGS, except for Arg and Lys, which were greater ($P < 0.01$) than in DDGS.

DISCUSSION

The corn coproducts used in this experiment were obtained from different manufacturing facilities and likely originated from different hybrids of corn grain. Some of the differences in AA digestibility among the

Table 4. Apparent ileal digestibility (AID)[1] of AA in corn, corn coproducts, and bakery meal fed to growing pigs[2]

Item	Corn	DDGS	Bakery meal	Corn gluten meal	Corn gluten feed	Corn germ meal	Hominy feed	SEM	*P*-value
CP, %	59.0[b]	53.8[bc]	54.1[bc]	77.5[a]	52.1[bc]	55.2[b]	47.5[c]	2.4	<0.01
Indispensable AA, %									
Arg	74.1[c]	65.5[d]	72.3[c]	83.9[a]	71.7[c]	81.1[ab]	75.8[bc]	1.8	<0.01
His	74.9[ab]	70.3[bc]	66.1[c]	79.6[a]	70.2[bc]	73.5[b]	72.1[bc]	2.0	<0.01
Ile	72.1[b]	69.7[bc]	65.4[cd]	84.2[a]	70.7[bc]	72.6[b]	62.2[d]	2.1	<0.01
Leu	83.3[b]	82.1[b]	74.8[c]	90.4[a]	78.2[bc]	76.6[c]	79.3[bc]	1.7	<0.01
Lys	58.0[bc]	39.2[d]	39.7[d]	73.6[a]	64.0[ab]	64.4[ab]	50.6[cd]	3.6	<0.01
Met	82.3[b]	79.3[bc]	73.5[d]	89.9[a]	75.3[cd]	78.6[bc]	73.1[d]	1.7	<0.01
Phe	79.6[b]	77.2[bc]	73.4[c]	88.0[a]	75.9[bc]	78.8[b]	73.0[c]	1.8	<0.01
Thr	57.8[cde]	60.6[bcd]	50.6[e]	78.6[a]	68.4[b]	63.8[bc]	51.0[de]	2.9	<0.01
Trp	64.9[c]	75.6[b]	75.9[b]	86.8[a]	80.0[b]	76.5[b]	66.2[c]	1.9	<0.01
Val	70.3[bc]	68.4[bcd]	63.3[d]	81.9[a]	68.7[bcd]	72.0[b]	62.8[cd]	2.2	<0.01
Mean	74.5[b]	70.8[b]	71.3[b]	86.0[a]	72.0[b]	74.1[b]	68.7[b]	2.3	<0.01
Dispensable AA, %									
Ala	72.9[b]	70.1[b]	63.0[c]	84.9[a]	69.5[b]	68.7[bc]	67.4[bc]	2.3	<0.01
Asp	62.7[b]	60.7[b]	52.8[c]	79.2[a]	58.0[bc]	60.8[b]	57.6[bc]	2.6	<0.01
Cys	69.8[b]	67.6[bc]	62.3[cd]	78.0[a]	58.3[d]	57.4[d]	67.6[bc]	2.3	<0.01
Glu	81.2[ab]	77.6[bc]	78.2[bc]	86.1[a]	72.1[d]	73.8[cd]	76.9[bcd]	1.6	<0.01
Gly	30.9	24.6	41.0	39.2	36.4	42.9	35.3	5.8	0.27
Pro	6.4[ab]	−20.6[bc]	45.8[a]	53.2[a]	7.3[ab]	−44.5[c]	6.6[abc]	17.0	<0.01
Ser	70.6[b]	68.5[b]	65.5[b]	86.0[a]	66.6[b]	67.7[b]	69.9[b]	2.1	<0.01
Tyr	77.6[b]	76.5[bc]	71.8[c]	88.0[a]	74.9[bc]	75.2[bc]	70.7[c]	1.8	<0.01
Mean	61.7[bc]	53.6[c]	68.1[b]	77.5[a]	55.5[c]	53.9[c]	58.5[bc]	3.7	<0.01

[a–e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]AID = 1 − (CP or AA in digesta/CP or AA in feed) × (Cr in feed/Cr in digesta) × 100%.

[2]Distillers dried grains with solubles (DDGS; Big Rivers Resources, West Burlington, IA), bakery meal (Custom Trading & Blending, Terre Haute, IN), hominy feed (Agricor Inc., Marion, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources, and corn was obtained from the University of Illinois Feed Mill (Champaign, IL).

coproducts may, therefore, be related to the growing conditions and genetic background of the corn grain that was used in the manufacturing of the products.

The AA concentrations in corn, DDGS, bakery meal, corn gluten meal, corn gluten feed, corn germ meal, and hominy feed were close to expected values (NRC, 1998; Sauvant et al., 2004; Slominski et al., 2004; Stein and Shurson, 2009), with the exception that the concentrations of Lys in corn gluten feed and corn germ meal were greater than reported previously. In contrast, hominy feed contained less CP than reported previously (Sauvant et al., 2004).

The AID values for Pro in DDGS and corn germ meal were negative and the AID values for Pro in corn, corn gluten feed, and hominy feed were very low. In contrast, SID values for Pro for several ingredients were greater than 100%. The possible reason for these observations is that estimates for digestibility and endogenous losses of Pro often are inaccurate when pigs are fed diets that are inadequate in indispensable AA (Stein et al., 2007). It has also been reported that restrictively fed animals have greater endogenous losses of Pro than do animals provided feed on an ad libitum basis (Stein et al., 1999), which may further explain the greater values for endogenous losses of Pro that were observed in this experiment.

A substantial database exists on the digestibility of AA in DDGS (Fastinger and Mahan, 2006; Stein et al., 2006, 2009; Pahm et al., 2008a; Urriola et al., 2009), but very little or no research has been conducted in North America to determine the AID and SID of AA in bakery meal, corn gluten meal, corn gluten feed, corn germ meal, and hominy feed. The values for AID and SID of AA in corn that were determined in this experiment agree with previous reports (Stein et al., 2006; Pedersen et al., 2007). Likewise, the AID and SID values for all AA in the DDGS that was used in this experiment are within the range of previously reported values for corn DDGS (Stein and Shurson, 2009). The SID of Lys for DDGS was less than the SID of Lys for corn. This observation indicates that the DDGS used in this experiment may have been heat damaged, which is not uncommon for corn DDGS (Fastinger and Mahan, 2006; Pahm et al., 2008b).

The SID for CP in bakery meal was much greater than the value reported by NRC (1998). The SID of all indispensable AA except Arg and Thr, however, were less than the values reported for the SID of AA in bakery meal fed to Peking ducks (Ragland et al., 1999). The reason for these differences between experiments may be that the nutrient composition among different sources of bakery coproducts is relatively variable (Slominski et al., 2004).

For corn gluten meal, the values for the AID and SID of AA that were determined in the present experiment concur with previously published values from North America (NRC, 1998), but they are slightly less than European values (Sauvant et al., 2004) and also less than values reported for the SID of AA in corn gluten meal fed to cecectomized roosters (de Godoy et al.,

Table 5. Standardized ileal digestibility (SID)[1] of AA in corn, corn coproducts, and bakery meal fed to growing pigs[2]

Item	Corn	DDGS	Bakery meal	Corn gluten meal	Corn gluten feed	Corn germ meal	Hominy feed	SEM	P-value
CP, %	89.1[a]	70.5[b]	72.5[b]	85.5[a]	70.9[b]	69.5[b]	74.8[b]	2.5	<0.01
Indispensable AA, %									
Arg	100.1[a]	81.3[d]	91.5[bc]	93.7[bc]	90.4[c]	89.7[c]	96.3[ab]	1.8	<0.01
His	83.7[a]	75.5[cd]	72.5[d]	82.8[ab]	75.9[cd]	77.6[bcd]	79.8[abc]	2.0	<0.01
Ile	80.9[ab]	74.7[bc]	71.0[c]	86.4[a]	76.6[bc]	76.7[bc]	70.8[c]	2.1	<0.01
Leu	88.0[ab]	84.8[bc]	78.2[e]	91.3[a]	82.2[cde]	79.8[de]	83.8[bcd]	1.7	<0.01
Lys	69.2[ab]	46.0[d]	48.4[cd]	78.7[a]	68.8[ab]	68.4[b]	58.8[bc]	3.6	<0.01
Met	86.2[ab]	81.6[bc]	76.5[d]	90.6[a]	78.8[cd]	80.8[cd]	77.0[cd]	1.7	<0.01
Phe	85.9[ab]	81.1[bc]	77.7[c]	89.4[a]	81.2[bc]	82.0[bc]	79.2[c]	1.8	<0.01
Thr	74.9[ab]	69.5[bc]	62.1[c]	83.5[a]	75.2[ab]	71.3[b]	65.8[bc]	2.9	<0.01
Trp	83.9[bc]	82.6[bc]	83.1[bc]	91.8[a]	87.5[ab]	81.4[c]	82.4[bc]	1.9	<0.01
Val	80.1[ab]	73.9[bc]	69.8[c]	84.9[a]	74.9[bc]	76.0[bc]	71.7[c]	2.2	<0.01
Mean	84.9[ab]	76.7[c]	78.5[bc]	88.6[a]	78.7[bc]	78.9[bc]	78.0[bc]	2.3	<0.01
Dispensable AA, %									
Ala	86.6[ab]	77.8[c]	73.0[c]	87.8[a]	77.9[c]	75.8[c]	79.3[bc]	2.3	<0.01
Asp	77.2[ab]	68.1[c]	62.2[c]	83.2[a]	66.4[c]	66.4[c]	68.8[bc]	2.6	<0.01
Cys	79.6[ab]	73.4[bc]	69.0[cd]	81.0[a]	65.2[d]	64.1[d]	76.1[abc]	2.3	<0.01
Glu	87.7[a]	81.8[bc]	81.8[bc]	87.6[a]	77.1[c]	77.8[bc]	82.9[ab]	1.6	<0.01
Gly	107.4[a]	64.8[d]	88.7[bc]	66.5[d]	76.2[cd]	68.6[d]	97.1[ab]	5.8	<0.01
Pro	193.3[a]	86.4[c]	158.2[ab]	97.2[c]	130.9[bc]	98.9[c]	190.2[a]	14.5	<0.01
Ser	85.1[ab]	76.9[cd]	75.6[d]	89.7[a]	77.1[cd]	75.1[d]	82.4[bc]	2.1	<0.01
Tyr	84.8[ab]	81.1[bc]	77.0[c]	89.6[a]	81.0[bc]	79.4[bc]	77.8[c]	1.8	<0.01
Mean	103.3[a]	77.8[d]	94.1[ab]	83.6[bc]	83.5[cd]	76.2[d]	95.6[ab]	3.7	<0.01

[a–e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]SID = apparent ileal digestibility of diet + (endogenous losses/intake) × 100%. Endogenous losses (g/kg of DMI) of CP and AA were as follows: CP, 23.40; Arg, 0.98; His, 0.19; Ile, 0.26; Leu, 0.41; Lys, 0.27; Met, 0.06; Phe, 0.25; Thr, 0.45; Trp, 0.09; Val, 0.39; Ala, 0.71; Asp, 0.68; Cys, 0.15; Glu, 0.84; Gly, 2.31; Pro, 11.01; Ser, 0.45; Tyr, 0.21.

[2]Distillers dried grains with solubles (DDGS; Big Rivers Resources, West Burlington, IA), bakery meal (Custom Trading & Blending, Terre Haute, IN), hominy feed (Agricor Inc., Marion, IN), corn gluten meal, corn gluten feed, and corn germ meal (Archer Daniels Midland, Decatur, IL) were obtained from commercial sources, and corn was obtained from the University of Illinois Feed Mill (Champaign, IL).

2009). Values for the AID of CP and AA obtained for corn gluten meal in the present experiment are also less than values obtained for corn gluten meal by Knabe et al. (1989). Nevertheless, the increased concentration of AA in corn gluten meal and the relatively greater values for the SID of AA that were determined in the present experiment indicate that corn gluten meal is a good source of AA that may be used in diets fed to swine.

The AID and SID values for AA in corn gluten feed were in agreement with previously reported values (NRC, 1998; Sauvant et al., 2004). The digestibility values of CP and AA in corn gluten feed are similar to values determined for corn germ meal. The reason for this similarity may be that corn gluten feed is produced by mixing of fiber, germ cake, and concentrated steep water; therefore, it contains CP and AA in concentrations that are similar to those in corn germ meal (Gulati et al., 1996).

The values for SID of CP and AA in corn germ meal that were calculated in this experiment agree with values determined in cecectomized roosters (de Godoy et al., 2009). The values also agree with data for the SID of AA in European corn germ meal (Sauvant et al., 2004), but they are less than the values reported by Jones (1987). The values that were calculated for the SID of AA in corn germ meal are, however, in good agreement with the average values for the SID of AA in corn DDGS (Stein and Shurson, 2009).

The concentrations of CP and AA in hominy feed were similar to the concentrations in corn, but the AID and SID of several AA in hominy feed were less than those in corn. To our knowledge, this is the first time SID values for AA have been determined in hominy feed in the United States, and we are not aware of any published reports from North America with such information. Values for the SID of AA in hominy feed determined in Europe have, however, been reported (Sauvant et al., 2004), and the SID of most AA obtained in the present experiment are in good agreement with the European values. Hominy feed also has a relatively high concentration of starch and a relatively low concentration of fiber, which makes it an attractive feed ingredient in diets fed to swine.

In conclusion, bakery meal is a poor source of digestible AA when compared with corn and corn coproducts. Corn gluten meal has SID values for most AA that are greater than in DDGS and other corn coproducts, and it may be used as a source of AA in swine diets provided that the diets are balanced for all indispensable AA. The digestibility values of most AA in corn gluten feed and corn germ meal are not different from the digestibility values of AA in DDGS. Hominy feed has

SID values for several AA that are less than in corn, but because of the greater concentration of starch in hominy feed, this ingredient may be used as an energy source in diets fed to pigs.

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