Determination of the ileal amino acid and energy digestibilities of corn distillers dried grains with solubles using grower-finisher pigs[1,2,3]

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ABSTRACT: An experiment evaluated the ileal apparent and standardized AA and apparent energy digestibilities in grower-finisher pigs of 5 sources of distillers dried grains with solubles (DDGS) from corn. The 5 DDGS sources were analyzed for AA, GE, NDF, ADF, and color score. Diets were formulated to contain 15% CP from the test DDGS sources (approximately 60% of the diet). A low-protein (5% casein) diet was used to estimate basal endogenous AA losses. The experiment was conducted in 2 replicates of a 6 × 6 Latin Square design, with 6 treatments and six 1-wk periods. The experiment used 12 crossbred barrows [(Yorkshire × Landrace) × Duroc], averaging 28 kg of BW and 60 d of age, and surgically fitted with a T-cannula in the distal ileum. After a 10-d recovery period, treatment diets were fed in meal form, initially at 0.09 kg·BW$^{0.75}$. Feed intake was equalized between pigs within each period and increased for each subsequent period. Periods included 5 d of diet acclimation followed by two 12-h ileal digesta collections, one on d 6 and one on d 7. Apparent and standardized digestibility of AA was calculated using chromic oxide (0.4%) as an indigestible marker. The results demonstrated that apparent and standardized lysine digestibilities ranged from 24.6 to 52.3% and 38.2 to 61.5%, respectively. Average apparent essential AA digestibility was lower ($P < 0.05$) in sources 1 and 5, the 2 sources that were darkest in color. Apparent and standardized digestibility of the averaged nonessential AA were lower ($P < 0.05$) in source 5 than in all other sources. Source 5, the darkest colored DDGS, had a 10% lower ($P < 0.05$) average apparent and standardized essential AA digestibility and was more than 15% lower ($P < 0.05$) in lysine digestibility than the 3 lightest colored sources. Apparent ileal energy digestibility did not differ among the 5 sources. Lysine content and digestibility seemed to be reduced to a greater extent by the darker colored DDGS than the other essential AA, suggesting that the Maillard reaction reduced total lysine content and lowered its digestibility. These results, therefore, imply that darker colored DDGS sources may have lower ($P < 0.05$) analyzed lysine contents, as well as lower ($P < 0.05$) lysine and essential AA digestibilities, than lighter colored DDGS sources.

Key words: amino acid, digestibility, distillers grain, ileum, pig

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INTRODUCTION

Production of ethanol from 100 kg of corn using the dry-grind method produces 34.4 kg of ethanol, 34.0 kg of carbon dioxide, and 31.6 kg of distillers dried grains with solubles (**DDGS**; RFA, 2005). The ethanol industry in the United States is increasing at approximately 30% annually, resulting also in large increases in carbon dioxide and DDGS supplies (DiPardo, 2000). Currently, a majority of corn DDGS is fed to ruminants because of their ability to ferment its high fiber content. Cromwell et al. (1993) suggests that the low lysine digestibility of DDGS may limit the amount that can be fed to pigs. Variable DDGS AA composition and poor AA quality may play a role in its limited use in swine diets.

The ileal digestibility technique reduces the confounding effects of the microbial populations present in

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[2]Animal care and procedures followed were approved by the Ohio State University Animal Care and Use Committee, protocol # 03-AG003.

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

		DDGS[1] source				
Ingredient	Endog.[2]	1	2	3	4	5
Hydrolyzed casein	5.00	—	—	—	—	—
DDGS source 1	—	60.40	—	—	—	—
DDGS source 2	—	—	60.40	—	—	—
DDGS source 3	—	—	—	60.40	—	—
DDGS source 4	—	—	—	—	60.40	—
DDGS source 5	—	—	—	—	—	60.40
Sucrose	30.00	30.00	30.00	30.00	30.00	30.00
Cornstarch	53.63	3.70	3.70	3.70	3.70	3.70
Cellulose[3]	5.00	—	—	—	—	—
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00
Dicalcium phosphate	1.50	1.85	1.85	1.85	1.85	1.85
Limestone	0.90	0.60	0.60	0.60	0.60	0.60
Potassium carbonate (55% K)	0.60	0.40	0.40	0.40	0.40	0.40
Trace mineral mix[4]	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin mix[5]	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.35	0.30	0.30	0.30	0.30	0.30
Magnesium oxide (58% Mg)	0.27	—	—	—	—	—
Chromic oxide	0.40	0.40	0.40	0.40	0.40	0.40

[1]DDGS = distillers dried grains with solubles; diets were calculated to contain 15% CP, 0.45% lysine, 0.70% Ca, 0.64% available P, 0.18% Mg, and 0.33% K.

[2]Diet used for endogenous (Endog.) AA determination was calculated to contain 4.6% CP, 0.37% total lysine, 0.70% Ca, 0.35% available P, 0.18% Mg, and 0.33% K.

[3]Solka floc (International Fiber Corp., New York, NY).

[4]Provided per kilogram of diet: 90 mg of Fe (ferrous sulfate); 5 mg of Mn (manganese oxide); 8 mg of Cu (copper sulfate); 0.20 mg of I (potassium iodate); 0.21 mg of Se (sodium selenite); and 90 mg of Zn (zinc sulfate).

[5]Provided per kilogram of diet: 2,000 IU of vitamin A; 300 IU of vitamin D_3; 20 IU of vitamin E; 1.0 mg of vitamin K (menadione sodium bisulfate); 4 mg of thiamin; 15 mg of niacin; 4 mg of riboflavin; 12 mg of pantothenic acid; 15 μg of vitamin B_{12}; 2 mg of pyridoxine; 0.1 mg of D-biotin; 0.5 mg of folic acid; and 0.60 g of choline.

the cecum and large intestine (Low and Zebrowska, 1989). Amino acids collected from ileal digesta, however, are not solely of dietary origin. Endogenous AA from microbial protein, sloughed intestinal cells, mucosal proteins, and digestive enzymes are present in the digesta (Moughan and Schuttert, 1991), thus confounding ileal digestibility values. An adjustment for the endogenous fractions allows for a more accurate assessment of AA digestibility. Providing a low-protein casein diet should more closely mimic the metabolic state of a fed animal than a protein-free diet (Low, 1980).

This study evaluated different response criteria using apparent and standardized AA digestibility as well as energy digestibility from 5 different sources of corn DDGS that varied in their degree of color (light to dark).

MATERIALS AND METHODS

All animal care procedures were approved by The Ohio State University Institutional Animal Care and Use Committee.

Samples of DDGS were collected from 5 corn ethanol plants in the upper Midwestern United States that used the dry-grinding process. All DDGS diets were formulated to 15% CP solely from the test DDGS source (Table 1), based on an assumed CP content of 24.8% in the DDGS sources. The 5 DDGS treatment diets were fortified with vitamins and minerals to meet or exceed the nutrient requirements for growing pigs (NRC, 1998).

A low protein (5% hydrolyzed casein) diet served as a sixth treatment group and was used to determine endogenous AA secretions within each study period. It was assumed that the hydrolyzed casein was completely digested and provided AA and energy to reduce the small intestinal tissue catabolism that normally occurs. Subsequently, AA analyzed from the ileal digesta were considered to be of endogenous origin and were subtracted from the quantity exiting the small intestine when calculating the standardized digestibility coefficients. As an indigestible marker, chromic oxide was added to all diets at 0.4%.

The experiment was conducted as a 6 × 6 Latin-square design replicated twice. After fasting for 24-h, 12 crossbred barrows [(Yorkshire × Landrace) × Duroc] averaging 28 ± 1.1 kg of BW were surgically fitted with a T-cannula in the distal ileum, according to the method by Sauer et al. (1983). During an approximately 10-d recovery period, pigs were fed a restricted amount of a corn-soybean meal diet formulated to contain 1.00% total lysine.

Pigs were housed in individual 0.6 × 1.2-m, stainless steel adjustable-width metabolism crates (Rohn Agri Products, Peoria, IL). Room temperatures were maintained at 26 ± 2°C, with fluorescent lighting provided from 0600 to 1830. The surgical site around the cannula was cleaned daily with an antibacterial soap (Palmolive Antibacterial, Colgate-Palmolive, New York, NY) followed by application of a thin layer of zinc oxide cream (Desitin, Pfizer, New York, NY).

Pigs within each replicate were allotted to treatment sequences such that each animal received the 6 diets in a different order, with each pig being fed 1 treatment diet within each collection period. The quantity of feed provided daily during the initial period was adjusted to the average animal's metabolic body weight ($0.09 \cdot BW^{0.75}$) but equalized for all pigs within each study period. Feed intake was increased by approximately 150 g/d for each subsequent period. Diets were provided in meal form twice daily in equal amounts at 12-h intervals (0600 and 1800) with an approximate water to diet ratio of 1.5:1 (wt/wt). Within each pen, additional water was provided free choice via an adjacent nipple waterer.

Study periods totaled 7 d, with a 5-d diet acclimation period followed by 2 d of digesta collection for two 12-h (0600 to 1800) periods on d 6 and 7. Plastic collapsible tubes (50-mm inside diameter) were attached to the cannula, with digesta collected at 20- to 30-min intervals for the 12-h period. Care was taken to ensure that digesta flow into the tube was unobstructed during collection. Samples were frozen immediately (–20°C) upon collection, subsequently thawed and pooled by pig for the 2-d period, mixed, and freeze-dried before analysis.

Analyses

Color score (L*, a*, and b*) was measured using a model CR-410 colorimeter (Konica Minolta Photo Imaging USA Inc., Mahwah, NJ). Samples of DDGS were placed in aluminum pans (23 × 23 × 2.5 cm deep), leveled, and measured by lightly setting the probe on the surface of the DDGS. The mean color score was the average of 10 measurements, with the sample being mixed and leveled between each determination. Low values for L* indicate a dark color, whereas high scores indicate a light color (0 = black; 100 = white). Greater values of a* and b* indicate a greater degree of redness and yellowness, respectively.

Freeze-dried digesta and DDGS were analyzed for energy, N, AA, and Cr content. Crude protein was calculated from the N content using a Perkin-Elmer 2410 Series II N analyzer (Perkin-Elmer, Norwalk, CT). Amino acids were determined using a Beckman 6300 AA analyzer (Beckman Coulter Inc., Fullerton, CA) by methods outlined by AOAC (1995; methods 988.15 [sulfur and regular] and 994.12 [tryptophan]) at the University of Missouri Agriculture Experiment Station Chemical Labs. The analytical AA values for DDGS sources were used to calculate the dietary contribution used in digestibility equations. Chromium was determined by atomic absorption spectrophotometry after wet ashing in HCl (AOAC, 1995) at the University of Missouri Agriculture Experiment Station Chemical Labs. Gross energy was analyzed for treatment diets and freeze-dried digesta using an adiabatic oxygen bomb calorimeter (model 1241, Parr Instrument Manual, Parr Instruments, Moline, IL).

Apparent ileal digestibility (**AID**, %) was calculated using the Cr concentration in the feed and digesta by using the equation: AID = 100 – ([ND/NF] × [CrF/CrD] × 100). In this equation, ND is the nutrient concentration present in the ileal digesta, NF is the nutrient concentration in the feed, CrF is the Cr concentration in the feed, and CrD is the Cr concentration in the ileal digesta.

Endogenous AA losses (**EAL**) were calculated according to the equation reported by Moughan et al. (1992): EAL = (ND × [CrF/CrD]). Standardized ileal digestibility (**SID**, %) was calculated using the equation: SID = (AID + [EAL/NF]) × 100.

The data were analyzed using the Mixed procedure of SAS (V. 9.1, SAS Inst. Inc., Cary, NC). A Latin Square design was followed according to the method of Steel and Torrie (1980), using the individual pig as the experimental unit. The low protein treatment diet was not incorporated in the treatment contrast comparisons. Instead, the low protein treatment was used solely for calculating standardized digestibility within each study period and was used to compare across study periods.

The statistical model was: $ND_{ijkl} = \mu + r_i + p_j + D_k + a_{l:i} + e_{ijkl}$, where i = 1,2; j = 1,2,3,4,5,6; k = 1,2,3,4,5; $r_i \sim iidN(0, \sigma^2_r)$; $p_j \sim iidN(0, \sigma^2_p)$; $a_{l:i} \sim iidN(0, \sigma^2_a)$; and $e_{ijkl} \sim iidN(0, \sigma^2_e)$, where ND is nutrient digestibility; r = random effect of replicate; p = random effect of experimental period; D = fixed effect of the 5 DDGS sources; and a = random effect of pig nested within replicate. Mean comparisons were calculated using the DIFF option of the LSMEANS statement and using the Tukey Kramer adjustment for multiple contrasts for all pairwise comparisons. A probability of $P < 0.05$ was accepted as statistically significant.

RESULTS

Color scores of the 5 DDGS sources (Table 2) demonstrated that 1 was dark (i.e., source 5 had the lowest L*), sources 2 and 4 were the lightest (greatest L*), whereas sources 1 and 3 were intermediate. There was little variation in redness (a*), whereas the yellow color (b*) followed a pattern similar to the L* value.

The analyzed AA, CP, and GE contents of the 5 DDGS sources are presented in Table 3. Lysine (total) ranged from 0.48 to 0.76%, whereas NDF was between 29.7 to 34.2%, and ADF content ranged from 10.3 to 13.2%. Gross energy ranged from 4,848 to 4,969 kcal/kg in the 5 DDGS sources.

Apparent lysine digestibilities (Table 4) ranged from 24.6 to 52.3%, with source 4 having the greatest digestibility ($P < 0.05$), sources 2 and 3 intermediate ($P < 0.05$); source 5 was lower ($P < 0.05$), and source 1 had the lowest ($P < 0.05$) value. Apparent AA digestibilities were generally similar among sources 1 to 4, except

Table 2. Color characteristics of the 5 DDGS sources[1]

	DDGS source				
Item	1	2	3	4	5
Color score[2]					
Hunter L*	34.1 ± 0.83	55.1 ± 0.79	39.8 ± 0.69	52.3 ± 0.88	28.0 ± 0.19
a*	7.1 ± 0.36	9.0 ± 0.06	8.6 ± 0.14	7.9 ± 0.03	6.7 ± 0.07
b*	20.1 ± 0.47	41.9 ± 0.33	28.1 ± 0.51	33.8 ± 0.66	15.8 ± 0.08

[1]Ten observations per mean ± SD. DDGS = distillers dried grains with solubles.
[2]L* = lightness of sample, 0 = black, 100 = white; greater values of a* and b* indicate greater degree of redness and yellowness, respectively.

for isoleucine, leucine, lysine, tryptophan, cysteine, and glutamic acid. Apparent digestibility of all AA was lowest ($P < 0.05$) in source 5, the darkest colored DDGS. Overall, DDGS sources 2, 3, and 4 had similar apparent digestibilities of the essential AA whereas sources 1 and 3 were similar. However, the apparent digestibilities of EAA in sources 1 to 4 were greater ($P < 0.05$) than source 5. The average nonessential AA digestibility was lowest ($P < 0.05$) in source 5 but similar among the other 4 sources.

Apparent CP digestibility was lowest ($P < 0.05$) in source 5, greatest ($P < 0.05$) in source 2, and intermediate and similar for sources 1, 3, and 4. Energy digestibility was not affected by DGGS source and ranged from 66.7 to 69.2%.

Endogenous AA losses (mg/kg of feed intake) determined by the low-protein 5% casein diet are presented in Table 5. There were no period differences in endogenous AA losses. Consequently, standardized lysine digestibility (Table 6) ranged from 38.2 to 61.5% being the lowest in sources 1 and 5 ($P < 0.05$) and greatest for sources 2, 3, and 4. Standardized digestibility was similar among sources 1 to 4 for all AA except leucine, lysine, glutamic acid and proline. Standardized digestibilities of all AA except histidine, lysine and proline were approximately 10% lower ($P < 0.05$) for source 5 than the other DDGS sources.

DISCUSSION

Our experiment suggests that DGGS sources of a lighter (L*) and more yellow (b*) color resulted in greater apparent and standardized digestibility of AA than those DDGS sources of a darker color. The reduced digestibility seemed to be exacerbated for the essential AA, lysine, which had a greater difference between the

Table 3. Amino acid, CP, GE, NDF, and ADF content of the 5 DDGS sources (as-fed basis)[1]

	DDGS source				
Item	1	2	3	4	5
Essential AA, %					
Arg	0.96	1.06	1.08	1.06	0.86
His	0.61	0.66	0.70	0.65	0.63
Ile	0.84	1.03	1.09	0.99	0.96
Leu	2.86	3.05	3.26	3.05	3.13
Lys	0.51	0.75	0.70	0.76	0.48
Met	0.48	0.48	0.50	0.51	0.45
Phe	1.19	1.36	1.44	1.34	1.36
Thr	0.89	0.98	1.03	1.01	0.84
Trp	0.25	0.26	0.28	0.25	0.20
Val	1.21	1.32	1.42	1.29	1.26
Nonessential AA, %					
Ala	1.80	1.85	1.99	1.85	1.84
Asp	1.66	1.72	1.77	1.71	1.46
Cys	0.46	0.48	0.50	0.50	0.45
Glu	4.39	3.89	3.94	3.68	4.01
Gly	0.96	1.01	1.06	0.98	0.91
Pro	1.94	2.09	2.17	1.95	1.84
Ser	1.13	1.01	1.08	1.06	0.91
Tyr	0.86	0.98	1.01	1.03	0.96
CP, %	28.2	28.3	29.8	27.3	27.0
GE, kcal/kg	4,969	4,895	4,898	4,888	4,848
NDF, %	34.2	29.7	32.8	32.9	31.5
ADF, %	12.0	10.3	13.0	11.0	13.2

[1]DDGS = distillers dried grains with solubles.

Table 4. Apparent ileal AA, CP, and energy digestibility of the 5 DDGS sources[1,2]

	DDGS source					
Item	1	2	3	4	5	SED
Essential AA, %						
Arg	75.7[x]	76.3[x]	77.0[x]	76.2[x]	68.0[w]	1.7
His	71.7	70.4	68.9	69.7	66.0	2.9
Ile	67.9[x]	72.2[y]	71.0[xy]	70.9[xy]	62.1[w]	1.9
Leu	82.7[y]	82.7[y]	77.9[x]	81.1[y]	73.7[w]	1.3
Lys	24.6[w]	46.0[y]	47.1[y]	52.3[z]	29.3[x]	3.5
Met	79.6[x]	78.4[x]	78.4[x]	79.5[x]	69.3[w]	1.2
Phe	76.5[x]	78.4[x]	77.0[x]	77.2[x]	70.9[w]	1.4
Thr	59.2[x]	62.8[x]	61.9[x]	63.6[x]	46.3[w]	2.4
Trp	68.4[x]	72.7[y]	72.6[y]	69.4[x]	57.0[w]	3.4
Val	68.9[x]	70.3[x]	68.9[x]	69.9[x]	59.9[w]	2.1
EAA[3] average	67.5[x]	71.0[y]	69.9[xy]	71.0[y]	60.2[w]	1.9
Nonessential AA, %						
Ala	75.6[x]	76.8[x]	74.1[x]	75.9[x]	68.0[w]	1.4
Asp	61.3[x]	61.9[x]	57.8[x]	62.3[x]	44.7[w]	2.5
Cys	61.8[x]	64.9[xy]	62.2[xy]	66.4[y]	51.5[w]	2.5
Glu	79.9[z]	77.0[yz]	71.0[x]	74.8[y]	66.3[w]	1.5
Gly	49.9[x]	50.5[x]	52.0[x]	51.6[x]	39.7[w]	4.0
Pro	65.2[x]	64.4[x]	61.9[x]	54.0[wx]	47.2[w]	7.0
Ser	73.8[x]	70.3[x]	70.0[x]	71.1[x]	56.1[w]	1.8
Tyr	76.2[x]	78.2[x]	76.5[x]	78.1[x]	71.7[w]	1.5
NEAA[4] average	67.8[x]	68.0[x]	65.6[x]	66.8[x]	55.5[w]	2.6
CP, %	64.1[wx]	67.1[x]	62.9[wx]	63.3[wx]	58.0[w]	3.5
Energy, %	68.1	69.2	67.1	68.9	66.7	1.6

[w–z]Means within the same row without a common superscript letter differ, $P < 0.05$.
[1]DDGS = distillers dried grains with solubles.
[2]Twelve observations per mean.
[3]EAA = dietary essential AA.
[4]NEAA = dietary nonessential AA.

Table 5. Endogenous AA losses by experimental period (mg of feed intake/kg on a DM basis)[1]

	Experimental period						
Item	1	2	3	4	5	6	SED
Essential AA, mg of feed intake/kg							
Arg	334	302	273	443	352	366	102
His	174	151	142	222	169	175	51
Ile	385	345	344	503	460	475	117
Leu	526	475	427	597	531	557	138
Lys	432	421	356	495	404	444	114
Met	89	97	119	119	103	119	27
Phe	296	291	237	324	268	284	75
Thr	602	485	416	606	474	485	140
Trp	136	119	83	111	99	114	26
Val	517	463	380	571	484	490	132
EAA[2] average	349	315	278	399	334	351	92
Nonessential AA, mg of feed intake/kg							
Ala	498	539	451	614	502	547	142
Asp	790	723	641	930	737	754	215
Cys	226	173	142	188	136	134	43
Glu	1,410	1,262	1,282	1,962	1,508	1,528	452
Gly	630	658	606	1,092	714	862	250
Pro	846	1,726	1,152	2,678	1,832	2,317	614
Ser	573	475	534	759	550	645	175
Tyr	273	259	226	307	291	294	71
NEAA[3] average	656	727	629	1,066	784	885	245

[1]Two observations per mean.
[2]EAA = dietary essential AA.
[3]NEAA = dietary nonessential AA.

Table 6. Standardized ileal AA digestibility of the 5 sources of DDGS[1,2]

Item	DDGS source 1	2	3	4	5	SED
Essential AA, %						
Arg	81.7^{y}	81.7^{y}	82.3^{y}	81.5^{y}	74.6^{x}	1.8
His	76.2	74.8	73.0	74.2	70.2	2.9
Ile	76.1^{y}	79.0^{y}	77.2^{y}	77.8^{y}	69.2^{x}	2.0
Leu	85.6^{z}	85.5^{z}	80.5^{y}	83.9^{z}	76.3^{x}	1.3
Lys	38.2^{x}	55.4^{y}	57.3^{y}	61.5^{y}	43.6^{x}	3.5
Met	83.3^{y}	82.1^{y}	82.0^{y}	83.1^{y}	73.2^{x}	1.2
Phe	80.4^{y}	81.9^{y}	80.2^{y}	80.7^{y}	74.3^{x}	1.4
Thr	68.6^{y}	71.5^{y}	70.1^{y}	72.0^{y}	56.1^{x}	2.4
Trp	75.7^{y}	79.6^{y}	79.0^{y}	76.7^{y}	66.0^{x}	3.3
Val	75.5^{y}	76.4^{y}	74.1^{y}	76.1^{y}	66.2^{x}	2.2
EAA[3] average	74.1^{y}	76.8^{y}	75.5^{y}	76.8^{y}	67.0^{x}	2.0
Nonessential AA, %						
Ala	80.4^{y}	81.6^{y}	78.5^{y}	80.6^{y}	72.6^{x}	1.4
Asp	68.9^{y}	69.3^{y}	65.0^{y}	69.8^{y}	53.2^{x}	2.5
Cys	67.6^{y}	70.7^{y}	67.7^{y}	72.0^{y}	57.5^{x}	2.3
Glu	85.5^{z}	83.4^{z}	77.3^{y}	81.5^{z}	72.5^{x}	1.6
Gly	63.1^{y}	63.0^{y}	63.9^{y}	64.5^{y}	53.1^{x}	4.3
Pro	79.8^{z}	78.6^{z}	75.3^{yz}	69.0^{xy}	61.8^{x}	6.9
Ser	82.6^{y}	79.8^{y}	79.2^{y}	80.5^{y}	66.6^{x}	2.0
Tyr	81.5^{y}	82.9^{y}	81.0^{y}	82.5^{y}	76.3^{x}	1.5
NEAA[4] average	76.1^{y}	76.1^{y}	73.4^{y}	75.0^{y}	64.1^{x}	2.6

[x–z]Means within the same row without a common superscript letter differ, $P < 0.05$.
[1]DDGS = distillers dried grains with solubles.
[2]Twelve observations per mean.
[3]EAA = dietary essential AA.
[4]NEAA = dietary nonessential AA.

5 DDGS sources than the other AA. Although other factors may influence DDGS color, our results imply that colorimetric measurements, such as L* and b*, may provide a rapid and useful method for predicting high, intermediate, or low AA and lysine digestibilities.

Although the number of DDGS samples in our study were limited, our results indicate considerable differences in the degree of lightness or darkness between samples as measured by the Minolta equipment. It seems from this and other studies that excessive heat during the drying process may form several results from Maillard reactions between lysine residues and carbohydrate moieties. The process may not only darken the color of the final product (Parsons et al., 1992) but may also influence the digestibility of the AA lysine. The more firmly bound lysine is apparently not available for use by the animal, nor does the bound lysine seem to be easily released during acid hydrolysis conditions used in AA analysis (Hurrell, 1983). Depending upon the extent of the Maillard reaction and or the drying process, some lysine may be chemically converted to other products, thus reducing the total lysine content of the DDGS. However, the Maillard reaction may firmly bind products not readily released during the digestive process and therefore may not be utilized by the animal. Therefore, the darker colored DDGS sources (1 and 5) in our experiment may have had a greater degree of Maillard reaction that may have resulted in a lower analyzed value, and also a lower digestible lysine content.

Reduction in the overall AA digestibility suggests another role that excessive heat may have on other dietary components. Research by Evans and Butts (1948) suggests that excessive heating can bind AA and protein to other compounds, such as fiber, effectively reducing the digestibility of AA in nonruminants. However, unlike lysine that is altered in Maillard reactions, these bound AA and proteins may be liberated during the acid hydrolysis procedure. This may explain why there was no marked reduction in the amount or digestibility of essential AA other than lysine in the darker colored DDGS sources.

Other research investigating corn DDGS have come to similar conclusions about the relationship of color and AA digestibility. Spiehs et al. (2001) reported that lighter colored DDGS had an AID for lysine of 47.4%, which is similar to our value of 49.2%. Darker colored DDGS in the current experiment had an AID for lysine of 23.0% that differed from the 0% values reported by Spiehs et al. (2001). The differences between the 2 values in the darker colored samples may be due to the degree of darkness but also to differences in the amount of DDGS in the diets and the way in which the digestibility values were calculated. Cromwell et al. (1993) reported that darker colored DDGS resulted in poorer performance responses in both pigs and chickens, suggesting reduced lysine digestibility. The NRC (1998) and Ajinomoto Heartland (2004) reported AID values for lysine in DDGS of 47 and 52.9%, respectively. These values are comparable with the values determined in the current experiment but only for the lighter colored DDGS samples.

Standardized lysine digestibility in the current experiment varied from 40.9 in the darkest 2 sources to 58.1% in the lightest 3 DGGS sources. For the lighter sources, our standardized lysine digestibility values are similar to the values of 59 and 58.2% reported by the NRC (1998) and Ajinomoto Heartland (2004), respectively.

There were no differences in energy digestibility among the sources suggesting that the fiber component does not seem to be affected by DDGS color as the AA.

IMPLICATIONS

Amino acid digestibility of corn distillers dried grains with solubles varies among various sources, with lysine digestibility having more variation than other amino acids. Darker colored distillers dried grains with solubles sources tend to have lower total lysine contents, reduced AA digestibilities, and reduced lysine digestibilities when compared with lighter colored distillers dried grains with solubles sources. Therefore, distillers dried grains with solubles color may be a good indicator of overall amino acid and particularly lysine digestibility.

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