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Amino acid digestibility and energy concentration in a novel source of high-protein distillers dried grains and their effects on growth performance of pigs

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ABSTRACT: Three experiments were conducted to evaluate a novel source of high-protein distillers dried grains produced by Buhler Inc. (HP-DDG$_{Buhler}$) and fed to growing pigs. The standardized ileal digestibility (SID) of AA in HP-DDG$_{Buhler}$ and in soybean meal (SBM) was determined in Exp. 1. Nine pigs (109.8 ± 2.78 kg of BW) were fitted with a T-cannula in the distal ileum and allotted to a triplicated 3 × 3 Latin square design with 3 diets and 3 periods per square. Diets containing HP-DDG$_{Buhler}$ or SBM as the only source of AA and an N-free diet were formulated. The SID of indispensable AA was less ($P < 0.01$) in HP-DDG$_{Buhler}$ than in SBM (Arg, 87.5 vs. 93.9%; His, 76.7 vs. 88.7%; Ile, 76.4 vs. 87.5%; Leu, 77.8 vs. 86.8%; Lys, 75.4 vs. 88.4%; Met, 82.8 vs. 88.4%; Phe, 77.9 vs. 87.3%; Thr, 72.5 vs. 83.5%; Trp, 85.1 vs. 91.0%; Val, 73.3 vs. 84.3%). The DE and ME in HP-DDG$_{Buhler}$ and in corn were measured in Exp. 2 using 16 growing barrows (24.6 ± 1.66 kg of BW). A corn-based diet and a diet containing 50% corn and 48.2% HP-DDG$_{Buhler}$ were formulated. The total collection method and the difference procedures were used. The concentrations of DE and ME in HP-DDG$_{Buhler}$ were greater ($P < 0.001$) than in corn (5,043 vs. 4,002 kcal/kg of DM and 4,690 vs. 3,921 kcal/kg of DM, respectively). Experiment 3 was a 9-wk growth assay using 40 pigs (initial BW: 58.2 ± 2.28 kg) allotted to 5 dietary treatments, with 8 replicates of individually housed pigs per treatment. Treatments included a control diet based on corn and SBM and 4 diets in which HP-DDG$_{Buhler}$ replaced 33, 66, 66, or 100% of the SBM in the control diet. All HP-DDG$_{Buhler}$ diets contained supplemental Lys and Thr to provide similar concentrations of SID Lys and Thr in all diets; one of the diets in which HP-DDG$_{Buhler}$ replaced 66% of the SBM and the diet in which HP-DDG$_{Buhler}$ replaced 100% of the SBM also contained crystalline Trp. Dietary treatments had no effect on ADG (1.15, 1.13, 1.16, 1.12, and 1.14 kg), ADFI (3.33, 3.35, 3.39, 3.30, and 3.33 kg), or G:F (0.35, 0.34, 0.34, 0.34, and 0.34 kg/kg). Carcass traits of pigs fed the diet in which HP-DDG$_{Buhler}$ replaced 100% of the SBM were not different from those of pigs fed the control diet. In conclusion, HP-DDG$_{Buhler}$ contains more DE and ME than corn, but has decreased SID values for AA compared with SBM. Soybean meal can be replaced by HP-DDG$_{Buhler}$ in diets fed to finishing pigs without any effect on growth performance or carcass characteristics, provided that diets are adequate in indispensable AA.

Key words: amino acid digestibility, carcass characteristic, energy, growth performance, high-protein distillers dried grains, pig

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INTRODUCTION

The digestibility of AA in conventional distillers dried grains with solubles fed to pigs has been measured (Fastinger and Mahan, 2006; Stein et al., 2006; Pahm et al., 2008a), and the digestibility of P and energy in distillers dried grains with solubles has also been reported (Pedersen et al., 2007a; Stein et al., 2009). Recently, a fractionation technology called BFrac (Poet Companies, Sioux Falls, SD) was developed. In this process, bran and germ are removed from the corn, resulting in endosperm that is used for ethanol production. A coproduct from this fermentation is high-protein distillers dried grains (**HP-DDG$_{BFrac}$**), which contains approximately 41% CP. The nutritional value of HP-DDG$_{BFrac}$ to growing-finishing pigs has been measured (Widmer et al., 2007, 2008).

A different fractionation technology was developed by Buhler Inc. (Minneapolis, MN). With this technology,

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Table 1. Analyzed nutrient composition of high-protein distillers dried grains ($HP\text{-}DDG_{Buhler}$), soybean meal (SBM), and corn (as-fed basis)[1,2]

	Ingredient		
Item	$HP\text{-}DDG_{Buhler}$	SBM	Corn
Composition, %			
DM	91.76	92.72	89.08
CP	44.90	47.65	8.23
Crude fat	3.69	0.80	3.83
NDF	40.50	8.41	10.78
ADF	18.98	4.81	2.35
Ash	1.44	6.26	1.40
Ca	0.03	0.38	0.02
P	0.32	0.74	0.30
GE, kcal/kg	5,236	4,213	3,896
Indispensable AA, %			
Arg	1.83	3.43	—
His	1.00	1.21	—
Ile	2.04	2.05	—
Leu	6.61	3.58	—
Lys	1.32	3.00	—
Met	1.06	0.66	—
Phe	2.52	2.28	—
Thr	1.69	1.86	—
Trp	0.25	0.63	—
Val	2.15	2.00	—
Total indispensable AA	20.47	20.70	—
Dispensable AA, %			
Ala	3.55	2.00	—
Asp	3.04	5.35	—
Cys	0.86	0.69	—
Glu	8.18	8.58	—
Gly	1.46	1.93	—
Pro	3.68	2.12	—
Ser	2.09	2.24	—
Tyr	1.83	1.66	—
Total dispensable AA	24.69	24.57	—

[1]$HP\text{-}DDG_{Buhler}$ from Buhler Energy Inc. (Minneapolis, MN).

[2]Amino acids were not analyzed in the corn used in the energy experiment (Exp. 2).

germ is removed from the corn grain and the degermed grain is passed through roller mills and aspirators to remove the bran. The resulting endosperm is fermented, ethanol is produced, and high-protein distillers dried grains (**$HP\text{-}DDG_{Buhler}$**) are produced. This product contains approximately 45% CP and 3.7% crude fat. However, no information is available on the feeding value of $HP\text{-}DDG_{Buhler}$ to pigs. Therefore, the objective of the present experiments was to measure the nutritional value of $HP\text{-}DDG_{Buhler}$ when fed to growing-finishing pigs.

MATERIALS AND METHODS

Two digestibility experiments were conducted in environmentally controlled rooms at the University of Illinois at Urbana-Champaign. The protocols for the experiments were reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. All pigs used in these experiments were the offspring of line 337 boars that were mated to C22 females (Pig Improvement Company, Hendersonville, TN). A growth performance experiment was conducted at the University of Missouri, Columbia. The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Missouri. Pigs used at the University of Missouri were the offspring of TR-4 boars that were mated to C22 females (Pig Improvement Company).

Exp. 1: AA Digestibility

Nine barrows with an initial BW of 109.8 ± 2.78 kg were used to measure the ileal digestibility of CP and AA in $HP\text{-}DDG_{Buhler}$ and soybean meal (**SBM**; Table 1). Animals were randomly allotted to a triplicated 3 × 3 Latin square design with 3 diets and 3 periods per square. Pigs were surgically fitted with a T-cannula in the distal ileum using procedures adapted from Stein et al. (1998). After the surgery, pigs were housed in individual pens (0.9 × 1.8 m). Each pen was equipped with a feeder and a nipple drinker and had fully slatted concrete floors.

Three experimental diets were prepared (Tables 2 and 3). One diet contained $HP\text{-}DDG_{Buhler}$ at a concentration of 50.0% (as-fed basis) as the sole source of AA. The second diet contained 38.0% (as-fed basis) SBM as the sole source of AA, and the last diet was an N-free diet that was used to estimate basal endogenous losses of CP and AA. All diets contained 0.4% chromic oxide as an indigestible marker. Vitamins and minerals were included in all diets to meet or exceed nutrient requirement estimates (NRC, 1998). Feed was provided at daily amounts of 3 times the estimated maintenance requirement for energy (i.e., 106 kcal of ME/kg of $BW^{0.75}$), and equal meals were provided at 0800 and 1700 h. The ME of each diet was calculated based on ME values for each ingredient (NRC, 1998; Widmer et al., 2007). The feed allowance for each pig was adjusted at the beginning of each period when the BW of the pigs was recorded. Animals had free access to water through a bowl-type drinker. Each period lasted 7 d. The initial 5 d was an adaptation period to the diet, and ileal digesta samples were collected for 8 h on d 6 and 7. A plastic bag was attached to the cannula barrel using a cable tie and digesta flowing into the bag were collected. Bags were removed whenever they were filled with digesta, or at least once every 30 min. Collected samples were stored at −20°C to prevent bacterial degradation of AA in the digesta.

At the conclusion of the experiment, frozen ileal samples were allowed to thaw at room temperature and then mixed within animal and diet, and a subsample was collected for chemical analysis. Ileal digesta samples were lyophilized and finely ground before chemical analysis. All samples were analyzed for DM and CP (method 930.15 and 990.03, respectively; AOAC, 2005). Amino acids were analyzed on a Hitachi Amino Acid Analyzer (Model L8800, Hitachi High Technologies America Inc., Pleasanton, CA) using ninhydrin for

Table 2. Ingredient composition of experimental diets (as-fed basis), Exp. 1

	Diet[1]		
Ingredient, %	HP-DDG$_{Buhler}$	SBM	N-free
HP-DDG$_{Buhler}$	50.00	—	—
Soybean meal, 48% CP	—	38.00	—
Cornstarch	35.55	45.75	68.60
Soybean oil	2.00	3.60	4.00
Sucrose	10.00	10.00	20.00
Solka-Floc[2]	—	—	4.00
Limestone	1.35	0.75	0.60
Monocalcium phosphate	—	0.80	1.20
Magnesium oxide	—	—	0.10
Potassium carbonate	—	—	0.40
Chromic oxide	0.40	0.40	0.40
Salt	0.40	0.40	0.40
Vitamin-mineral premix[3]	0.30	0.30	0.30

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN); SBM = soybean meal.

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

[3]Supplied per kilogram of complete diet: vitamin A, 11,120 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.41 mg; thiamine, 0.24 mg; riboflavin, 6.6 mg; pyridoxine, 0.24 mg; vitamin B_{12}, 0.031 mg; D-pantothenic acid, 24 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 0.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 125 mg as zinc oxide.

postcolumn derivatization and norleucine as the internal standard. Before analysis, samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C (method 982.30 E; AOAC, 2005). Methionine and Cys were analyzed as Met sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis. Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C. The Cr concentrations of diets and ileal digesta samples were measured using an inductive coupled plasma atomic emission spectrometric method (method 990.08; AOAC, 2005) after nitric acid-perchloric acid wet ash sample preparation (method 968.088D; AOAC, 2005).

Values for apparent ileal digesitibility (**AID**) and standardized ileal digestibility (**SID**) were calculated as described previously (Stein et al., 2007). Data were analyzed by ANOVA, using GLM procedures (SAS Inst. Inc., Cary, NC). The initial model included the dietary treatment and period as independent variables, but no effects of period were detected; therefore, period was removed from the final model. Least squares means were calculated for each variable. The pig was the experimental unit, and the α level used for determination of significance between means was 0.05.

Exp. 2: Energy Measurements

Sixteen barrows with an initial BW of 24.6 ± 1.66 kg were used to measure DE and ME in HP-DDG$_{Buhler}$ and in corn. Pigs were housed in metabolism cages equipped with a feeder and a nipple drinker and were assigned to 2 dietary treatments with 8 pigs per treatment in a completely randomized design.

A corn-based diet and a diet containing 50.0% corn and 48.2% HP-DDG$_{Buhler}$ were formulated (Table 4). Vitamins and minerals were included in both diets to meet or exceed the requirement estimates for growing pigs (NRC, 1998). The daily feed allowance per pig was calculated as 3 times the estimated requirement for maintenance energy and was divided into 2 equal meals that were provided at 0800 and 1700 h. Diets were provided in a meal form and pigs had free access

Table 3. Analyzed nutrient composition (%) of experimental diets (as-fed basis), Exp. 1

	Diet[1]		
Item	HP-DDG$_{Buhler}$	SBM	N-free
DM	91.90	89.78	90.70
CP	22.14	19.31	0.31
Indispensable AA			
Arg	0.91	1.18	—
His	0.51	0.42	—
Ile	0.99	0.76	0.01
Leu	3.31	1.27	0.02
Lys	0.67	1.05	0.01
Met	0.53	0.22	—
Phe	1.30	0.81	0.01
Thr	0.83	0.63	0.01
Trp	0.15	0.26	<0.04
Val	1.09	0.75	—
Total indispensable AA	10.29	7.35	<0.10
Dispensable AA			
Ala	1.81	0.71	0.02
Asp	1.56	1.87	0.01
Cys	0.43	0.23	—
Glu	4.34	3.04	0.03
Gly	0.73	0.68	0.01
Pro	1.68	0.75	—
Ser	1.01	0.73	0.01
Tyr	0.86	0.50	—
Total dispensable AA	12.42	8.51	0.08

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN); SBM = soybean meal.

Table 4. Composition of experimental diets (as-fed basis), Exp. 2

Item	Diet	
	Corn	HP-DDG$_{Buhler}$[1] + corn
Ingredient, %		
Corn	97.40	50.00
HP-DDG$_{Buhler}$	—	48.20
Limestone	0.90	1.10
Monocalcium phosphate	1.00	—
Salt	0.40	0.40
Vitamin-mineral premix[2]	0.30	0.30
Analyzed composition		
GE, kcal/kg	3,795	4,474
CP, %	7.98	25.22

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

[2]Provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A, 11,120 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.41 mg; thiamine, 0.24 mg; riboflavin, 6.6 mg; pyridoxine, 0.24 mg; vitamin B_{12}, 0.031 mg; D-pantothenic acid, 24 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 0.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 125 mg as zinc oxide.

to water. During the initial 7 d, pigs were adapted to their diet, and urine and fecal materials were collected during the following 5 d. The initiation and termination of feces collections were marked by the addition of 0.5% chromic oxide to the morning feed on d 8 and 13 (Adeola, 2001). The collection of urine was initiated on d 8 at 1700 h and ceased on d 13 at 1700 h. Urine was collected in urine buckets over 50 mL of 6 *N* HCl. The total quantities of feces and 20% of the collected urine were stored at −20°C immediately after collection. At the end of the experiment, urine samples were thawed and mixed within animal and diet, and subsamples for analysis were collected.

Feces were dried in a forced-air oven and finely ground before analysis. Fecal, urine, and feed samples were analyzed for DM and GE by bomb calorimetry (Parr 6300 calorimeter, Parr Instruments Co., Moline, IL). The GE in urine was determined in triplicate samples. Approximately 10 mL of urine was added to a small cotton ball (0.2 to 0.3 g) that was placed in a plastic bag (approximately 0.2 g). The weights of the plastic bag, the cotton ball, and the plastic bag containing the cotton ball and urine were recorded. The bag was then lyophilized, the weight was recorded again, and the GE of the bag containing the cotton and the lyophilized urine was measured. The weight and the GE of 6 empty plastic bags and of 6 virgin cotton balls were also recorded, and the average GE of the 6 bags and of the 6 cotton balls on a per-gram basis was assumed to represent the GE of the bags and the cotton, respectively. These values were then multiplied by the weight of the bag and the cotton ball, respectively, that had been bombed together with the urine, and the GE contributed by the plastic bag and the cotton ball was subtracted from the total GE that was measured in the bag containing the cotton ball and the urine to calculate the GE of the urine in the sample.

Values for DE and ME for each experimental diet were calculated by subtracting fecal energy and both fecal and urinary energy, respectively, from energy intake (Adeola, 2001). The energy concentration in the corn diet was divided by 0.974 to obtain the energy concentration in corn. The contribution of DE or ME from corn to the HP-DDG$_{Buhler}$ diet was then subtracted from the DE and ME of the HP-DDG$_{Buhler}$ diet to calculate the amount of DE and ME that was contributed by HP-DDG$_{Buhler}$ in the HP-DDG$_{Buhler}$ diet. These values were then divided by 0.482 to calculate DE and ME for HP-DDG$_{Buhler}$.

Data were analyzed as described for the AA digestibility experiment. In pigs fed the corn-based diet, an outlier was detected by the UNIVARIATE procedure of SAS. Fecal energy output of this pig (328 kcal) during 5 d of collection deviated by more than 3.0 times the interquartile ranges (384 kcal) from the mean of the treatment group (1,567 kcal), whereas values for the other pigs were within 1.5 times the interquartile range of the mean. Therefore, values for this pig were removed from the final analysis.

Exp. 3: Growth Performance and Carcass Traits

In a 63-d growth assay consisting of 3 phases of 21 d, a total of 40 barrows with an initial BW of 58.2 ± 2.28 kg were allotted to 5 treatments and 8 replicates in a randomized complete block design based on BW. Pigs were individually housed in pens (1.22 × 1.68 m) with fully slatted cast-iron floors. Each pen was equipped with a feeder and a nipple drinker. All diets were fed in meal form, and pigs had free access to feed and water throughout the experiment.

A control diet based on corn and SBM was formulated (Table 5). Four additional diets in which HP-DDG$_{Buhler}$ replaced 33, 66, 66, or 100% of the SBM in the control diet were also formulated. Crystalline Lys was included in all diets, and crystalline Thr was included in all diets containing HP-DDG$_{Buhler}$. Because the concentration of Trp in the 2 diets in which HP-DDG$_{Buhler}$ replaced 66% of the SBM in the control diet was considered marginal (Kendall et al., 2007), crystalline Trp was added to one of these diets, but not to the other diet. Crystalline Trp was also included in the diet in which HP-DDG$_{Buhler}$ replaced 100% of the SBM. Minerals and vitamins were added to meet or exceed current requirement estimates (NRC, 1998).

Individual pig BW and feed disappearance were recorded on d 0, 21, and 42 and at the conclusion of the experiment on d 63, and ADG, ADFI, and G:F were calculated. Pigs receiving the control diet and the diet in which HP-DDG$_{Buhler}$ replaced 100% of the SBM were fed their respective diets for an additional 3 d and then slaughtered to determine carcass characteristics. After a 24-h chill, carcasses were ribbed at the 10th rib to

Table 5. Composition of experimental diets containing increasing concentrations of HP-DDG$_{Buhler}$[1] (as-fed basis), Exp. 3[2]

	d 0 to 21					d 21 to 42					d 42 to 63				
Item	Control	HP33	HP66	HP66T	HP100T	Control	HP33	HP66	HP66T	HP100T	Control	HP33	HP66	HP66T	HP100T
Ingredient, %															
Corn	75.94	75.69	75.45	75.43	75.14	80.39	80.34	80.15	80.13	79.76	85.59	85.57	85.43	85.42	85.16
Soybean meal, 48% CP	21.00	14.05	7.15	7.15	—	16.67	11.00	5.50	5.50	—	11.50	7.59	3.80	3.80	—
HP-DDG$_{Buhler}$	—	6.95	13.85	13.85	21.00	—	5.50	11.00	11.00	16.67	—	3.80	7.59	7.59	11.50
Choice white grease	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
L-Lys·HCl	0.150	0.323	0.492	0.492	0.672	0.150	0.293	0.427	0.427	0.560	0.150	0.245	0.339	0.339	0.432
L-Thr	—	0.038	0.069	0.069	0.104	—	0.029	0.053	0.053	0.076	—	0.018	0.036	0.036	0.052
L-Trp	—	—	—	0.019	0.043	—	—	—	0.015	0.031	—	—	—	0.009	0.021
Limestone	0.68	0.75	0.82	0.82	0.92	0.59	0.67	0.73	0.73	0.80	0.56	0.61	0.65	0.65	0.70
Dicalcium phosphate	0.44	0.40	0.37	0.37	0.32	0.47	0.44	0.41	0.41	0.37	0.50	0.48	0.46	0.46	0.44
Salt	0.50	0.50	0.50	0.50	0.50	0.43	0.43	0.43	0.43	0.43	0.40	0.40	0.40	0.40	0.40
Vitamin-mineral premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calculated composition															
ME, kcal/kg	3,386	3,442	3,497	3,497	3,553	3,392	3,436	3,480	3,479	3,525	3,395	3,426	3,456	3,456	3,487
CP, %	16.4	16.1	15.9	15.9	15.6	14.7	14.5	14.2	14.2	14.1	12.7	12.5	12.6	12.4	12.2
SID[4] of Lys, %	0.84	0.85	0.84	0.85	0.85	0.73	0.74	0.74	0.74	0.73	0.60	0.60	0.60	0.60	0.60
SID of Trp:Lys, %	19.1	15.7	12.3	14.5	13.7	18.8	15.5	12.4	14.5	13.5	18.3	15.6	13.0	14.4	13.7
SID of Thr:Lys, %	61.5	62.2	62.2	62.2	62.2	62.6	62.6	62.6	62.6	62.6	64.3	64.3	64.3	64.3	64.3
SID of Met + Cys:Lys, %	59.8	60.5	61.4	61.4	62.1	63.2	63.5	64.4	64.4	65.5	68.8	69.4	70.0	70.0	70.8
Ca, %	0.45	0.45	0.45	0.45	0.45	0.41	0.42	0.42	0.42	0.42	0.39	0.39	0.39	0.39	0.39
Available P, %	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

[2]HP33 = diet in which HP-DDG$_{Buhler}$ replaced 33% of the soybean meal (SBM) in the control diet; HP66 = diet in which HP-DDG$_{Buhler}$ replaced 66% of the SBM in the control diet; HP66T = diet in which HP-DDG$_{Buhler}$ and crystalline Trp replaced 66% of the SBM in the control diet; HP100T = diet in which HP-DDG$_{Buhler}$ and crystalline Trp replaced 100% of the SBM in the control diet.

[3]Provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A, 6,614 IU; vitamin D_3, 661 IU; vitamin E, 13.2 IU; riboflavin, 4.96 mg; vitamin B_{12}, 0.02 mg; menadione, 2.4 mg; D-pantothenic acid, 16.9 mg; niacin, 19.8 mg; Cu, 16.5 mg as copper sulfate; Fe, 165.3 mg as iron sulfate; I, 0.3 mg as potassium iodate; Mn, 33 mg as manganese sulfate; Se, 0.29 mg as sodium selenite; and Zn, 165.3 mg as zinc oxide.

[4]SID = standardized ileal digestibility.

Table 6. Apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of CP and AA in HP-DDG_{Buhler}[1] and soybean meal (SBM) by growing pigs,[2,3] Exp. 1

	AID, %				SID, %			
Item	HP-DDG_{Buhler}	SBM	SEM	*P*-value	HP-DDG_{Buhler}	SBM	SEM	*P*-value
CP	68.1	82.7	1.80	<0.001	72.4	87.5	1.80	<0.001
Indispensable AA								
Arg	84.2	91.4	1.08	<0.001	87.5	93.9	1.08	<0.001
His	74.8	86.5	1.39	<0.001	76.7	88.7	1.39	<0.001
Ile	74.4	84.9	1.43	<0.001	76.4	87.5	1.43	<0.001
Leu	76.8	84.3	1.46	0.002	77.8	86.8	1.46	<0.001
Lys	72.1	86.3	2.10	<0.001	75.4	88.4	2.10	<0.001
Met	81.9	86.2	1.22	0.024	82.8	88.4	1.22	0.005
Phe	76.5	85.1	1.47	<0.001	77.9	87.3	1.47	<0.001
Thr	68.3	78.1	2.00	0.003	72.5	83.5	2.00	0.001
Trp	80.9	88.7	1.02	<0.001	85.1	91.0	1.02	<0.001
Val	71.2	81.3	1.72	<0.001	73.3	84.3	1.72	<0.001
Mean	75.8	85.4	1.42	<0.001	77.8	88.1	1.42	<0.001
Dispensable AA								
Ala	73.8	77.8	1.52	0.081	75.9	83.0	1.52	0.004
Asp	69.6	81.6	1.97	<0.001	72.6	84.1	1.97	<0.001
Cys	72.3	75.4	1.87	0.263	74.8	80.0	1.87	0.068
Glu	75.2	82.2	1.75	0.013	76.6	84.1	1.75	0.008
Gly	58.2	68.2	2.07	0.004	69.1	79.5	2.07	0.003
Pro	71.4	76.8	2.91	0.210	84.0	104.4	2.91	<0.001
Ser	75.5	83.4	1.69	0.004	78.6	87.5	1.69	0.002
Tyr	78.6	83.9	1.82	0.053	80.3	86.9	1.82	0.021
Mean	72.5	79.9	1.66	0.006	76.7	85.7	1.66	0.001

[1]HP-DDG_{Buhler} = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

[2]Each least squares mean represents 9 observations.

[3]Values for SID were calculated by correcting AID values for basal endogenous losses. Basal endogenous losses were determined from pigs fed the N-free diet (g/kg of DMI): CP, 10.3; Arg, 0.33; His, 0.11; Ile, 0.22; Leu, 0.35; Lys, 0.25; Met, 0.06; Phe, 0.20; Thr, 0.38; Trp, 0.07; Val, 0.25; Ala, 0.41; Asp, 0.52; Cys, 0.12; Glu, 0.66; Gly, 0.86; Pro, 2.31; Ser, 0.34; and Tyr, 0.16.

measure backfat depth and LM area. Color values of L*, a*, and b* on LM were measured using a Minolta Chroma Meter (Model CR-310, Minolta Corp., Ramsey, NJ).

Data were analyzed by ANOVA using the GLM procedures of SAS. The model included dietary treatment and block as independent variables. Least squares means were calculated for each variable. The pig was the experimental unit, and an α level of 0.05 was used to determine significance among means.

RESULTS AND DISCUSSION

Exp. 1: AA Digestibility

The CP concentration of HP-DDG_{Buhler} was close to the concentration in SBM (44.9 vs. 47.7%; Table 1), but the AA profiles of these ingredients were different. In particular, the Lys and Trp concentrations in HP-DDG_{Buhler} were much less than in SBM (1.32 vs. 3.00% and 0.25 vs. 0.63%, respectively), whereas the concentrations of Leu and Met in HP-DDG_{Buhler} were greater than in SBM (6.61 vs. 3.58% and 1.06 vs. 0.66%, respectively). The relatively smaller concentrations of Lys and Trp in HP-DDG_{Buhler} were not surprising because the concentrations of Lys and Trp were similar to the calculated concentrations, assuming the same AA-to-CP ratio in HP-DDG_{Buhler} as in corn. The ratio of Lys to CP in HP-DDG_{Buhler} was also consistent with that in HP-DDG_{BFrac} (Widmer et al., 2007).

The AID of CP was less (68.1 vs. 82.7%; $P < 0.001$) in HP-DDG_{Buhler} than in SBM (Table 6), and the AID of all indispensable AA was also less ($P < 0.05$) in HP-DDG_{Buhler} than in SBM. For dispensable AA, the AID for Asp, Glu, Gly, and Ser was less ($P < 0.05$) in HP-DDG_{Buhler} than in SBM.

The SID of CP and all AA except Cys was less ($P < 0.05$) in HP-DDG_{Buhler} than in SBM (Table 6). The SID of Lys was 13.0 percentage units less ($P < 0.001$) in HP-DDG_{Buhler} than in SBM (75.4 vs. 88.4%), but the SID of Lys that was measured for HP-DDG_{Buhler} was greater than the value that was previously reported for HP-DDG_{BFrac} (Widmer et al., 2007).

Heat treatment may cause reductions in Lys digestibility because of Maillard reactions (Cromwell et al., 1993; Pahm et al., 2008b). The SID of Lys in HP-DDG_{Buhler} that was measured in the present experiment is similar to the SID of Lys in corn (Pedersen et al., 2007b), which indicates that it is unlikely that heat damage had reduced the SID of Lys in the source of HP-DDG_{Buhler} that was used in this experiment.

Exp. 2: Energy Measurements

Fecal and urine energy excretion were greater (494 vs. 349 kcal/d and 205 vs. 76 kcal/d, respectively; *P*

Table 7. Energy digestibility and retention of pigs fed experimental diets (as-fed basis), Exp. 2[1]

	Diet			
Item	Corn	$\text{HP-DDG}_{\text{Buhler}}$[2]	SEM	*P*-value
Feed GE, kcal/kg	3,795	4,474	—	—
Feed consumption, kg/d	1.08	1.07	—	—
GE intake, kcal/d	4,099	4,787	—	—
Fecal energy, kcal/d	349	494	26.0	0.001
Energy digestibility, %	91.5	89.7	0.56	0.037
Feed DE, kcal/kg	3,472	4,013	24	<0.001
Urine energy, kcal/d	76	205	16.6	<0.001
Retained energy, kcal/d	3,674	4,088	34	<0.001
Energy retention rate, % of intake	89.6	85.4	0.73	<0.001
Feed ME, kcal/kg	3,402	3,821	32	<0.001

[1]Each least squares mean represents 8 observations.
[2]$\text{HP-DDG}_{\text{Buhler}}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

< 0.01) in pigs fed the $\text{HP-DDG}_{\text{Buhler}}$ diet than in pigs fed the corn diet (Table 7). Despite the reduced energy digestibility (89.7 vs. 91.5%; $P < 0.05$) by pigs fed the $\text{HP-DDG}_{\text{Buhler}}$ diet compared with pigs fed the corn diet, DE was greater (4,013 vs. 3,472 kcal/kg; $P < 0.001$) in the diet containing $\text{HP-DDG}_{\text{Buhler}}$ compared with the corn diet because of the greater GE (4,474 vs. 3,795 kcal/kg) in the $\text{HP-DDG}_{\text{Buhler}}$ diet than in the corn diet. The ME in the $\text{HP-DDG}_{\text{Buhler}}$ diet was also greater ($P < 0.001$) than in the corn diet (3,821 vs. 3,402 kcal/kg).

The DE and ME in $\text{HP-DDG}_{\text{Buhler}}$ on an as-fed basis (Table 8) were greater ($P < 0.001$) than in corn (4,627 vs. 3,565 kcal/kg and 4,303 vs. 3,493 kcal/ kg, respectively). When calculated on a DM basis, DE and ME in $\text{HP-DDG}_{\text{Buhler}}$ were also greater ($P < 0.001$) than in corn (5,043 vs. 4,002 kcal/kg and 4,690 vs. 3,921 kcal/kg of DM, respectively).

The DE and ME values for corn obtained in this experiment agree with previous values (NRC, 1998; Stein et al., 2004; Widmer et al., 2007). Greater energy values in $\text{HP-DDG}_{\text{BFrac}}$ than in corn were also reported by Widmer et al. (2007), but $\text{HP-DDG}_{\text{Buhler}}$ contains more GE, DE, and ME than $\text{HP-DDG}_{\text{BFrac}}$, which is likely a result of the greater concentration of CP in $\text{HP-DDG}_{\text{Buhler}}$ than in $\text{HP-DDG}_{\text{BFrac}}$. The energy digestibility and energy retention rate by pigs fed $\text{HP-DDG}_{\text{Buhler}}$ are similar to the values for pigs fed $\text{HP-DDG}_{\text{BFrac}}$ (Widmer et al., 2007). The DE and ME in $\text{HP-DDG}_{\text{Buhler}}$ are greater than the DE and ME in SBM (NRC, 1998), which indicates that if $\text{HP-DDG}_{\text{Buhler}}$ replaces SBM in a diet, the DE and ME in the diet will increase.

Exp. 3: Growth Performance and Carcass Traits

The replacement of SBM with $\text{HP-DDG}_{\text{Buhler}}$, regardless of inclusion amount, had no effects on ADG, ADFI, or G:F (Table 9). This observation illustrates that under the conditions of the present experiment, $\text{HP-DDG}_{\text{Buhler}}$ can replace all the SBM in a corn-based diet fed to pigs from 58 kg to slaughter, provided that diets are fortified with crystalline AA to meet the needs for SID AA. The observation that there were no differences in performance between pigs fed the 2 diets in which $\text{HP-DDG}_{\text{Buhler}}$ replaced 66% of the SBM indicates that it is not necessary to add crystalline Trp to this type of a diet.

Table 8. Energy values for corn and $\text{HP-DDG}_{\text{Buhler}}$,[1] Exp. 2

	Ingredient			
Item	Corn	$\text{HP-DDG}_{\text{Buhler}}$	SEM	*P*-value
As-fed basis				
GE, kcal/kg	3,896	5,236	—	—
DE, kcal/kg	3,565	4,627	46	<0.001
ME, kcal/kg	3,493	4,303	65	<0.001
DM basis				
GE, kcal/kg	4,374	5,707	—	—
DE, kcal/kg	4,002	5,043	51	<0.001
ME, kcal/kg	3,921	4,690	71	<0.001

[1]Each least squares mean represents 8 observations. $\text{HP-DDG}_{\text{Buhler}}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

Table 9. Growth performance of pigs fed experimental diets containing increasing amounts of HP-DDG$_{Buhler}$,[1,2] Exp. 3

Item	Diet[3]					SEM	*P*-value
	Control	HP33	HP66	HP66T	HP100T		
d 0 to 21							
Initial BW, kg	58.2	58.2	58.2	58.2	58.2	0.17	1.000
ADG, kg	1.17	1.16	1.09	1.08	1.08	0.059	0.696
ADFI, kg	2.63	2.71	2.58	2.64	2.59	0.117	0.939
G:F, kg/kg	0.45	0.43	0.43	0.41	0.41	0.011	0.212
Final BW, kg	82.8	82.5	81.1	80.8	80.9	1.25	0.697
d 21 to 42							
ADG, kg	1.24	1.18	1.22	1.17	1.20	0.045	0.756
ADFI, kg	3.43	3.41	3.49	3.32	3.47	0.119	0.864
G:F, kg/kg	0.36	0.35	0.35	0.35	0.35	0.015	0.941
Final BW, kg	108.8	107.2	106.7	105.2	106.1	1.84	0.716
d 42 to 63							
ADG, kg	1.04	1.06	1.17	1.11	1.16	0.063	0.515
ADFI, kg	3.93	3.95	4.11	3.92	4.02	0.113	0.749
G:F, kg/kg	0.26	0.27	0.28	0.28	0.29	0.012	0.539
Final BW, kg	130.7	129.4	131.3	128.5	130.1	2.14	0.907
Overall							
ADG, kg	1.15	1.13	1.16	1.12	1.14	0.034	0.900
ADFI, kg	3.33	3.35	3.39	3.30	3.33	0.082	0.948
G:F, kg/kg	0.35	0.34	0.34	0.34	0.34	0.009	0.954

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

[2]Each least squares mean represents 8 observations.

[3]HP33 = diet in which HP-DDG$_{Buhler}$ (Buhler Energy Inc.) replaced 33% of the soybean meal (SBM) in the control diet; HP66 = diet in which HP-DDG$_{Buhler}$ replaced 66% of the SBM in the control diet; HP66T = diet in which HP-DDG$_{Buhler}$ and crystalline Trp replaced 66% of the SBM in the control diet; HP100T = diet in which HP-DDG$_{Buhler}$ and crystalline Trp replaced 100% of the SBM in the control diet.

A linear reduction in ADG with increasing amounts of HP-DDG$_{BFrac}$ was reported for 22- to 60-kg pigs, but not for pigs that were heavier than 60 kg (Widmer et al., 2008). Pigs in this experiment were 58 kg when they were allotted to the HP-DDG$_{Buhler}$ diets, which may be the reason why no differences were observed among treatments. A linear reduction in LM area with increasing amounts of HP-DDG$_{BFrac}$ was also reported by Widmer et al. (2008), which may have been a result of the pigs fed the HP-DDG$_{BFrac}$ diets having a lighter slaughter weight than the control pigs. In this experiment, no differences in LM area were observed, but slaughter weights were also similar for the pigs fed the control diet and the pigs fed the diet in which HP-DDG$_{Buhler}$ replaced all the SBM (Table 10).

Conclusion

The concentration of CP in HP-DDG$_{Buhler}$ (45%) is close to the concentration in SBM, but the concentrations of total Lys (1.32%) and Trp (0.25%) are much less in HP-DDG$_{Buhler}$ than in SBM. The SID of all AA except Cys are less in HP-DDG$_{Buhler}$ than in SBM. The GE, DE, and ME of HP-DDG$_{Buhler}$ are 5,236, 4,627, and 4,303 kcal/kg (as-fed basis; 91.8% DM), respectively. These values are greater than those in corn. In

Table 10. Carcass traits of pigs fed a corn-soybean meal control diet or a corn HP-DDG$_{Buhler}$ diet,[1,2] Exp. 3

Item	Diet		SEM	*P*-value
	Corn-soybean meal	Corn-HP-DDG$_{Buhler}$[3]		
HCW, kg	94.4	94.1	1.68	0.908
10th-rib fat, mm	19.8	18.7	1.79	0.674
Last-rib fat, mm	23.3	24.0	1.52	0.776
10th-rib LM area, cm^2	48.5	48.0	1.01	0.745
LM color, L*	57.1	56.9	1.38	0.926
LM color, a*	16.3	16.5	0.48	0.778
LM color, b*	10.8	10.7	0.09	0.806

[1]HP-DDG$_{Buhler}$ = high-protein distillers dried grains (Buhler Energy Inc., Minneapolis, MN).

[2]Each least squares mean represents 8 observations.

[3]HP-DDG$_{Buhler}$ and crystalline AA replaced 100% of the soybean meal that was included in the control diet.

corn-based diets, $HP\text{-}DDG_{Buhler}$ can replace 100% of the SBM without negative effects on growth performance or carcass characteristics, provided that diets are fortified with crystalline Lys, Thr, and Trp.

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