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Short communication

Coefficient of standardized ileal digestibility of amino acids in corn, soybean meal, corn gluten meal, high-protein distillers dried grains, and field peas fed to weanling pigs

G.I. Petersen[1], Y. Liu, H.H. Stein*

Department of Animal Sciences, University of Illinois, Urbana 61801, United States

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ABSTRACT

The objective of this experiment was to determine the coefficient of standardized ileal digestibility (CSID) of amino acids (AA) in corn, soybean meal (SBM), corn gluten meal (CGM), high protein distillers dried grains (HP DDG), and field peas fed to weanling pigs. Twelve weanling barrows (initial body weight: 10.3 ± 0.9 kg) were prepared with a T-cannula in the distal ileum and randomly allotted to a replicated 6×6 Latin square design with 6 diets and 6 periods in each square. Five diets were formulated using corn, SBM, CGM, HP DDG, or field peas as the sole source of protein and AA. An N-free diet used to calculate basal endogenous losses was also formulated. The CSID of all indispensable AA were greater ($P<0.05$) in SBM, CGM, and field peas than in HP DDG, except that no differences in the CSID of leucine, methionine, and tryptophan were observed between field peas and HP DDG. The CSID of methionine and tryptophan were greater ($P<0.05$) in SBM than in field peas, and the CSID of all indispensable AA were greater ($P<0.05$) in CGM than in field peas except for the CSID of arginine, histidine, lysine, and threonine. However, no differences in the CSID of all indispensable AA were observed between SBM and CGM. The CSID of arginine, histidine, and lysine in corn were less ($P<0.05$) than in SBM, but for all other indispensable AA, no differences between corn and SBM were observed. It is concluded that the CSID of all AA in CGM is similar to that in SBM, but HP DDG has lower CSID values than in corn, CGM, and SBM.

1. Introduction

Diets for pigs should be formulated based on the concentration of coefficient of standardized ileal digestibility (CSID) of amino acids (AA; Stein et al., 2007). The CSID of AA in corn, field peas, corn gluten meal (CGM), and high protein distillers dried grains (HP DDG) has been determined in growing pigs (Almeida et al., 2011; Ji et al., 2012; NRC, 1998; Widmer et al., 2007). However, there are limited data for the CSID of AA in these ingredients when fed to weanling pigs. It has been suggested that weanling pigs have a reduced digestibility of AA compared with growing pigs (Urbaityte et al., 2009). Therefore, it was the objective of this experiment to determine the CSID of AA in corn, CGM, HP DDG, and field peas when fed to weanling pigs, and to compare these values to the CSID of AA in soybean meal (SBM).

Abbreviations: AA, amino acids; CGM, corn gluten meal; CSID, coefficient of standardized ileal digestibility; CP, crude protein; HP DDG, high protein distillers dried grains; SBM, soybean meal.

* Corresponding author. Tel.: +1 217 333 0013; fax: +1 217 333 7088.
E-mail addresses: hstein@illinois.edu, hstein@uiuc.edu (H.H. Stein).

[1] Current address: JBS United, 4310 State Road 38 West, Sheridan, IN, United States.

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Table 1
Analyzed crude protein and amino acids in corn, soybean meal (SBM), corn gluten meal (CGM), high protein distillers dried grains (HP DDG), and field peas (g/kg, as-fed basis).

Item	Corn	SBM	CGM	HP DDG	Field peas
Crude protein	67.2	445.1	654.6	405.5	197.1
Indispensable amino acids					
Arginine	3.6	33.0	23.2	15.5	16.9
Histidine	2.1	12.0	13.4	11.6	5.0
Isoleucine	2.6	22.0	26.7	18.0	9.6
Leucine	8.0	35.6	102.6	58.1	15.4
Lysine	2.4	28.8	12.4	11.9	15.3
Methionine	1.6	6.7	16.6	9.0	2.1
Phenylalanine	3.3	23.1	40.4	22.5	10.2
Threonine	2.5	17.6	21.4	15.2	7.3
Tryptophan	0.5	5.8	3.4	2.2	2.2
Valine	3.6	23.2	29.9	21.7	11.0
Dispensable amino acids					
Alanine	5.0	20.0	55.2	31.4	8.9
Aspartic acid	4.5	52.1	40.0	26.3	23.3
Cysteine	1.6	6.5	11.3	8.0	2.7
Glutamic acid	11.9	79.5	118.0	68.8	34.1
Glycine	3.0	19.7	19.4	13.8	9.0
Proline	5.3	22.2	58.6	35.5	7.8
Serine	3.0	20.0	29.0	17.9	8.4
Tyrosine	2.1	16.5	31.0	17.1	7.0
All amino acids	66.6	444.3	652.5	404.5	196.2

2. Materials and methods

2.1. General

The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. Corn and SBM were sourced from local supplier near Champaign, IL (Table 1). Corn gluten meal was sourced from Archer Daniels Midland, Decatur, IL. High protein distillers dried grains were sourced from Poet, LLC, Sioux Falls, SD. Field peas were sourced from Legume Matrix, LLC, Jamestown, ND. Pigs used in this experiment were derived from the matings of G-Performer boars and Fertilis 25 sows (Genetiporc, Alexandria, MN).

2.2. Diets, animals, and experimental design

Six diets were formulated (Table 2). A N-free diet without any protein containing ingredients was used to measure basal endogenous losses of AA. Five additional diets contained corn, SBM, CGM, HP DDG, or field peas at levels of 945.4, 400.0, 350.0, 500.0, and 765.0 g/kg, respectively, and these ingredients were the sole source of protein in the diets they were used in. Sucrose, cornstarch, and soybean oil were also included in these diets. Solka floc was included in the N-free diet at a level of 50.0 g/kg as a source of synthetic fiber. Chromic oxide (4.0 g/kg) was included in all diets as an inert marker and vitamins and minerals were included at levels that met or exceeded the NRC requirements for weanling pigs (NRC, 1998).

Twelve weanling barrows (initial body weight: 10.3 ± 0.9 kg) were randomly allotted to a replicated 6×6 Latin square design with 6 diets and 6 periods in each square. There were 12 replicates for each treatment. Pigs were surgically equipped with a T-cannula in the distal ileum. Pigs were housed individually in pens (1.8×2.7 m) that had partially slatted floors in an environmentally controlled room. A feeder and a nipple drinker were installed in all pens.

2.3. Feeding and sample collection

Each of the 6 diets was provided to 2 pigs in each square during 1 period. Pigs were fed at a daily level of 3 times the maintenance energy requirement (*i.e.*, 106 kcal ME per $kg^{0.75}$; NRC, 1998). Water was available at all times throughout the experiment. At the start of the experiment, samples of each diet and of each ingredient were collected. Individual pig body weights were recorded at the beginning and at the end of each period, and the amount of feed supplied each day was recorded. Each period lasted 6 d. The initial 4 d of each period were considered as an adaptation period to the diet. Ileal digesta were collected for 8 h on d 5 and 6 as described by Stein et al. (2006). At the conclusion of the experiment, ileal samples were thawed, mixed within animal and diet, and a sub-sample was collected for chemical analysis as previously described (Stein et al., 2006).

Table 2
Ingredient composition of experimental diets (g/kg, as-fed basis).[a]

Item	N-free	Corn	SBM	CGM	HP DDG	Field peas
Ground corn	–	945.4	–	–	–	–
SBM, 44% crude protein	–	–	400.0	–	–	–
CGM	–	–	–	350.0	–	–
HP DDG	–	–	–	–	500.0	–
Ground field peas	–	–	–	–	–	765.0
Corn starch	665.0	–	428.8	424.8	327.0	65.5
Vitamin mineral premix[b]	3.0	3.0	3.0	3.0	3.0	3.0
Soybean oil	40.0	20.0	40.0	40.0	40.0	40.0
Dicalcium phosphate	18.2	16.1	14.6	16.8	11.0	7.7
Ground limestone	7.0	7.5	5.6	7.4	11.0	10.8
Salt	4.0	4.0	4.0	4.0	4.0	4.0
Potassium carbonate	7.0	–	–	–	–	–
Magnesium oxide	1.8	–	–	–	–	–
Chromic oxide	4.0	4.0	4.0	4.0	4.0	4.0
Sucrose	200.0	–	100.0	150.0	100.0	100.0
Solka floc[c]	50.0	–	–	–	–	–
Analyzed nutrients						
Dry matter	918.9	876.7	910.6	918.2	926.7	904.3
Crude protein	5.6	65.1	201.4	235.1	204.9	161.6
Indispensable amino acids						
Arginine	0.1	3.0	13.1	8.4	7.5	13.2
Histidine	0.1	1.9	5.1	5.2	6.0	4.2
Isoleucine	0.1	2.2	8.7	10.0	8.4	7.3
Leucine	0.3	6.9	14.5	38.8	29.3	12.3
Lysine	0.1	2.1	11.6	4.6	5.9	12.1
Methionine	–	1.2	2.5	5.9	4.4	1.5
Phenylalanine	0.1	2.9	9.4	15.0	11.0	8.1
Threonine	0.1	2.1	7.1	7.8	7.8	5.8
Tryptophan	–	0.5	2.6	1.7	1.4	1.5
Valine	0.2	0.3	9.3	11.3	10.5	8.2
Dispensable amino acids						
Alanine	0.2	4.3	8.0	20.4	15.8	7.0
Aspartic acid	0.2	4.0	21.0	14.9	13.2	18.3
Cysteine	0.1	1.3	2.7	4.3	4.0	2.0
Glutamic acid	0.5	10.0	31.4	45.6	35.6	25.5
Glycine	0.1	2.5	7.8	7.1	6.7	6.9
Proline	0.2	5.1	8.7	20.3	17.8	6.2
Serine	0.1	2.5	8.3	11.0	9.9	7.0
Tyrosine	0.1	2.0	5.8	10.5	8.1	4.9
All amino acids	2.6	54.8	177.6	242.8	203.3	152.0

[a] SBM = soybean meal; CGM = corn gluten meal; HP DDG = high protein distillers dried grains.
[b] Provided the following quantities of vitamins and micro minerals per kilogram of complete diet: Vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2204 IU; vitamin E as DL-alpha 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 and nicotinic acid, 44 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.
[c] Fiber Sales and Development Corp., Urbana, OH.

2.4. Sample analysis and data processing

Digesta samples were lyophilized and finely ground prior to chemical analysis. Diets and digesta samples were analyzed in duplicate for dry matter (method 930.15; AOAC Int., 2007), crude protein (CP; method 990.03; AOAC Int., 2007), AA [Method 982.30 E (a, b, c); AOAC Int., 2007], and chromium using an inductive coupled plasma atomic emission spectrometric method (method 990.08; AOAC Int., 2007). Ingredients were also analyzed in duplicate for CP and AA as explained for diets.

Following chemical analysis, the CSID were calculated for CP and AA (Stein et al., 2007). Data were analyzed using the PROC MIXED of SAS (SAS Institute Inc., Cary, NC). An ANOVA was conducted with diet as main effect and pig and period as random effect. Treatment means were separated by using the LSMEANS statement and the PDIFF option of PROC MIXED. The pig was the experimental unit for all analyses and an alpha value of 0.05 was used to assess significance among treatments.

3. Results

The CSID of CP in CGM (0.865) was greater ($P<0.05$) than the CSID of CP in corn (0.801), HP DDG (0.682), and field peas (0.789), but not different from the CSID of CP in SBM (0.859; Table 3). The CSID of CP in SBM was not different from the CSID of CP in corn, but greater ($P<0.05$) than in HP DDG and field peas. The CSID of CP in HP DDG was less ($P<0.05$) than in all other ingredients.

Table 3
Coefficient of standardized ileal digestibility (CSID) of crude protein and amino acids in corn, soybean meal (SBM), corn gluten meal (CGM), high protein distillers dried grains (HP DDG), and field peas.[a,b]

	Corn	SBM	CGM	HP DDG	Field peas	SEM	P-value
Crude protein	0.801^{xy}	0.859^{yz}	0.865^{z}	0.682^{w}	0.789^{x}	0.023	<0.001
Indispensable amino acids							
Arginine	0.868^{y}	0.924^{z}	0.906^{yz}	0.715^{x}	0.896^{yz}	0.017	<0.001
Histidine	0.825^{y}	0.901^{z}	0.867^{yz}	0.704^{x}	0.863^{yz}	0.021	<0.001
Isoleucine	0.816^{y}	0.870^{yz}	0.882^{z}	0.720^{x}	0.822^{y}	0.021	<0.001
Leucine	0.871^{yz}	0.868^{yz}	0.906^{z}	0.818^{x}	0.832^{xy}	0.016	0.002
Lysine	0.759^{y}	0.866^{z}	0.845^{yz}	0.560^{x}	0.851^{z}	0.031	<0.001
Methionine	0.864^{z}	0.882^{z}	0.904^{z}	0.809^{y}	0.797^{y}	0.016	<0.001
Phenylalanine	0.854^{y}	0.875^{yz}	0.894^{z}	0.783^{x}	0.834^{y}	0.018	<0.001
Threonine	0.757^{y}	0.837^{yz}	0.865^{z}	0.649^{x}	0.790^{yz}	0.030	<0.001
Tryptophan	0.850^{yz}	0.881^{z}	0.889^{z}	0.756^{x}	0.789^{xy}	0.023	<0.001
Valine	0.814^{y}	0.863^{yz}	0.880^{z}	0.708^{x}	0.812^{y}	0.023	<0.001
Dispensable amino acids							
Alanine	0.836^{z}	0.835^{z}	0.890^{z}	0.778^{y}	0.776^{y}	0.020	<0.001
Aspartic acid	0.798^{z}	0.834^{z}	0.853^{z}	0.659^{y}	0.823^{z}	0.025	<0.001
Cysteine	0.804^{z}	0.797^{z}	0.839^{z}	0.668^{y}	0.645^{y}	0.031	<0.001
Glutamic acid	0.867^{z}	0.871^{z}	0.891^{z}	0.786^{y}	0.847^{z}	0.018	0.002
Glycine	0.765^{z}	0.853^{z}	0.831^{z}	0.563^{y}	0.740^{z}	0.047	<0.001
Proline	0.747	0.907	0.833	0.575	0.535	0.129	0.170
Serine	0.836^{y}	0.880^{yz}	0.911^{z}	0.761^{x}	0.830^{y}	0.021	<0.001
Tyrosine	0.830^{xy}	0.867^{yz}	0.894^{z}	0.791^{x}	0.833^{xy}	0.018	0.002
All amino acids	0.825^{yz}	0.866^{yz}	0.881^{z}	0.727^{x}	0.814^{y}	0.021	<0.001

[x–w]Within a row, means without a common superscript letter are different (P<0.05).

[a] Values for the CSID of crude protein and amino acids were calculated by correcting the coefficient of apparent ileal digestibility values for basal endogenous losses of crude protein and amino acids that were determined using pigs fed the N-free diet at the following quantities (g per kg dry matter intake): CP, 17.0; Arg, 0.56; His, 0.27; Ile, 0.38; Leu, 0.66; Lys, 0.51; Met, 0.10; Phe, 0.38; Thr, 0.64; Trp, 0.14; Val, 0.53; Ala, 0.61; Asp, 0.94; Cys, 0.26; Glu, 1.10; Gly, 1.65; Pro, 3.08; Ser, 0.60; and Tyr, 0.29.

[b] Data are means of 12 observations per treatment.

The CSID of indispensable AA in SBM and CGM were not different and greater (P<0.05) than in HP DDG. The CSID of all indispensable AA in SBM and field peas were not different except that the CSID of methionine and tryptophan were greater (P<0.05) in SBM than in field peas. The CSID of all indispensable AA were greater (P<0.05) in CGM than in field peas except that no differences in the CSID of arginine, histidine, lysine, and threonine were observed between CGM and field peas. The CSID of leucine, methionine, and tryptophan in corn was not different from that in CGM and SBM, but the CSID of arginine, histidine, and lysine in corn was less (P<0.05) than in SBM and the CSID of isoleucine, threonine, phenylalanine, and valine in corn were also less (P<0.05) than in CGM. The CSID of all indispensable AA in field peas were not different from the CSID in corn with the exception that the CSID of methionine was greater (P<0.05) in corn than in field peas, but the CSID of lysine was greater (P<0.05) in field peas than in corn. The CSID of leucine, methionine, and tryptophan in HP DDG were not different from the CSID in field peas, but less (P<0.05) than in SBM, corn, and CGM, and for all other AA, the CSID in HP DDG was less (P<0.05) than in all other ingredients.

4. Discussion

The CSID of CP and AA in corn that were observed in the present experiment are in agreement with those reported values from previous experiments (Bohlke et al., 2005; NRC, 2012; Stein et al., 2001). However, all previous experiments used growing-finishing pigs, whereas weanling pigs were used in this experiment. The CSID of CP and AA in SBM are similar to previously reported values (NRC, 1998, 2012). The CSID of AA in SBM that were measured in the current experiment are also similar to values reported by Cervantes-Pahm and Stein (2010) who also used weanling pigs. These values suggest that the SBM used in this experiment was of a quality similar to that used in other experiments.

The CSID for CP and AA in CGM that were measured in the present experiment concur with previously published values from North America (NRC, 1998, 2012), but they are slightly less than European values (Sauvant et al., 2004). However, the CSID of indispensable AA in CGM that were measured in this experiment agree with values reported by Almeida et al. (2011) and Ji et al. (2012) who used growing pigs and Urbaityte et al. (2009) who also used weanling pigs, with the exception that the CSID for lysine and Tryptophan are greater in the present experiment than in the experiment by Urbaityte et al. (2009).

There are relatively few data in the literature for the CSID of CP and AA in HP DDG and to our knowledge, no data have been reported for weanling pigs. However, the CSID of CP and AA in HP DDG obtained in this experiment are less than the CSID values reported by Jacela et al. (2010), Kim et al. (2009), and Widmer et al. (2007) who used growing pigs. In particular, the CSID of lysine is low, which may be due to Maillard reactions in this sample of HP DDG. After the fermentation process, distillers products are dried and the drying process may cause Maillard reactions (Pahm et al., 2008). These reactions cause the epsilon NH_2 group of lysine to bind to a reducing sugar producing unreactive lysine, which is unavailable to the pig (Pahm et al., 2008).

Field peas had values for the CSID of CP and AA that were similar to those in corn and SBM. The CSID of CP and AA in field peas are also in close agreement with previous values measured in weanling pigs (Urbaityte et al., 2009) and in growing pigs (Stein et al., 2004; Stein and Bohlke, 2007).

The observation that the CSID of AA in corn, SBM, CGM, and field peas measured in weanling pigs in the present study is in close agreement with published values measured in growing pigs indicates that weanling pigs have similar digestibility of AA in these ingredients compared with growing pigs. However, further research will be needed to compare AA digestibility of different ingredients in weanling pigs and growing pigs.

5. Conclusion

Results of the present experiment confirm that the AA in CGM have an excellent digestibility when fed to weanling pigs and the digestibility of most AA in field peas is not different from that in SBM. In contrast, the digestibility of most AA in HP DDG is less than in corn, SBM, CGM, and field peas when fed to weanling pigs.

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